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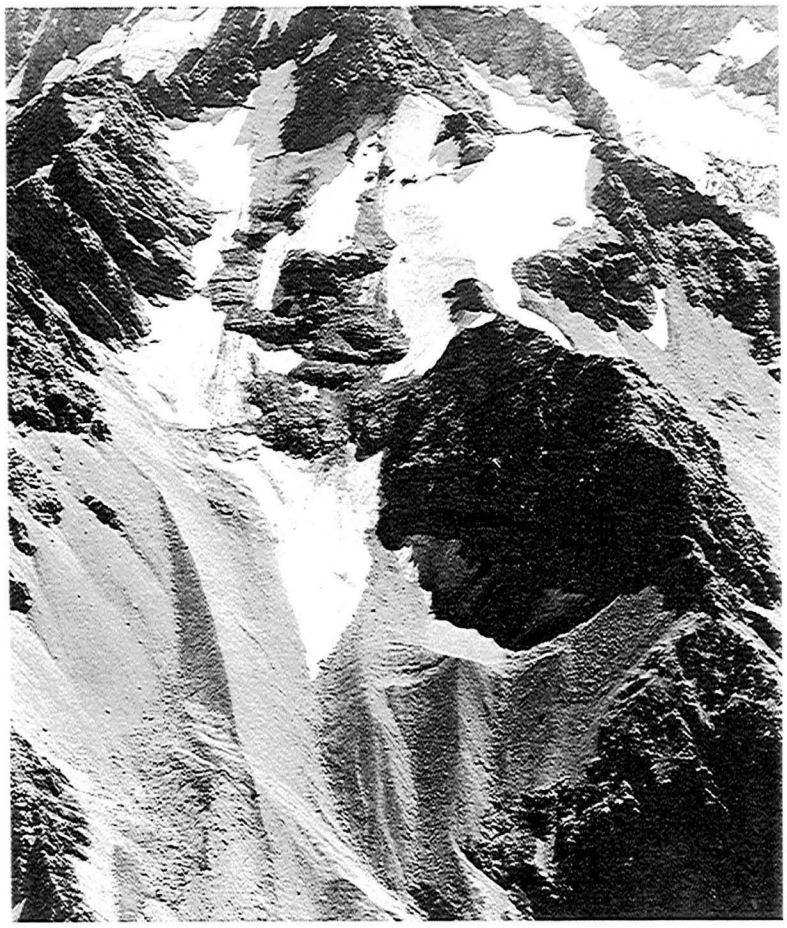
New Zealand glacier snowline survey, 1999

T. J. Chinn & M. J. Salinger



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Abstract

Chinn, T. J. & Salinger, M. J. 1999: New Zealand glacier snowline survey, 1999.
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Glaciers of New Zealand have experienced significant changes as a result of recent weather patterns. An extensive and detailed survey of direct, undelayed changes in annual glacier mass balance, which uses the altitude of end-of-summer glacier snowline as a surrogate for balance change, has shown that the recent trend of positive balances has now reversed. Although all balances measured were negative, the change has yet to pass through the glacier systems and they are currently continuing to advance. The survey was carried out by photographing the position of the snowline on 50 selected index glaciers from a light aircraft. The altitudes of some of the snowlines recorded were at the highest levels measured since surveys began in 1977, due to the strong effect of the summer La Niña circulation over New Zealand which brought warm temperatures and drought conditions to the east of the Southern Alps.

Introduction

The results presented here continue an annual glacier/climate monitoring programme, begun in 1977 for the New Zealand Glacier Inventory, in which the position (altitude) of the end-of-summer snowline of 49 selected glaciers arranged in transects across the Southern Alps is photographed (Figure 1).

The 3145 glaciers of New Zealand extend from Mount Ruapehu in the North Island at 39°15' S to southern Fiordland at 45° 57' S. Three North Island volcanic cones reach close to the permanent snowline, but only Mount Ruapehu, with a summit at 2752 m, supports glaciers. Because of the distances involved, these glaciers are not included in this survey. In the South Island, average peak summits range from 1850 m in Fiordland to 3000 m in the central Southern Alps and descend to 2000 m in the north-central Southern Alps. To the northeast, the Kaikoura Ranges reach to over 2700 m, where active rock glaciers have developed under the dry climate.

New Zealand has a humid maritime climate, with the Southern Alps lying across the path of prevailing westerly winds. Mean annual precipitation rises rapidly from 3000 mm along the narrow western coastal plains to a maximum of 15 000 mm or more in the western part of the Alps close to the Main Divide. From this maximum, precipitation diminishes exponentially to about 1000 mm in the eastern ranges. This creates steep eastward precipitation gradients and the mean altitudes of the glaciers closely follow these gradients (Chinn & Whitehouse 1980).

Glaciers and climate change

Glacier fluctuations are amongst the clearest signals of climate change, because glaciers are highly sensitive, large-scale indicators of the energy balance at the Earth's surface. They give convincing signals of past climate change from decades to millennia. Atmospheric changes are signalled by direct, undelayed changes in annual mass balance, which are filtered, smoothed, and enhanced before they become apparent at the glacier front. Glacier snowline altitudes give a direct value for annual glacier health and balance, whereas the climate signal indicated by glacier frontal positions is severely modified by glacier response times and dynamics.

The Equilibrium Line Altitude (ELA)

The winter snowpack normally covers the entire glacier in a wedge, with the greatest snow depths near the highest altitudes, tapering to zero at the lower edge. This lower margin, or transient snowline, of the snowpack rises as summer melt progresses until it reaches a maximum altitude for the year at the end of summer (in April). Located somewhere near the middle of the glacier, this end-of-summer snowline indicates an equilibrium line where snow fall exactly equals snow loss over the past glacial year. This line, normally visible as the contrast between the discoloured concentration of dust on firn and the clean snow of the previous winter, is the glacier snowline for that year. It is the *altitude of this glacier snowline* (defined as the Equilibrium Line Altitude (ELA) by Meier & Post (1962)) that is measured by these snowline surveys. For any individual glacier in equilibrium with the climate, the altitude of the annual glacier snowline, averaged over many years, defines the steady-state Equilibrium Line Altitude (steady-state ELA). A snowline of this altitude will indicate zero change to the balance of the glacier.

A climate change will change the glacier mass balance and shift the altitude of the annual ELA. Thus the annual snowline position with respect to the long-term or steady-state ELA is used as a surrogate for annual balance changes at each glacier (Chinn 1995). It is the *departure* of the *glacier snowline* from the steady-state ELA that is reported here. The trend surface of this difference *is not* a measure of absolute snowline altitude: it is a measure of the *change from the average climate* at each glacier.

Glacier studies worldwide have demonstrated that the ELA lies at an altitude where the ratio of the accumulation area to the total glacier area (AAR) has an average value close to 0.6. For glaciers in balance, the steady-state ELA would be the mean of many years' readings, but, as the New Zealand glaciers have been dominated by positive balances since this programme began, a mean value of observed snowlines is not appropriate. In past reports, the AAR and thus the annual ELA altitude has been estimated from glacier maps. With the recent completion of the NZMS 260 maps at a scale of 1:50 000, more appropriate and accurate ELA values for this report have been calculated by the laborious process of digitising area curves for each glacier. The long-term ELA is then read off the area curve at 0.4 of the area up from the glacier terminus.

Methods

Collection of field data involves flying over the glaciers in a light aircraft to take simple oblique photographs of the position of the end-of-summer glacier snowlines. The snowlines visible on the photographs are sketched on to a map of each glacier and the resulting accumulation areas measured by digitiser. The 'snowline altitude' is then accurately read from the glacier area-altitude curve.

On the flights, a folder of photographs of each glacier is held by the "navigator" seated beside the pilot. These photographs are used to closely duplicate the position from where previous photographs were taken. The photographer operates from the back seat, shooting from both sides of the aircraft. As has been customary on these surveys, in addition to the index glaciers, other glaciers, features and selected glacier termini are also photographed. The flights are made mainly between 9000 and 10 000 ft. An altitude of at least 10 000 ft gives the best angle on the glacier snowlines, but Civil Aviation regulations do not permit normal flights to remain above this altitude for prolonged periods.

Preparations

The flight should be made on the elusive "last perfect day before the first winter snowfall", after the end of significant summer melt. Significant melt continues throughout February and March, but by April there is a high probability that a snowfall will have occurred. Experience has shown that although successful surveys have been made in April, there is about a 1 in 4 probability of snow before this time. Even a light snowfall will conceal the position of the snowline, so the surveys are planned for March, but this cannot be guaranteed as there is also a 1 in 10 probability that there will be no suitable flying weather in March. Recently the adopted principle of making the flight on "the first clear weather after 1 March " has proved to be successful.

In 1999, as stable, warm summer weather continued into March, it was decided to allow ablation to continue for a further two weeks before making the snowline survey flight. However, the drought conditions were broken by cool southerly rain which fell over the southern South Island on 8 and 9 March. Described as the "most effective rain in Otago for 18 to 20 months" the weather system (Figure 2) was unfortunately accompanied by an unseasonable heavy snowfall with as much as 30 cm snow at 1500 m. This fresh snow would have concealed the true glacial snowlines, with the possibility that it may not clear the ELAs before winter, as only a further week could be safely allowed for this snow to melt.

Despite the possibility of fresh snow remaining on the ELAs, the glacier flights began in an anticyclone on 15 March before the next low passed on to the country. The flights were made in a Cessna Cardinal 177 chartered from Aspiring Air at Wanaka airfield. This high-wing aircraft is eminently suitable as it has no obstructing wing struts and a relatively high cruising speed. The detailed mountain knowledge of the pilot permitted direct "front window" navigation without any flying time lost to searching for the index glaciers.

Itinerary

The first legs of the snowlines flight were made on Monday, 15 March to complete the northern section before a forecast low passed on to the country (Figure 3) by Gareth Clare and Trevor Chinn, piloted by Andy Woods. The first leg completed the eastern glaciers (Figure 4) with a midday refuelling stop at Greymouth. Leg 2 continued on to the Kaikouras, where cloud impaired the views of the glaciers and a disturbance in the depression off East Cape (Figure 3) had plastered fresh snow over the glaciers of the Inland Kaikoura Range. On the return to Hokitika for an overnight refuelling stop, some difficulty was encountered in locating and photographing the Browning Range glacier through a thick afternoon cloud cover. The glacier was finally successfully viewed from beneath the cloud.

The next day, Tuesday 16, all of the Westland glaciers were covered from Whitcombe Pass south to Haast Pass, where cloud of the next front (Figure 5) ended the survey.

Persistent westerly drift south of an anticyclone centred over the North Island postponed the next attempt to complete the survey until 21 March, when on advice of conditions at Wanaka, an early start was made from Dunedin in an attempt to catch a 'window' between bouts of westerlies (Figure 6). Clare and Chinn took off at 0900, but managed to cover only Fog Peak and Snowy Creek before invading thick cloud was encountered.

Almost ideal anticyclonic conditions permitted the completion of the Fiordland glaciers on 25 March by Jim Salinger and Trevor Chinn, again flown by Andy Woods. Repeat surveys were made of Fog Peak and Snowy Creek, where it was disturbing to find that a thin skiff of snow from the front of 23 March (Figure 7) had obscured all layering on the glaciers visible on the previous visit. However, this snow was localised and the snowlines and features on most of

the remaining glaciers were clearly visible. The survey was completed in perfect weather (Figure 8) with a revisit to Brewster Glacier to record any changes over the intervening 9 days.

The difficulties encountered each year in leaving the survey as late as possible in the ablation season, yet pre-empting early snow cover, indicate that two survey flights should be made each year, the first in mid February to ensure a snow-free survey, and a second in mid March to capture the end of the ablation season should the glaciers remain snow free. When the March survey fails, a correction factor may be applied to the February results to give an appropriate increase in snowline elevation. This factor, amounting to a mean ablation rate, will be available from pairs of successful surveys.

Results

Despite favourable anticyclonic conditions, the 1999 survey was again dogged by afternoon cloud, particularly on glaciers of the northern section, and also by localised fresh snow. Although all of the index glaciers were visited, no values are available for seven glaciers.

Kaikoura Range: no snowline altitudes or estimate available because of cloud and a thick fresh snow cover.

Mounts Ella and Faerie Queene were both in cloud, but on the return flight from the Kaikouras, Faerie Queene was clear and showed that the snowline had risen well above the mountain summit.

Browning Range was in cloud, but sufficient was visible to show that the snowline lay well above the glacier, as was the snowline of Jaspur Glacier.

Both Ridge and Langdale Glaciers had a thin featureless cover of obscuring fresh snow.

For a number of other, smaller glaciers, where snowlines were at or above their altitude limits, snowline elevations have been estimated from adjacent glaciers.

Snowlines at all glaciers were among the highest recorded, indicating a year of strong negative balance, although this follows an early spring accumulation season under La Niña circulation when thicker than average snowpacks might be expected. The results emphasise the importance of ablation losses under La Niña summer circulation. The results also include an unknown effect of the early March snowfall, as it was not always possible to distinguish between the March snow and last winter's snowpack. A check on the possible error introduced by this snowfall is available from photographs obtained of the Tasman Glacier taken on 11 February prior to the snowfall. These photographs showed no measurable difference in altitude between the two dates. However, it is probable that the snowline measured was sometimes that of the March snow overlying the true summer snowline, this possibility has to be accepted, and the results printed here must be viewed as minimal values.

Results for individual glaciers, are listed as departures from the steady-state ELA value in Table 1 and plotted in Figure 9. Snowline fluctuation histories for each individual glacier are given in the histograms in the Appendices, as metres of departure from the steady-state ELA. Missing values are years of no survey, and arrows indicate measured zero values.

That high snowlines this year were above the upper limits of some of the smaller index glaciers indicates that provision should be made for future reading of high snowlines by correlating some small glacier snowlines with large nearby glaciers where this is possible. Many of the outlying small glaciers will not supply data in years of very high snowlines.

The 1999 results are summarised in Figure 9, where the snowline departures average 187 m above the long-term ELA positions. The high values for Siege and Brewster Glaciers are both reliable readings. The Siege Glacier value may be high because its extreme western position means it may not have received any of the early March snowfall.

Comparisons with previous years

The 1999 glacier year is compared with averages from very variable numbers of glaciers observed over the past 20 years (Figure 10): 1999 was one of the highest snowlines on record. The 1990 high value comes from one observation only on the Tasman Glacier. Figure 11 presents the percentage of all glaciers surveyed each year which showed a positive balance. Here 1999 is one of the years of highest recorded snowlines.

Analyses

This year (1999) all past and present snowline altitude records were upgraded by using more accurate and less subjective digitising methods. In past years, snowline elevations were subjectively derived from the photographs by manually transferring the estimated mean snowline to a contour map of the glacier, and the altitude read. In practice, the differences from year to year were quite accurately derived by arranging all past photographs in a sequence of ascending order of snowline elevations, and interpolating the altitudes. This gives a year-to-year comparative elevation precision of a few metres, but a large error remains in the absolute value of the altitude.

With the recent completion of the 1:50 000 scale metric map series for the Southern Alps, there was the opportunity to enhance the accuracy of the snowline dataset by mapping and digitising the annual accumulation area for each glacier, and reading the snowline elevation from a plotted area-altitude curve. Area-altitude curves have been constructed by digitising contour maps for each of the 49 index glaciers. From these area curves, the long-term average or equilibrium line altitude (ELA) for each glacier was found from the universally measured mean ratio of accumulation area to total glacier area (accumulation area ratio or AAR) of 0.6. These values are given in Table 1, and differ slightly from those of previous years.

Next, accurate maps of each glacier were constructed on enlarged sections of the 1:50 000 maps, using both the oblique snowline and vertical aerial photographs. This procedure proved to be difficult because the base maps lacked sufficient detail and as many features as possible had to be included to ensure accurate plots of the annual accumulation areas in the next step of the process. The glacier outlines were based on the 1978 and 1989 photographs which have high snowlines and were times when the glaciers were of similar size.

With a base map and an ELA value for each glacier, useable photographs were selected from the archive of all past years' snowline photographs for sketching accumulation areas on to the basemaps for digitising. 'MapInfo' was used to digitise and measure the areas of 411 mapped accumulation areas. The snowline elevations were then read off the area curves. For years for which where photographs were inadequate to map accumulation areas, revised snowline elevations were calculated by proportioning from the elevations of previous years. Finally, the mapped 1999 accumulation areas were mapped and digitised, and these accumulation maps overlain on the glacier base maps (Appendix 1).

The pattern of the 1999 snowline-elevation departures throughout the Southern Alps is presented diagrammatically in Figure 12, where the contoured trend surface shows some complex undulations. Any lowering of the snowlines towards the south east by the early March snowfall is not apparent: to the contrary, the snowline departure trend surface tends to lower towards the north.

The climatic signal measured by the snowline departures from the ELA also contain topographic signals. In particular, the steeper the glacier gradient, the greater the range of snowline elevations. Normalising the data for each year ((v – m)/s.d., where v is value, m is the mean, and s.d. is the standard deviation) may remove a large part of the variation due to topography. The 'representivity' of each glacier as an indicator of the overall annual climate of the Southern Alps is indicated by how well the annual values for an individual glacier correlates with the mean over the Alps. Correlation coefficients of individual snowline departures for each glacier correlated against the mean of all remaining values for each year are given in Table 2. The correlations give a surprising result where representivity appears to be independent of size or topography. Those glaciers which would intuitively have been chosen as being the most representative and useful for this study, based on shape and size, have been underlined. The high percentage of very good correlations gives confidence in the value of snowline studies as an indicator of the alpine climate.

Two additional points for Rolleston Glacier and Mount Franklin have been added to the meagre data for 1979 from mountaineering photographs taken on 24 February 1979.

Acknowledgment

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Table 1: **Results of the 1999 snowline survey. Departures from the steady-state ELA value in metres, and normalised values for each glacier surveyed**

GLACIER	INVENTORY NUMBER	LONG TERM ELA (m)	SNOWLINE DEPARTURES 1999 (m)	NORMALISED 1999 VALUES	No. OF READINGS TO DATE
KAIKOURA RA	621/001	2525	New snow		8
MT ELLA	932B/012	2154	Cloud		6
MT FAERIE QUEENE	646/006	2030	Above gl.		8
MT WILSON	None	1820	205	0.21	16
MT FRANKLIN	911A/002	1850	128	-0.69	14
ROLLESTON GL.	911A/004	1767	83	-1.21	19
MT CARRINGTON	646C/027	1665	240	0.62	17
MT AVOCA	685F/004	1950	130	-0.66	14
MARMADUKE GL.	664C/012	1865	129	-0.67	21
RETREAT GL.	906A/004	1720	168	-0.22	15
BROWNING RA.	906A/001	1564	Above gl.		14
DOUGLAS GL.	685B/001	2120	160	-0.31	17
MT BUTLER	685C/060	1835	103	-0.98	21
DAINTY GL.	897/019	1918	212	0.29	19
KEA GL.	897/007	1832	188	0.01	17
JASPUR GL.	897/003	1735	Above gl.		14
SIEGE GL.	893A/006	1630	520	3.87	18
VERTEBRAE COL	893A/025	1893	135	-0.60	18
RIDGE GL.	711L/024	2244	New snow		14
LANGDALE GL.	711I/035	2238	New snow		18
TASMAN GL.	711I/012	1790	186	-0.01	23
SALISBURY GL.	888B/003	1860	170	-0.20	20
JALF GL.	886/002	1732	318	1.52	20
CHANCELLOR DOME	882A/007	1830	120	-0.78	18
GLENMARY GL.	711F/006	2186	86	-1.17	17
BLAIR GL.	711D/038	1980	110	-0.90	16
MT McKENZIE	711D/021	1915	163	-0.28	16
JACKSON GL.	868B/094	2053	112	-0.87	15
JACK GL.	875/015	1930	78	-1.27	19
MT ST. MARY	711B/039	1910	290	1.20	12
THURNEYSON GL.	711B/012	1970	142	-0.52	18
BREWSTER GL.	868C/020	1905	375	2.19	18
MT STUART	752I/104	1728	77	-1.28	17
LINDSAY GL.	867/002	1754	121	-0.77	17
FOG PK	752E/051	1995	127	-0.70	14
SNOWY CK	752C/103	2092	208	0.24	15
MT CARIA	863B/001	1426	224	0.43	16
FINDLAY GL.	859/009	1664	226	0.45	15
PARK PASS GL.	752B/048	1815	147	-0.47	16
MT LARKINS	752E/002	1962	243	0.65	11
BRYANT GL.	752B/025	1752	258	0.83	17
AILSA MTS	752B/013	1605	225	0.44	14
MT GUNN	851B/057	1533	269	0.95	16
MT GENDARME	797G/033	1628	176	-0.13	14
LLAWRENNY PKS	846/035	1460	210	0.27	14
BARRIER PK	797f/004	1632	268	0.94	15
MT IRENE	797D/001	1515	150	-0.43	12
MERRIE RA.	797B/010	1505	183	-0.05	9
CAROLINE PK	803/001	1425	175	-0.14	6
	NUMBER	49	42	42	758
	MEAN	1835	187	0	15
	STD. DEV.	231	86	1	4
	No. below ELA (+ve balance)		0		
	% with +ve M.B.		0		

Table 2: **Correlation coefficients, arranged in descending order, of individual snowline departures for each glacier correlated against the mean of all remaining values for each year. Glaciers intuitively considered to be the most representative are underlined**

	R^2		R^2
Caroline Pk	0.965	Kea Gl.	0.757
Barrier Pk	0.934	Mt Carrington	0.757
Llawrenny Pks	0.908	Vertebrae Col	0.754
Mt Ella	0.902	Marmaduke Gl.	0.753
Jackson Gl.	0.884	Jack Gl.	0.752
Jalf Gl.	0.883	Rolleston Gl.	0.752
Findlay Gl.	0.873	Mt Caria	0.751
Siege Gl.	0.858	Lindsay Gl.	0.746
Mt Franklin	0.857	Fog Pk	0.744
Mt Gendarme	0.830	Jaspur Gl.	0.744
Thurneyson Gl.	0.822	Mt Butler	0.744
Mt McKenzie	0.819	Mt Larkins	0.734
Brewster Gl.	0.812	Tasman Gl.	0.725
Mt Gunn	0.809	Mt Wilson	0.724
Mt Irene	0.807	Chancellor Dome	0.712
Ailsa Mts	0.802	Mt Avoca	0.695
Browning Ra.	0.800	Retreat Gl.	0.665
Dainty Gl.	0.795	Snowy Ck	0.642
Mt St. Mary	0.791	Langdale Gl.	0.630
Salisbury Gl.	0.782	Ridge Gl.	0.612
Merrie Ra.	0.776	Glenmary Gl.	0.611
Park Pass Gl.	0.776	Blair Gl.	0.574
Bryant Gl.	0.767	Kaikoura Ra.	0.544
Mt Stuart	0.767	Mt Faerie Queene	0.322
Douglas Gl.	0.762		

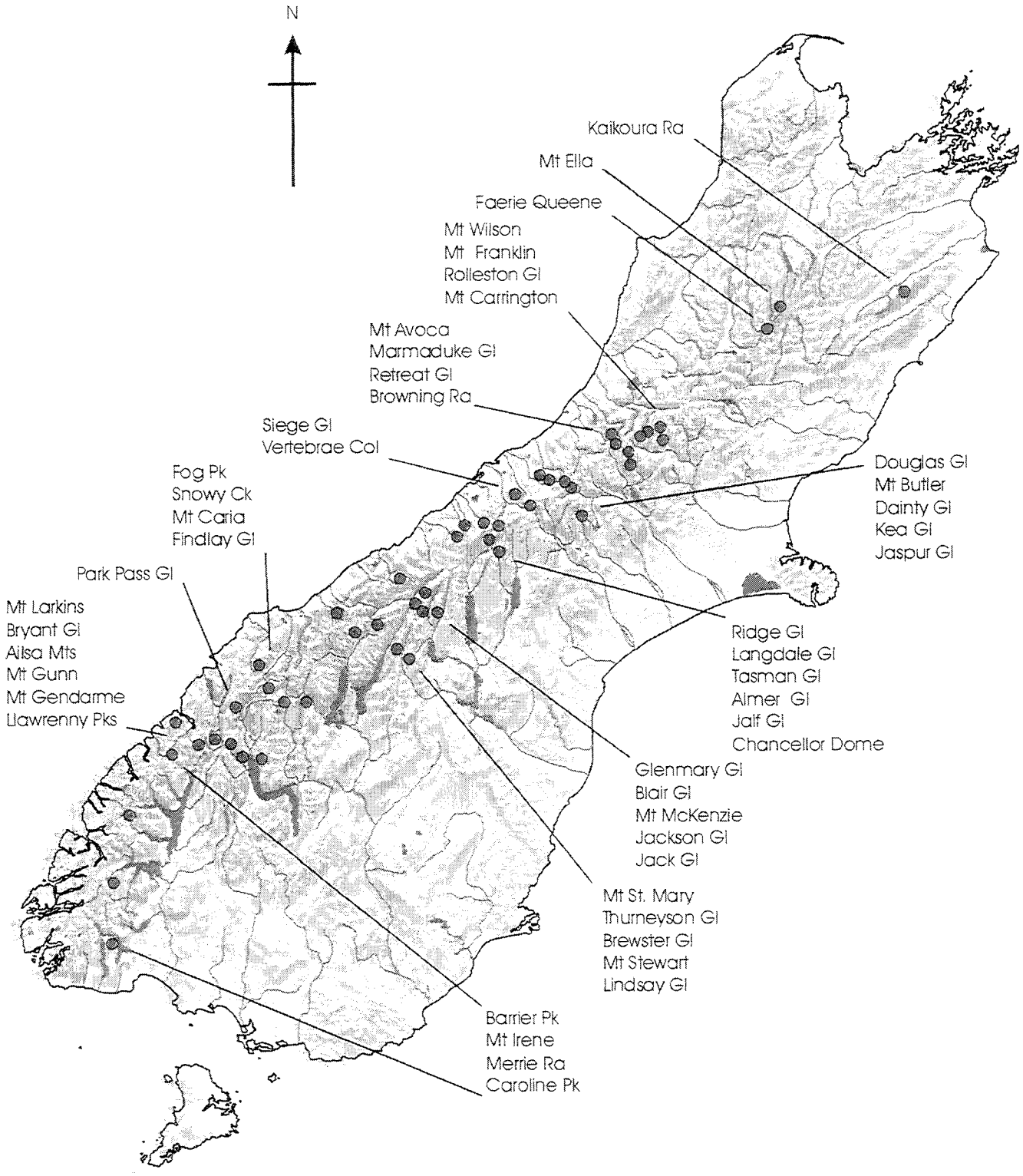


Figure 1: Location of the snowlines index glaciers.

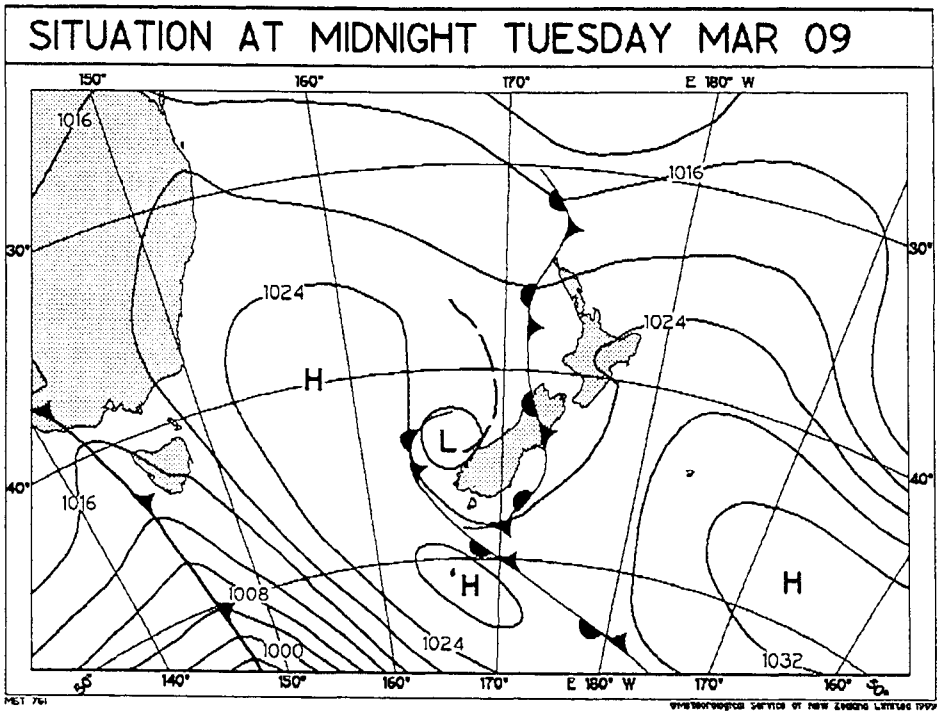


Figure 2: The weather situation responsible for the snowfall of 8 — 9 March.

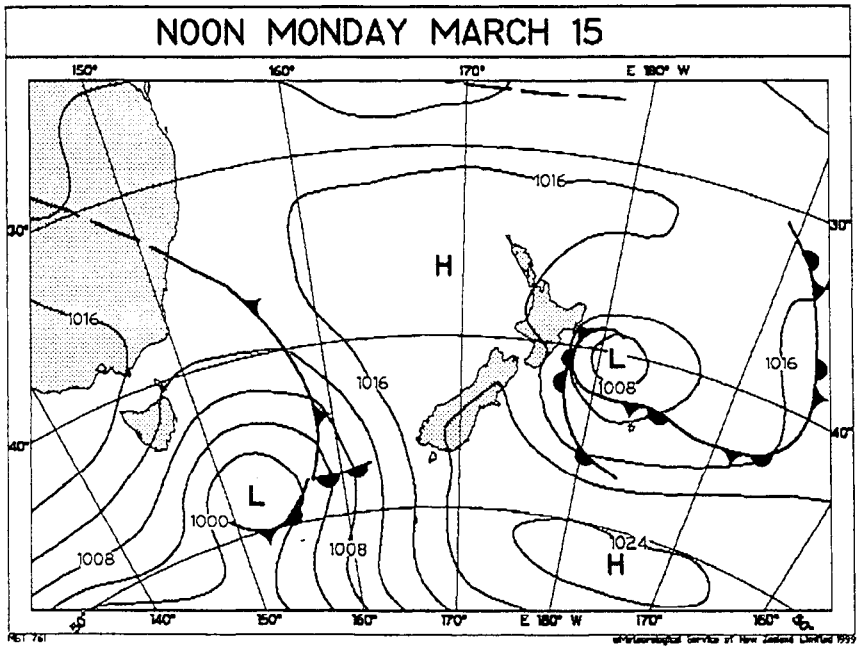


Figure 3: Weather map of the situation for the first flight legs on Monday, 15 March.

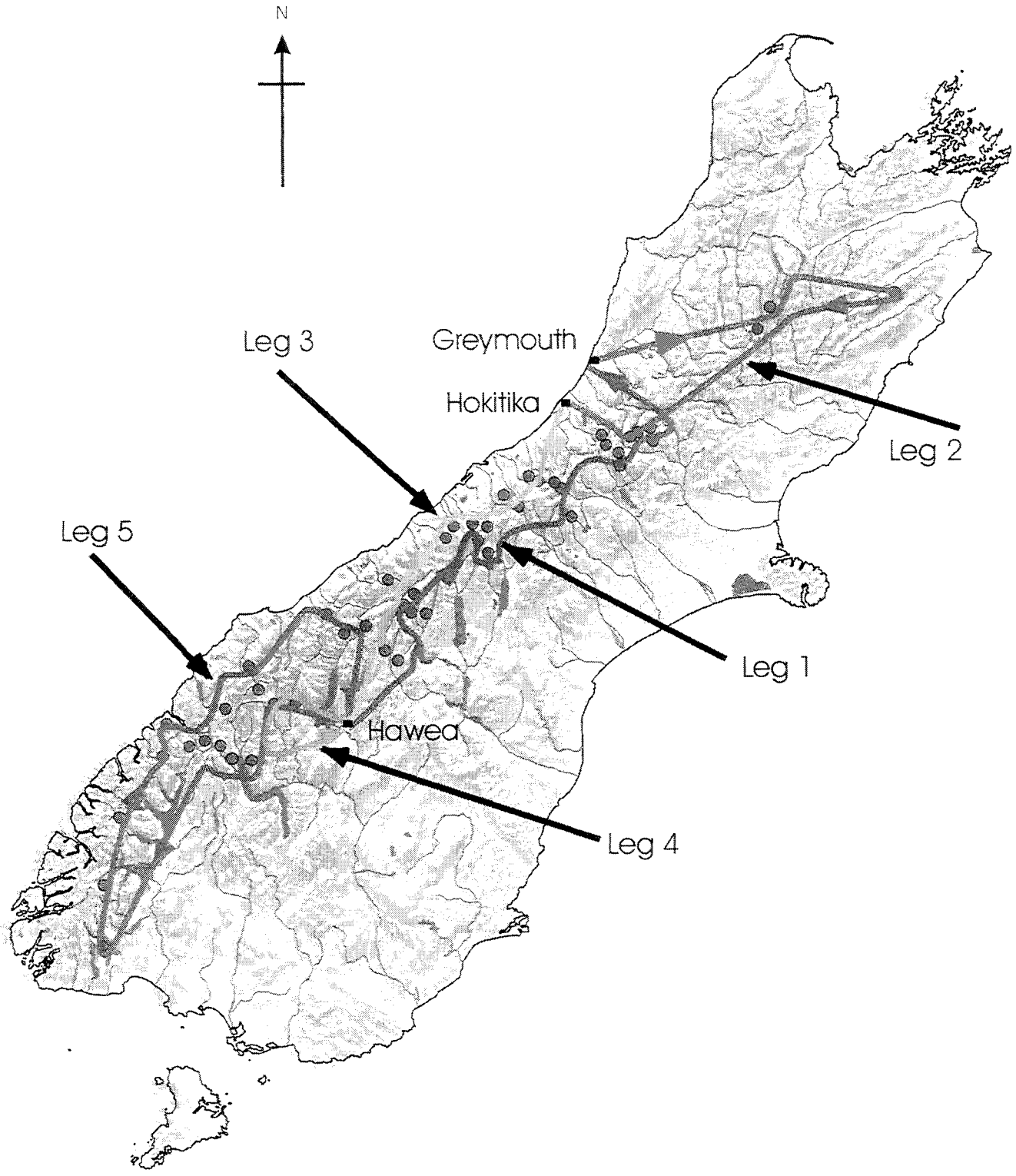


Figure 4: Flight paths for the 1999 glacier surveys.

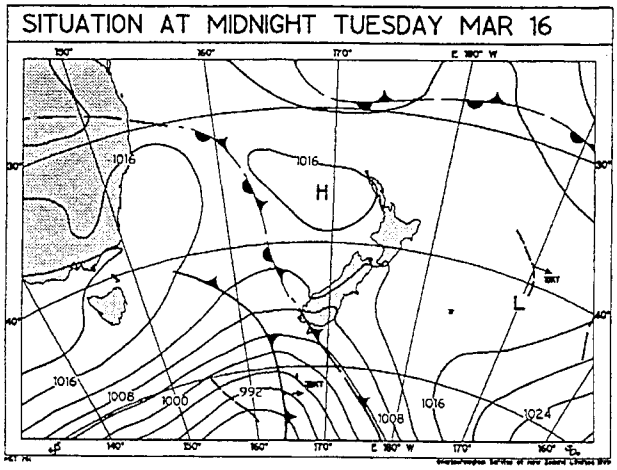


Figure 5: Weather map showing the front which terminated leg 3 on Tuesday, 16 March.

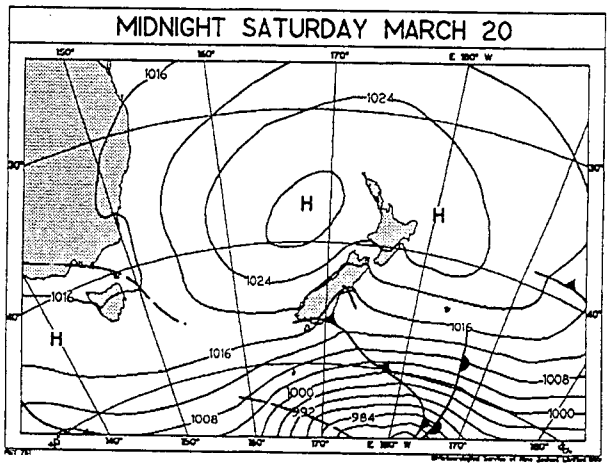


Figure 6: The forecast weather situation in which strato-cumulus cloud terminated leg 4 on Sunday, 21 March.

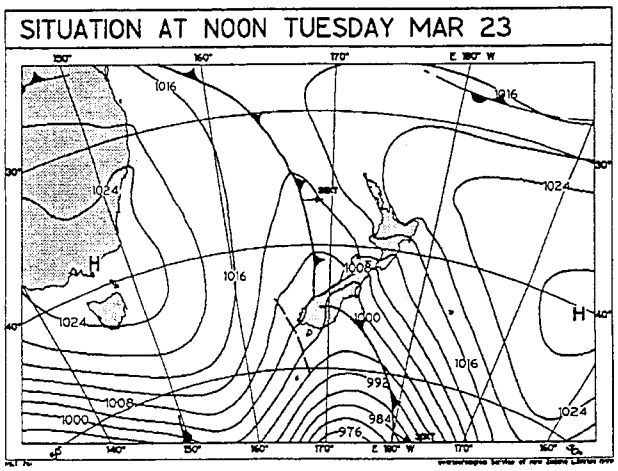


Figure 7: The frontal system that put a skiff of snow the eastern Darrans Section glaciers.

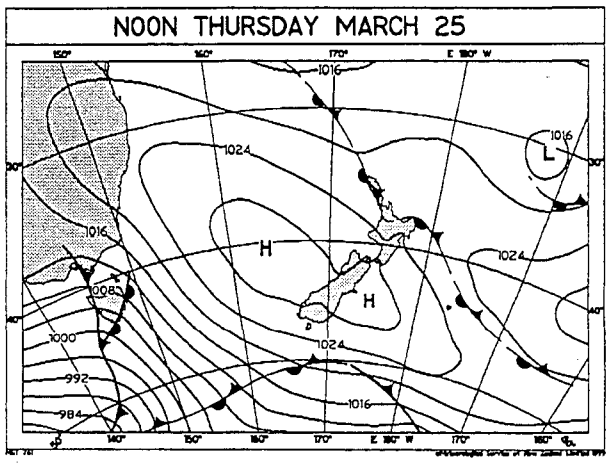


Figure 8: The situation which provided near perfect conditions for flying Fiordland on leg 5 on Thursday, 25 March.

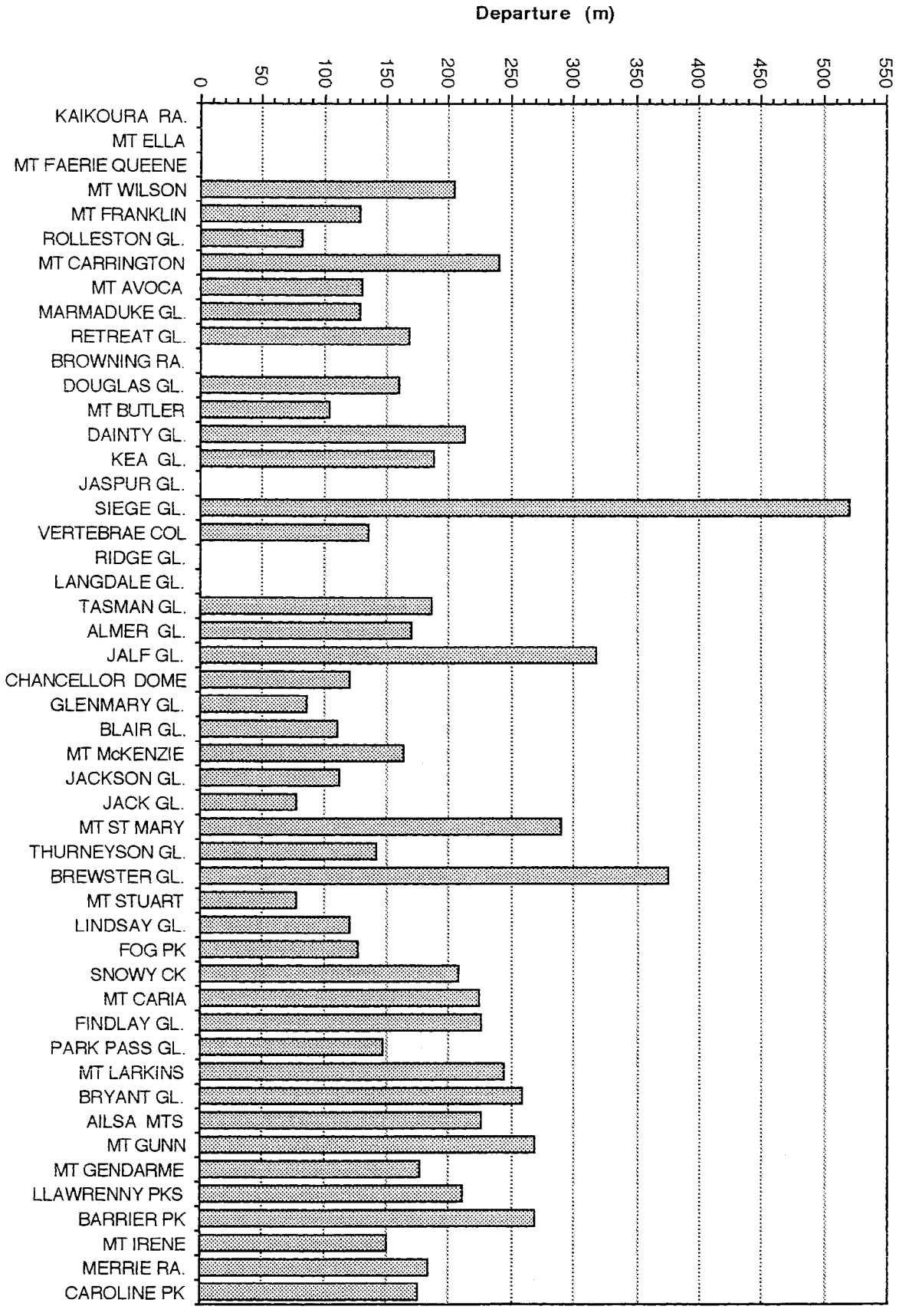


Figure 9: Summary of the 1999 snowline departures from the ELA.

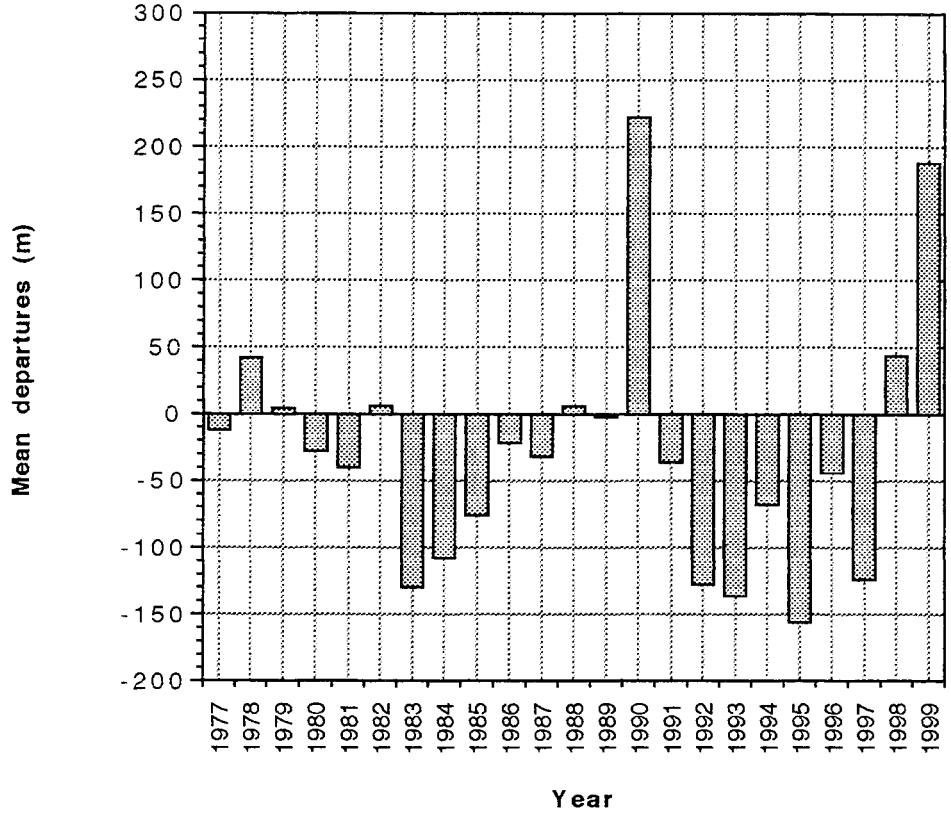


Figure 10: Mean annual snowline elevation departures from the steady state ELA, for the 22 years 1977 to 1999.

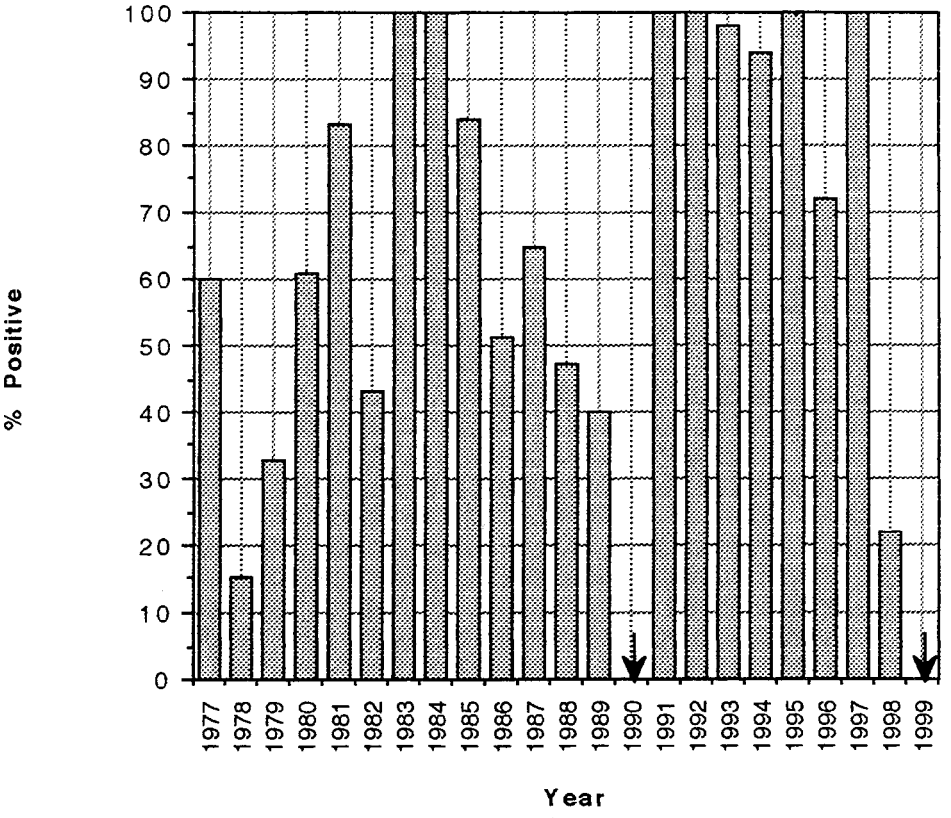


Figure 11: The percentage of all glaciers each year showing a positive balance. Arrows indicate years when all glaciers had negative balances.

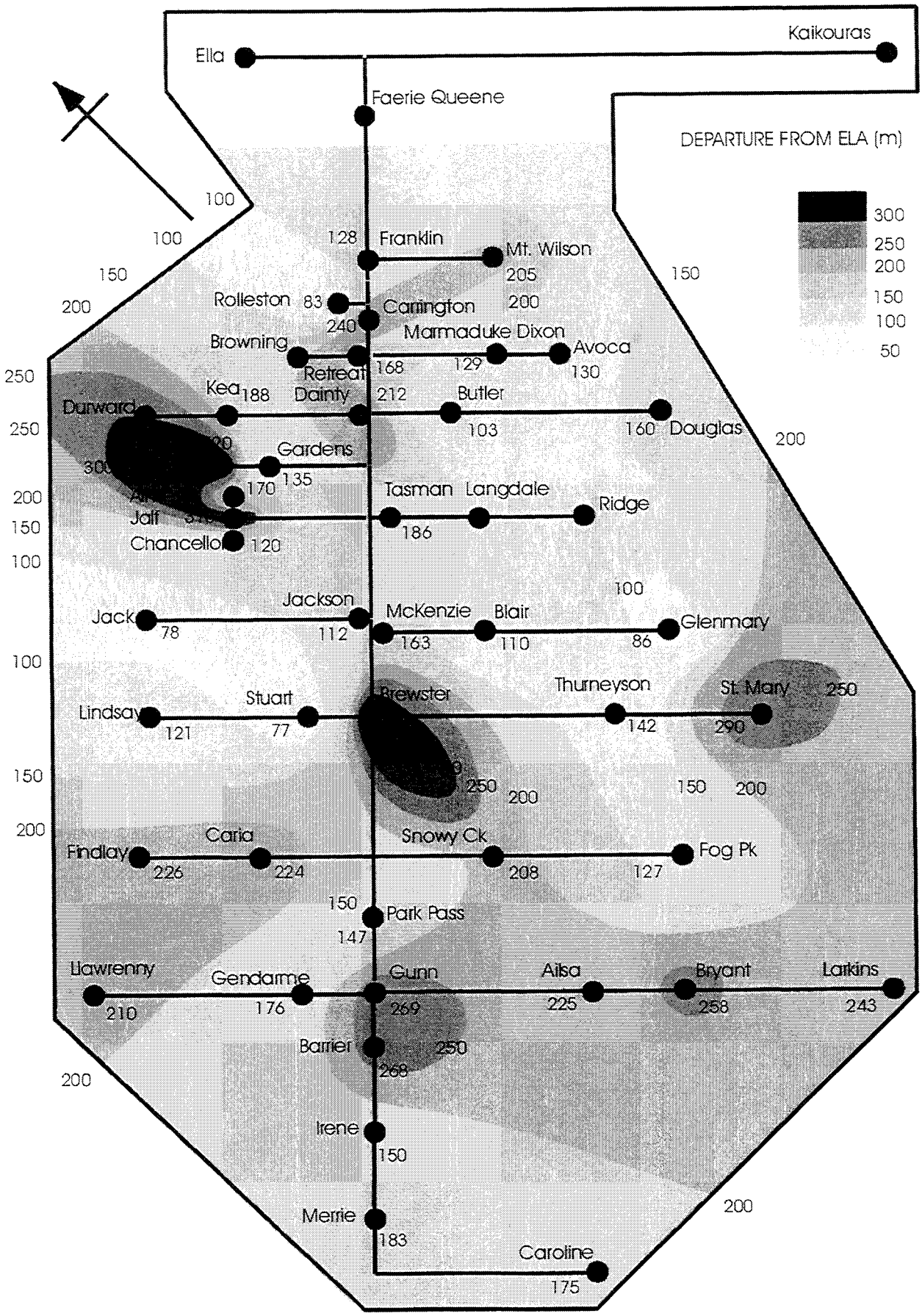


Figure 12: Diagrammatic trend surface of departures from the steady-state ELA, measured in m, for 1999. Plotted with respect to distance from the Main Divide, lateral exaggeration x 10.

Appendix 1: Individual glacier data

(a) Digitised maps for each glacier with the 1999 accumulation areas.

(b) Photograph of each glacier, selected to show the most appropriate angle for showing the snowlines and the 1978–89 glacier outline.

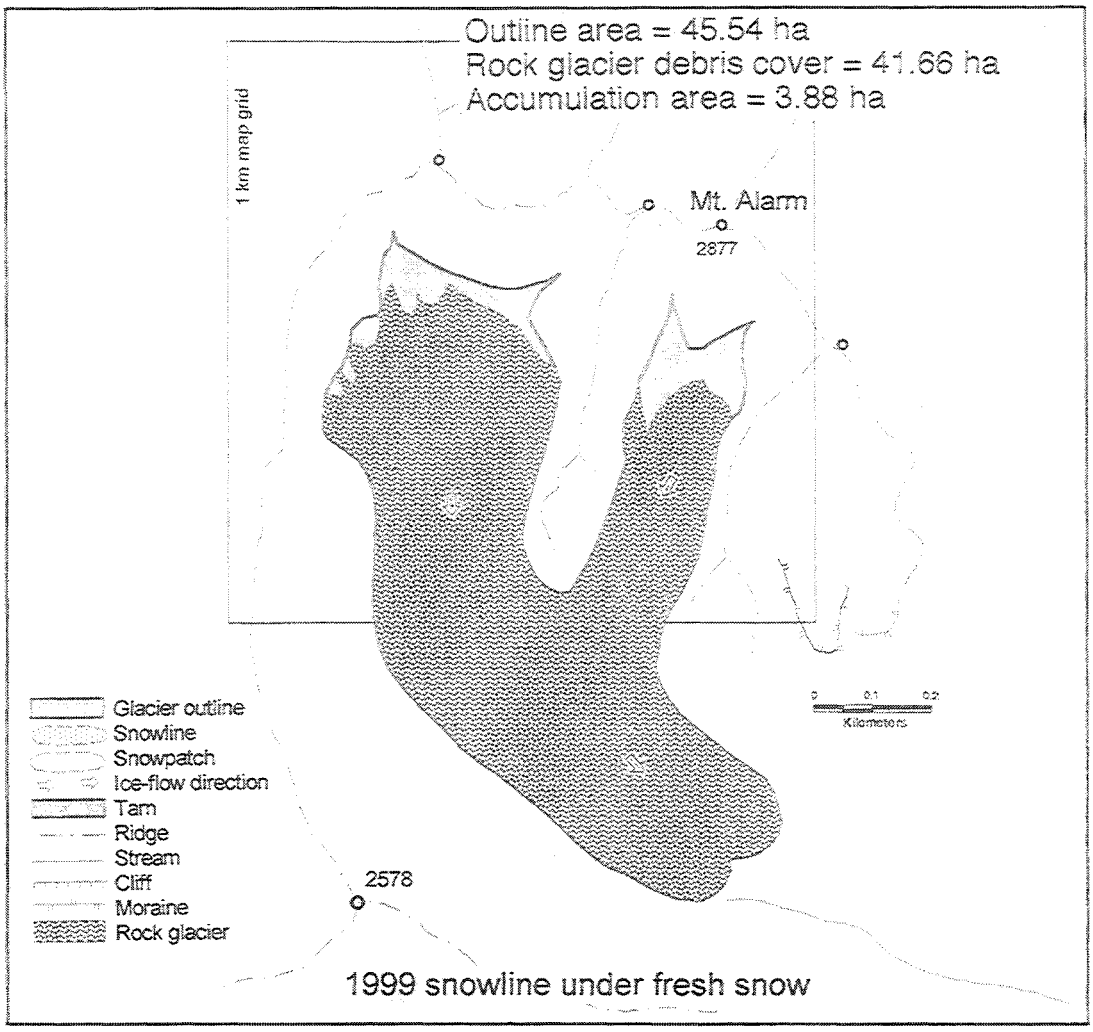
(c) Data for the individual glacier.

(d) Histogram of snowline departures from the ELA recorded at the glacier.

Table 3: **Transects of the Index glaciers with names and identification numbers**

GLACIER	INVENTORY NUMBER	GLACIER	INVENTORY NUMBER
Northern Glaciers		**Section V Ahuriri – Haast**	
Kaikoura Ra.	621/001	Mt St. Mary	711B/039
Mt Ella	932B/012	Thurneyson Gl.	711B/012
Mt Faerie Queene	646/006	Brewster Gl.	868C/020
Mt Wilson	None	Mt Stuart	752I/104
Mt Franklin	911A/002	Lindsay Gl.	867/002
Rolleston Gl.	911A/004		
Mt Carrington	646C/027		
Section I Avoca – Kokatahi		**Section VI Shotover – Arawata**	
Mt Avoca	685F/004	Fog Pk	752E/051
Marmaduke Gl.	664C/012	Snowy Ck	752C/103
Retreat Gl.	906A/004	Mt Caria	863B/001
Browning Ra.	906A/001	Findlay Gl.	859/009
Section II		**Section VII**	
Arrowsmith – Wanganui		**Wakatipu – Milford**	
Douglas Gl.	685B/001	Mt Larkins	752E/002
Mt Butler	685C/060	Bryant Gl.	752B/025
Dainty Gl.	897/019	Ailsa Mts	752B/013
Kea Gl.	897/007	Mt Gunn	851B/057
Jaspur Gl.	897/003	Mt Gendarme	797G/033
		Llawrenny Pks	846/035
Intermediate		**Intermediate**	
Siege Gl.	893A/006	Park Pass Gl.	752B/048
Vertebrae Col	893A/025		
Section III Jollie – Fox		**Fiordland Glaciers**	
Ridge Gl.	711L/024	Barrier Pk	797f/004
Langdale Gl.	711I/035	Mt Irene	797D/001
Tasman Gl.	711I/012	Merrie Ra.	797B/010
Almer Gl.	888B/003	Caroline Pk	803/001
Jalf Gl.	886/002		
Chancellor Dome	882A/007		
Section IV Dobson – Paringa			
Glenmary Gl.	711F/006		
Blair Gl.	711D/038		
Mt McKenzie	711D/021		
Jackson Gl.	868B/094		
Jack Gl.	875/015		

KAIKOURA RANGE



Kaikoura Range

Inventory No. 621/001
A large rock glacier on Mt. Alarm

Glacier data

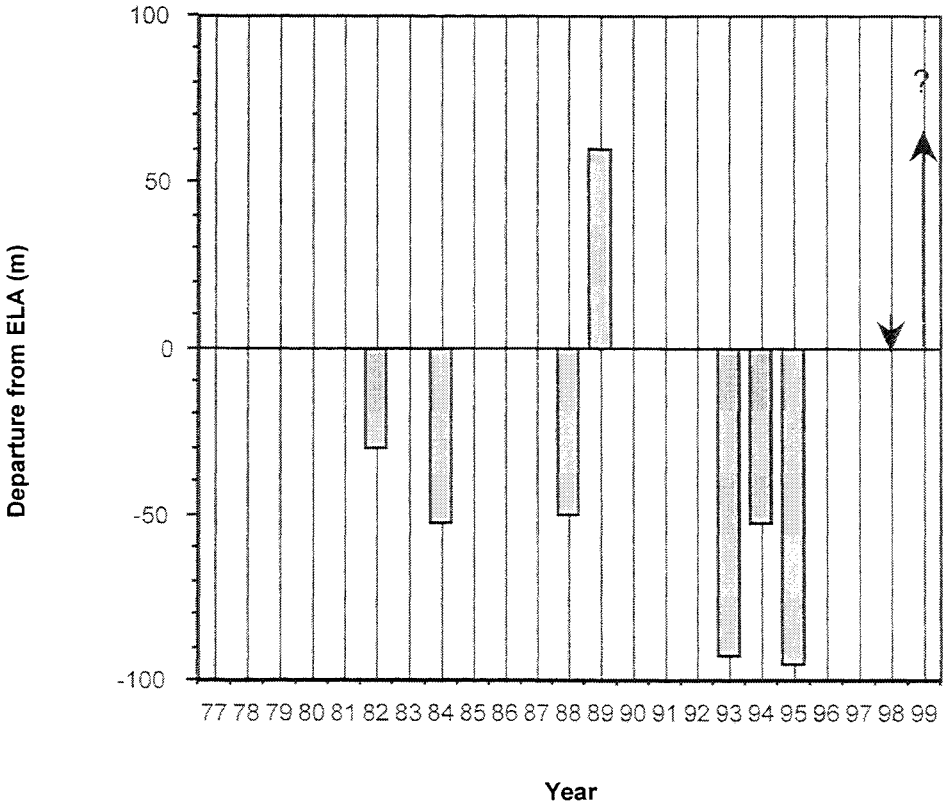
Glacier area (ha)	Including rock glacier	45.54
	Debris free area	3.88
Equilibrium line altitude (ELA)		2525
Maximum elevation (m)		2640
Minimum elevation (m)		2200
Mean elevation (m)		2420
Elevation range (m)		440
Length (km)		1.4
Gradient		0.314

1999 Snowline data

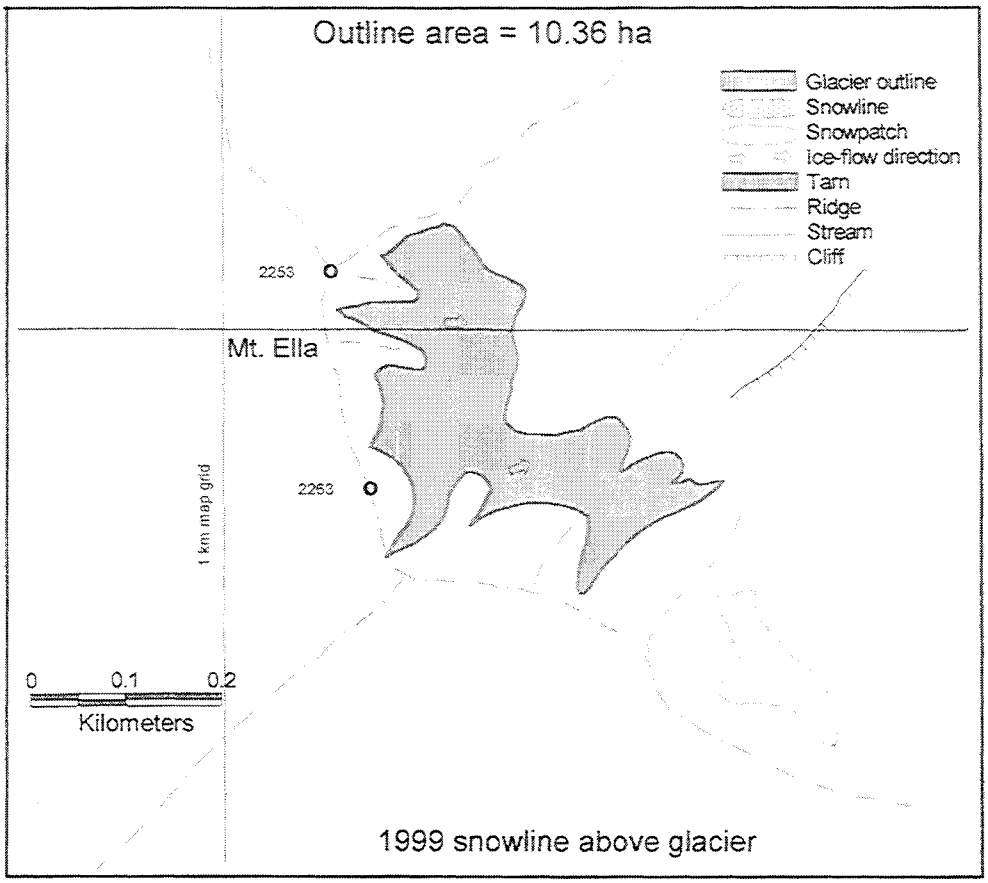
1999 accum area (ha)	Undetermined, new snow and cloud.
1999 snowline elevation (m)	Undetermined, new snow and cloud.
Snowline departure from ELA (m)	-
Accumulation area ratio (AAR)	-

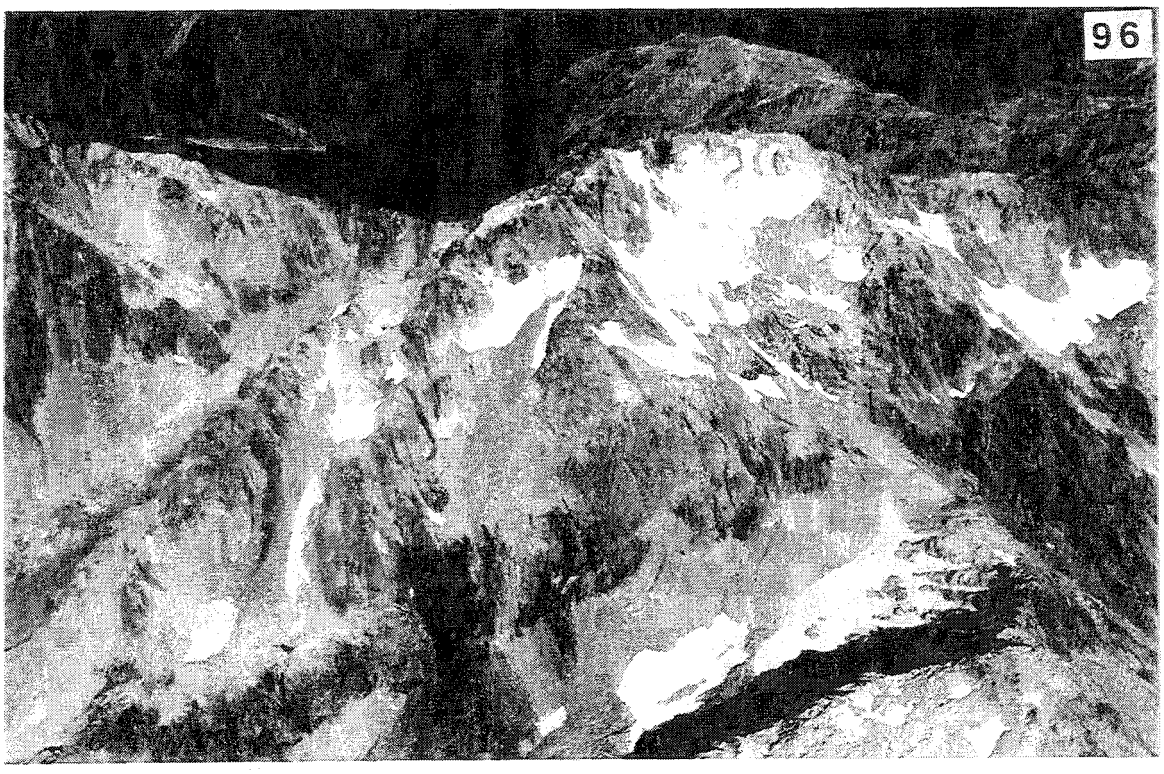
Left: Digitised map of Kaikoura Range index glacier and oblique aerial photograph taken 1998.

Below: Plot of all available annual snowline departures from the ELA for Kaikoura Range. Down arrow indicates zero value.



MOUNT ELLA


Outline area = 10.36 ha
Glacier outline
Snowline
Snowpatch
Ice-flow direction
Tarn
Ridge
Stream
Cliff
2253
Mt. Ella
2263
1 km map grid
0
0.1
0.2
Kilometers
1999 snowline above glacier


96

Mt. Ella

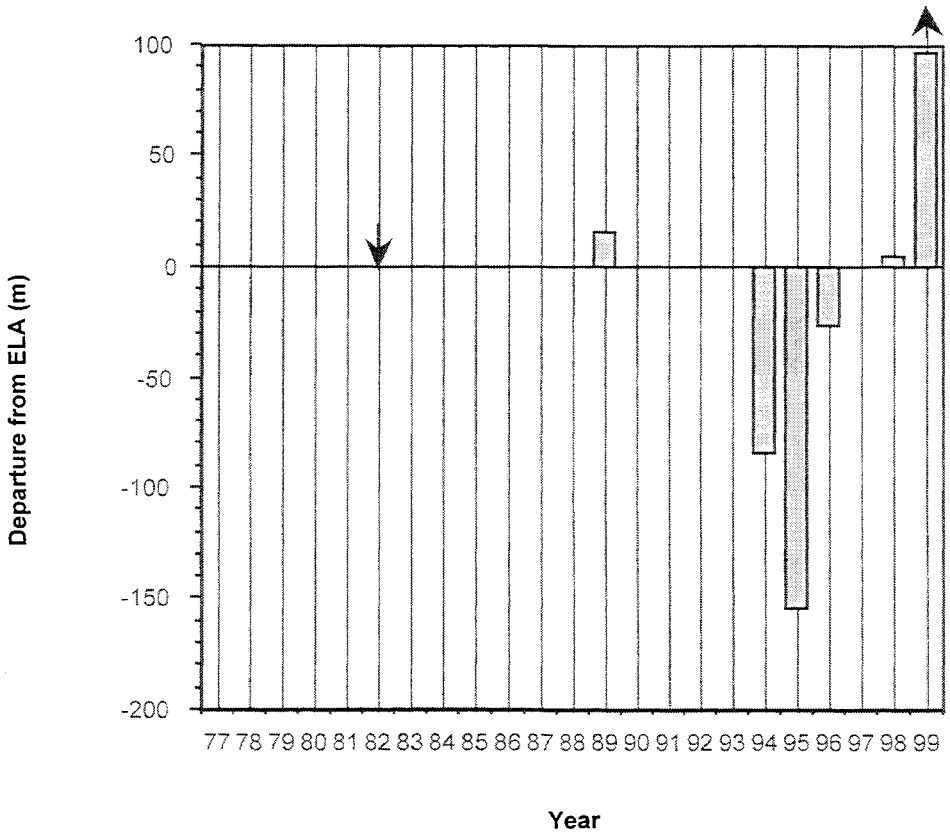
Inventory No. 932B/12
A small glacierette on Mt. Ella

Glacier Data	
Glacier area (Ha)	10.36
Equilibrium line altitude (ELA)	2154
Maximum elevation (m)	2250
Minimum elevation (m)	2080
Mean elevation (m)	2165
Elevation range (m)	170
Length (km)	0.2
Gradient	0.85

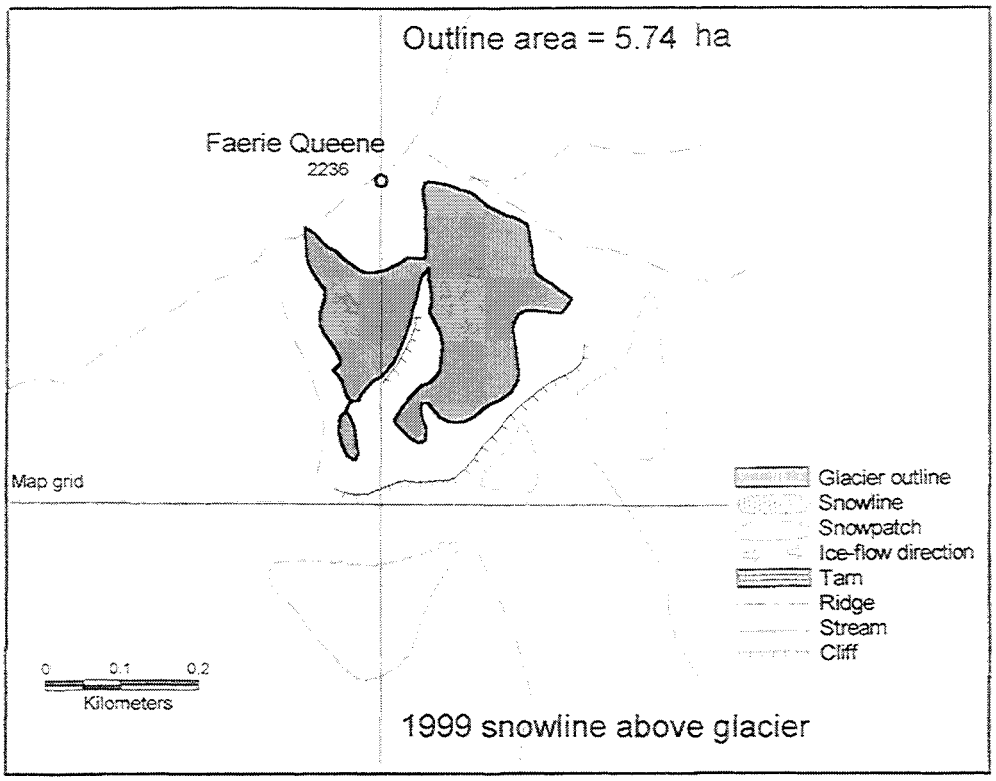
1999 Snowline Data	
1999 accum area (Ha)	Above glacier
1999 snowline elevation (m)	-
Snowline departure from ELA (m)	-
Accumulation area ratio (AAR)	-

Left: Digitised map of Mt. Ella index glacier and oblique aerial photograph taken 1996.

Below: Plot of all available annual snowline departures from the ELA for Mt. Ella. Down arrow indicates zero value.



FAERIE QUEENE



Mount Faerie Queene

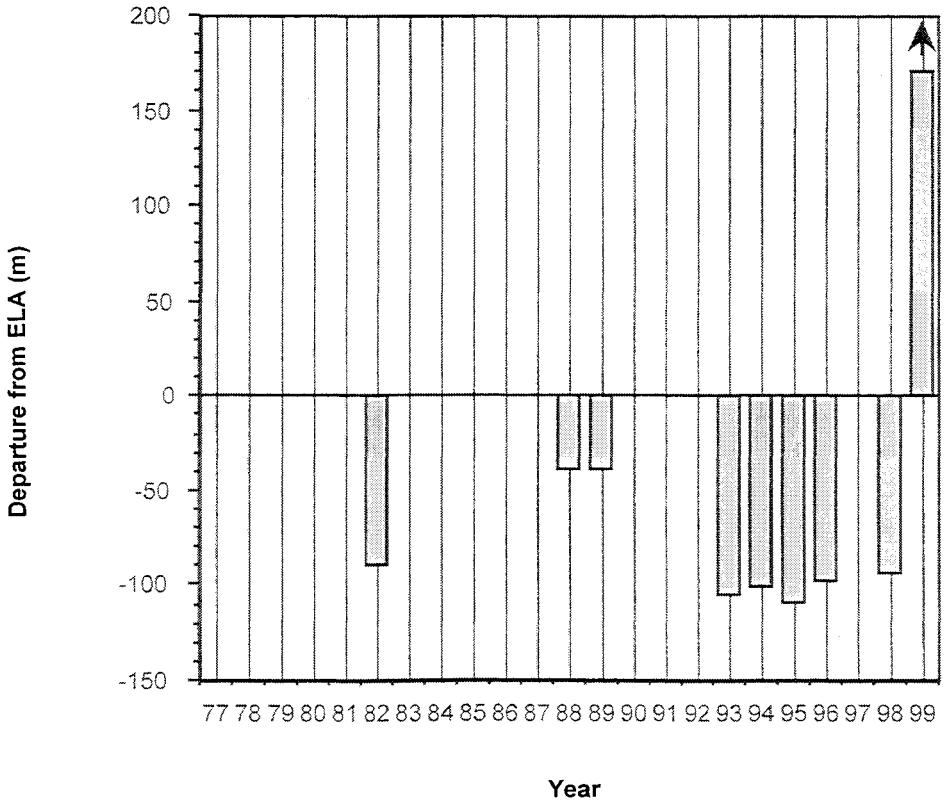
Inventory No. 646/006
A small glacierette on SE side of Mt. Faerie Queene

Glacier Data	
Glacier area (ha)	5.74
Equilibrium line altitude (ELA)	2030
Maximum elevation (m)	2190
Minimum elevation (m)	1940
Mean elevation (m)	2065
Elevation range (m)	250
Length (km)	0.3
Gradient	0.83

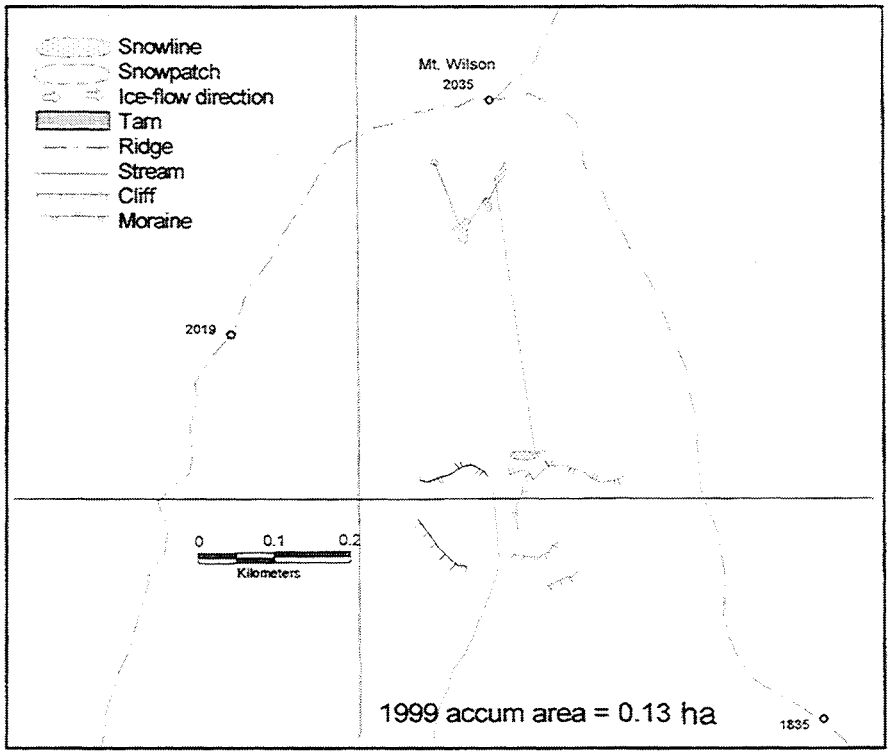
1999 Snowline Data	
1999 accum area (ha)	Above glacier
1999 snowline elevation (m)	-
Snowline departure from ELA (m)	-
Accumulation area ratio (AAR)	-

Left: Digitised map of Faerie Queene index glacier and oblique aerial photograph taken 1998.

Below: Plot of all available annual snowline departures from the ELA for Faerie Queene.



MOUNT WILSON SNOWPATCH



Mount Wilson snowpatch

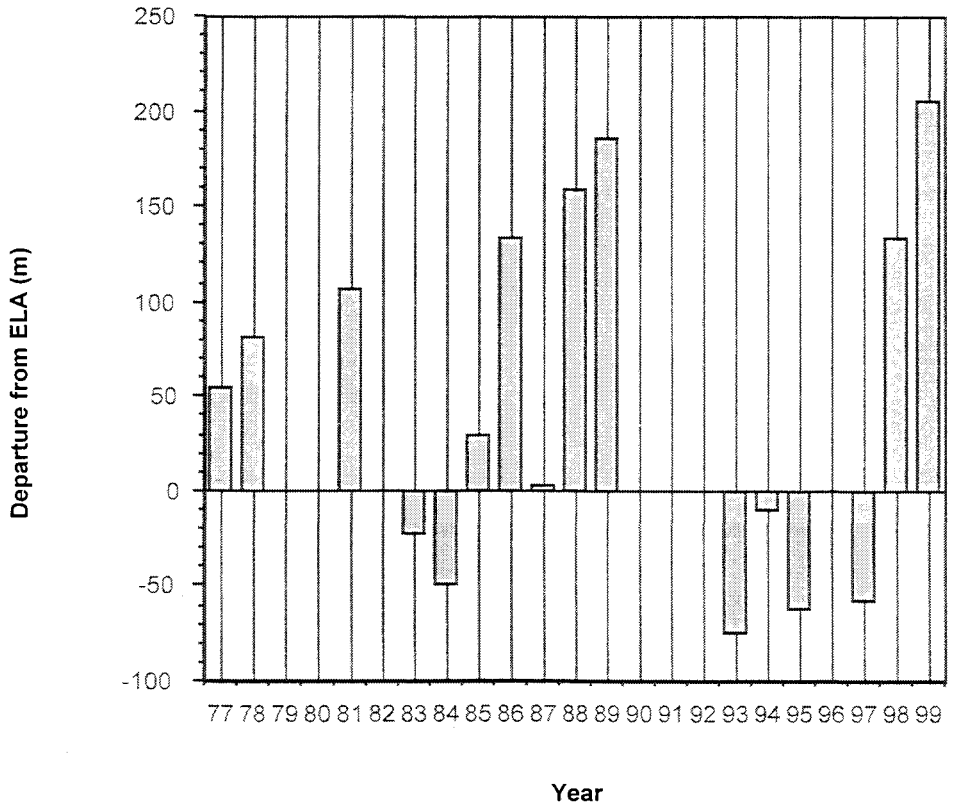
Inventory No. None
A variable snowpatch on S side of Mt. Wilson, Waimakariri R. catchment

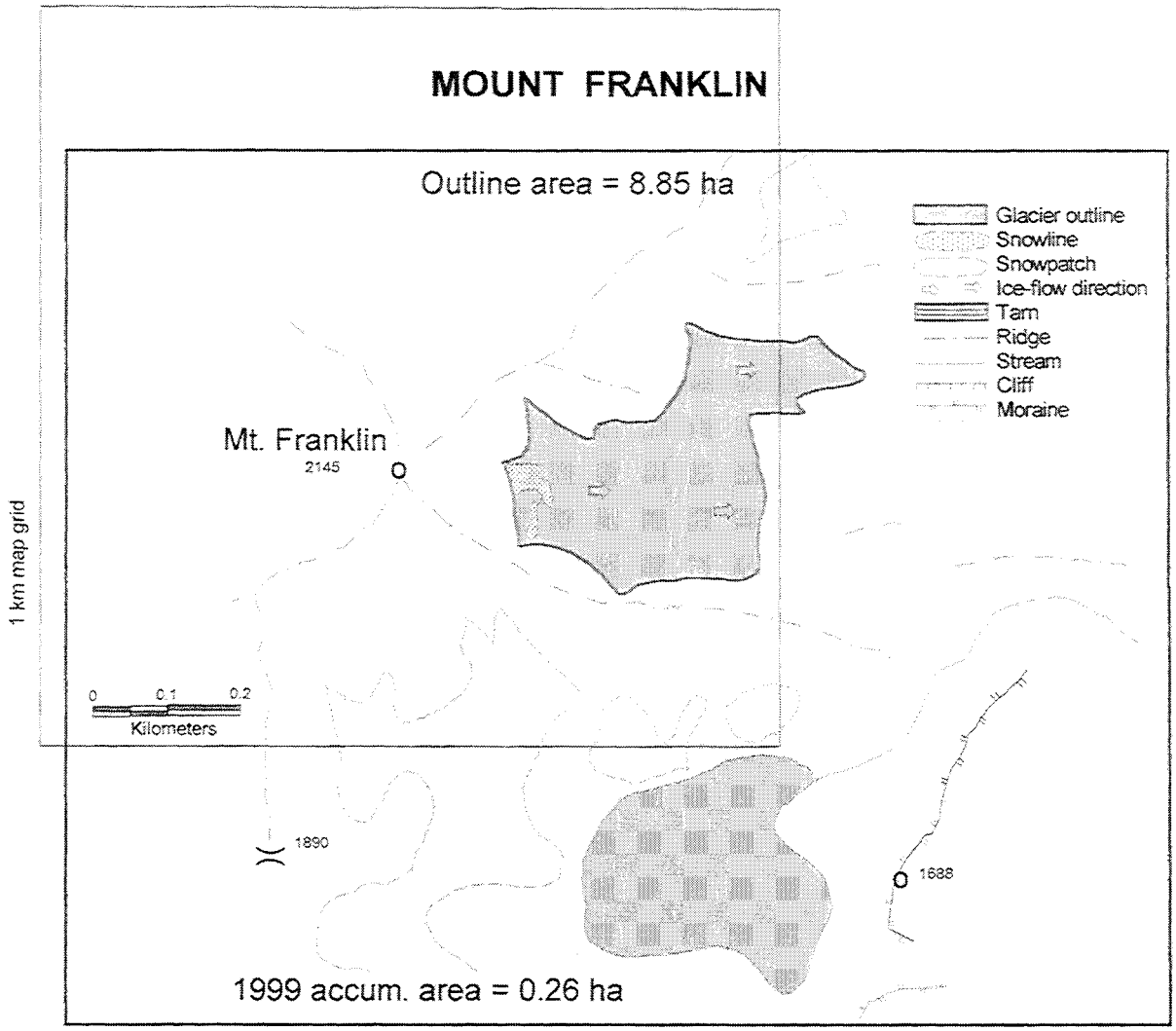
Glacier Data	
Glacier area (ha)	variable
Equilibrium line altitude (ELA)	1820
Maximum elevation (m)	2030
Minimum elevation (m)	1740
Mean elevation (m)	1885
Elevation range (m)	290
Maximum length (km)	0.5
Gradient	0.58

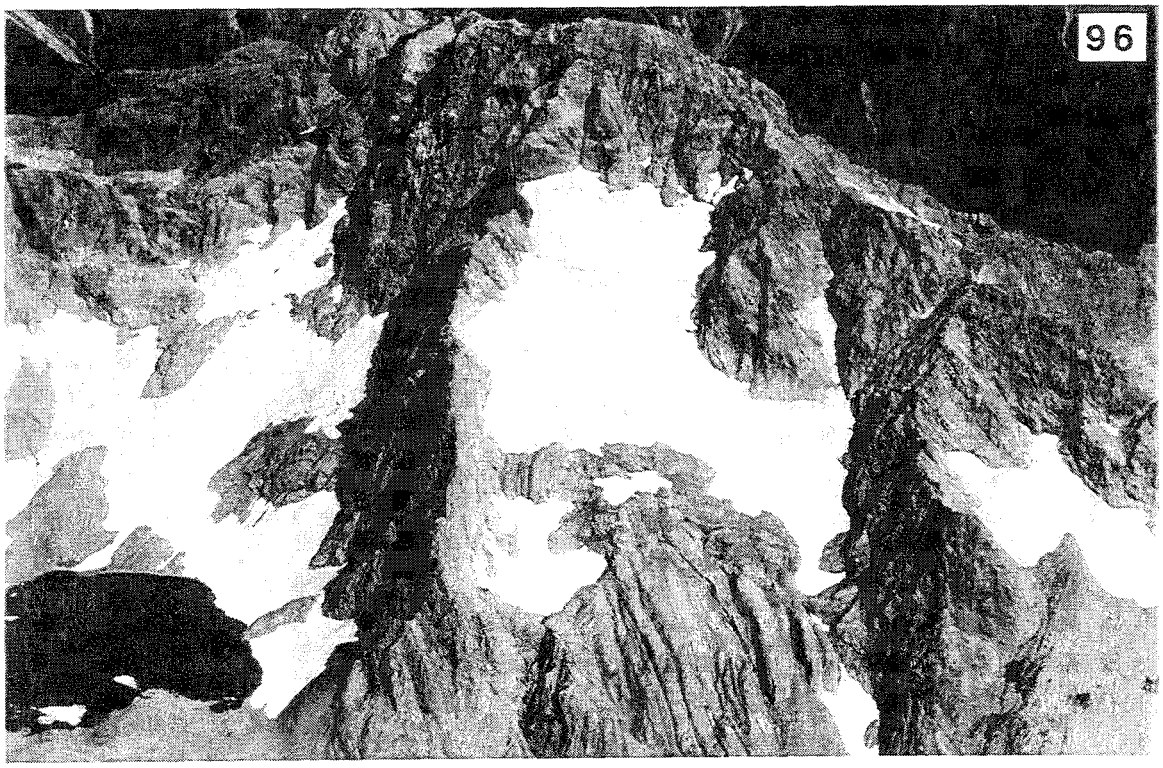
1999 Snowline Data	
1999 accum area (ha)	0.13
1999 snowline elevation (m)	2025
Snowline departure from ELA (m)	205
Accumulation area ratio (AAR)	-

Left: Digitised map of Mt. Wilson snowpatch for 1999 and oblique aerial photograph taken 1998.

Below: Plot of all available annual snowline departures from the ELA for Mt. Wilson.




MOUNT FRANKLIN
Outline area = 8.85 ha
Glacier outline
Snowline
Snowpatch
Ice-flow direction
Tarn
Ridge
Stream
Cliff
Moraine
Mt. Franklin
2145
1 km map grid
0
0.1
0.2
Kilometers
1890
1688
1999 accum. area = 0.26 ha


96

Mount Franklin

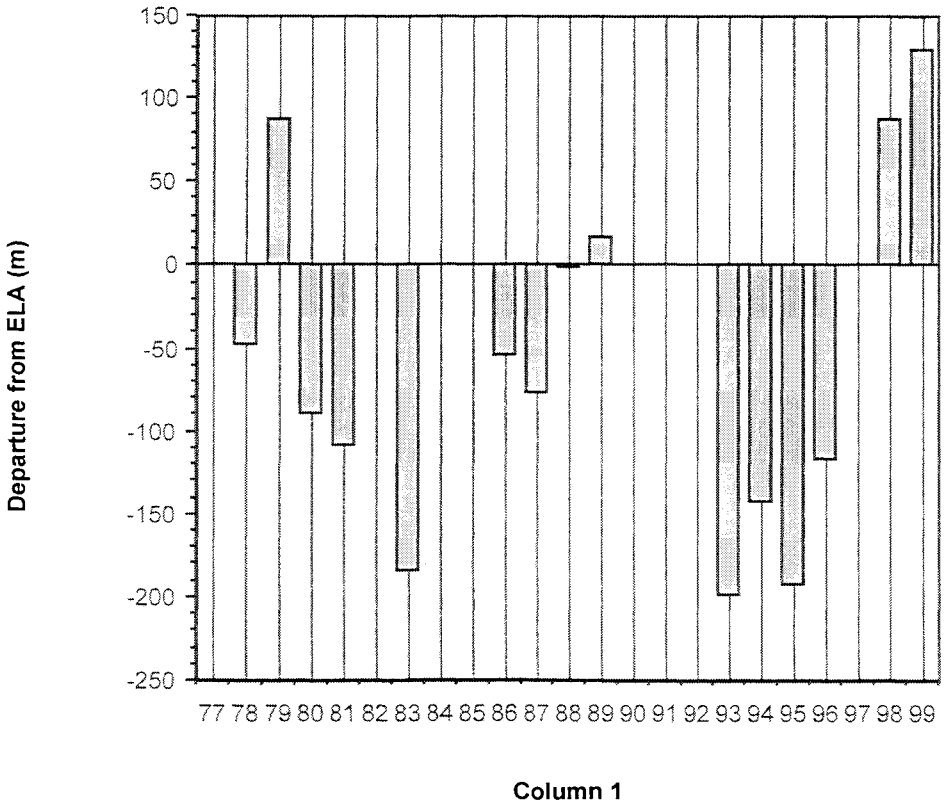
Inventory No. 911A/002
A small glacier on E side of Mt. Franklin, Taramakau R. catchment

Glacier Data	
Glacier area (ha)	8.85
Equilibrium line altitude (ELA)	1850
Maximum elevation (m)	1980
Minimum elevation (m)	1700
Mean elevation (m)	1840
Elevation range (m)	280
Maximum length (km)	0.5
Gradient	0.56

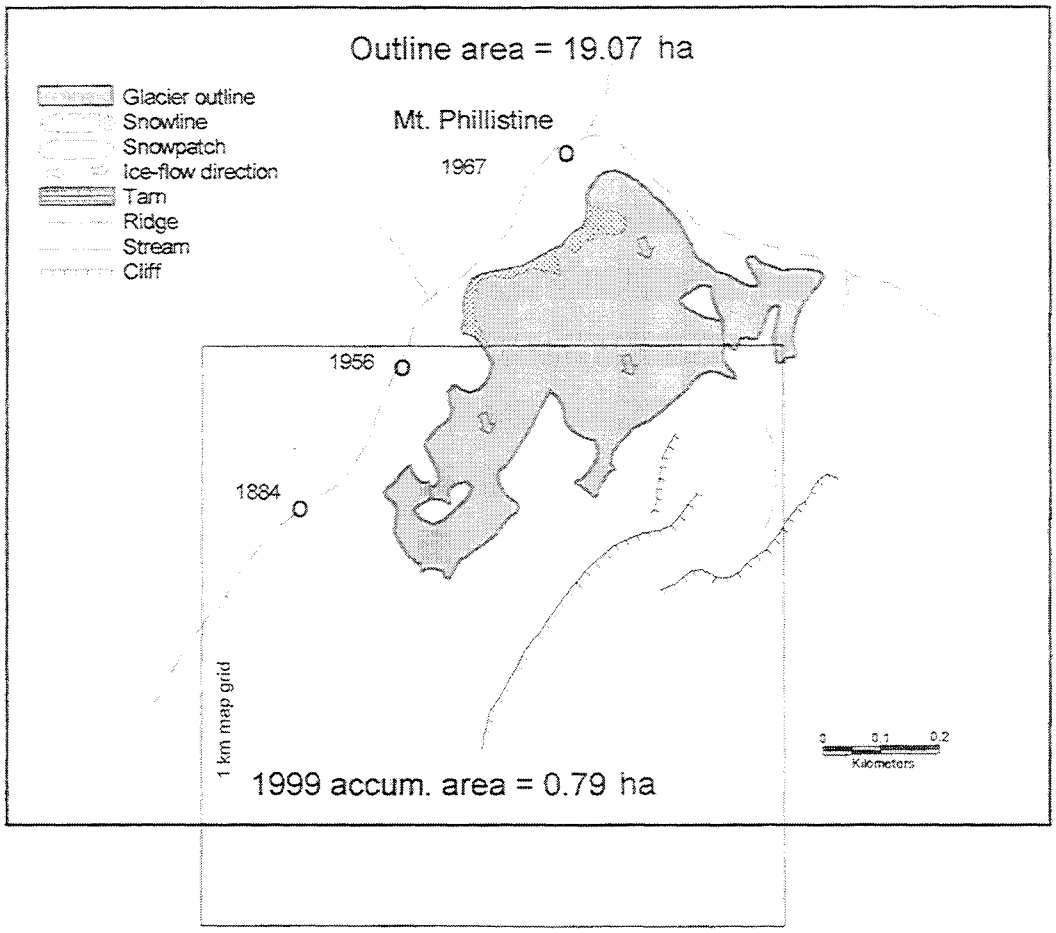
1999 Snowline Data	
1999 accumulation area (ha)	0.26
1999 snowline elevation (m)	1978
Snowline departure from ELA (m)	128
Accumulation area ratio (AAR)	0.03

Left: Digitised map of Mt. Franklin for 1999 and oblique aerial photograph taken 1996.

Below: Plot of all available annual snowline departures from the ELA for Mt. Franklin.



ROLLESTON GL



Rolleston Glacier

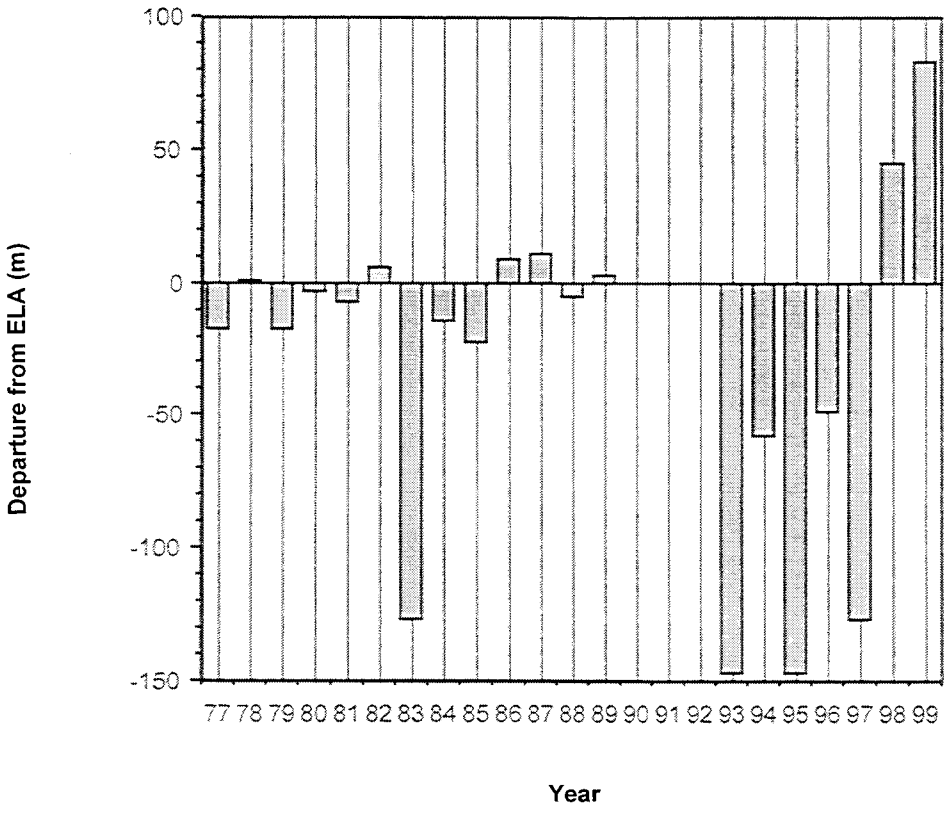
Inventory No. 911A/004
A small glacier on SE side of Mt. Philistine, Otira R. catchment

Glacier Data	
Glacier area (ha)	19.07
Equilibrium line altitude (ELA)	1767
Maximum elevation (m)	1900
Minimum elevation (m)	1690
Mean elevation (m)	1795
Elevation range (m)	210
Maximum length (km)	0.4
Gradient	0.525

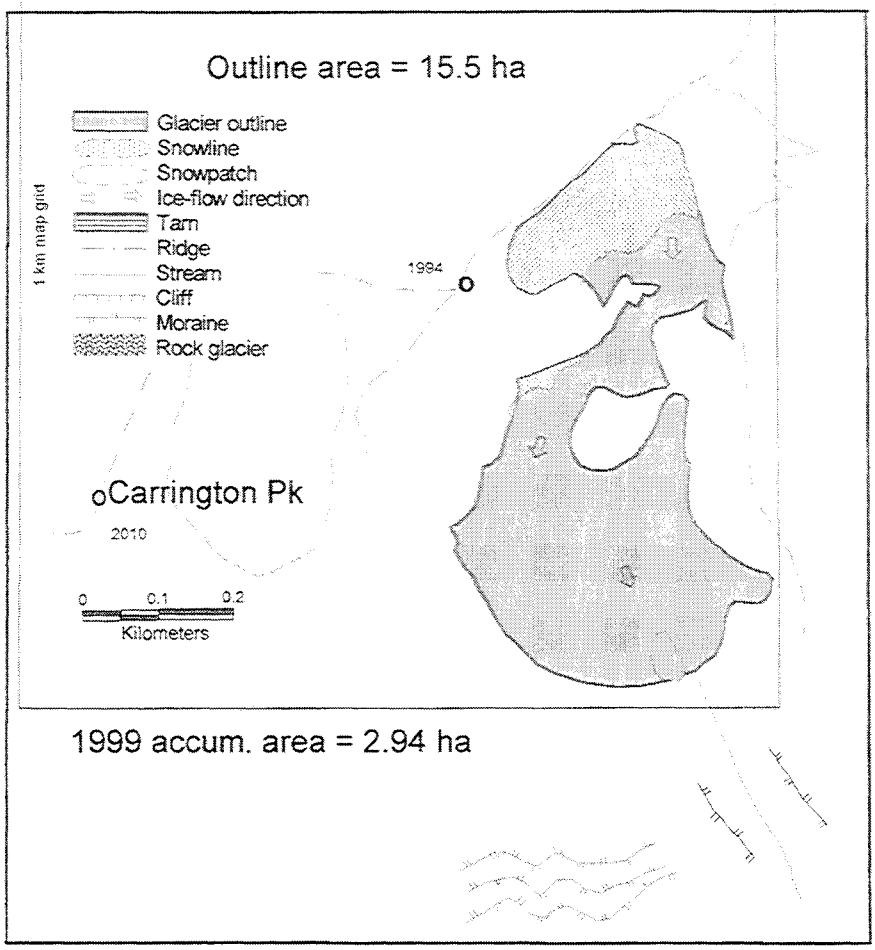
1999 Snowline Data	
1999 accumulation area (ha)	0.79
1999 snowline elevation (m)	1850
Snowline departure from ELA (m)	83
Accumulation area ratio (AAR)	0.04

Left: Digitised map of Rolleston Gl. for 1999 and oblique aerial photograph taken 1996.

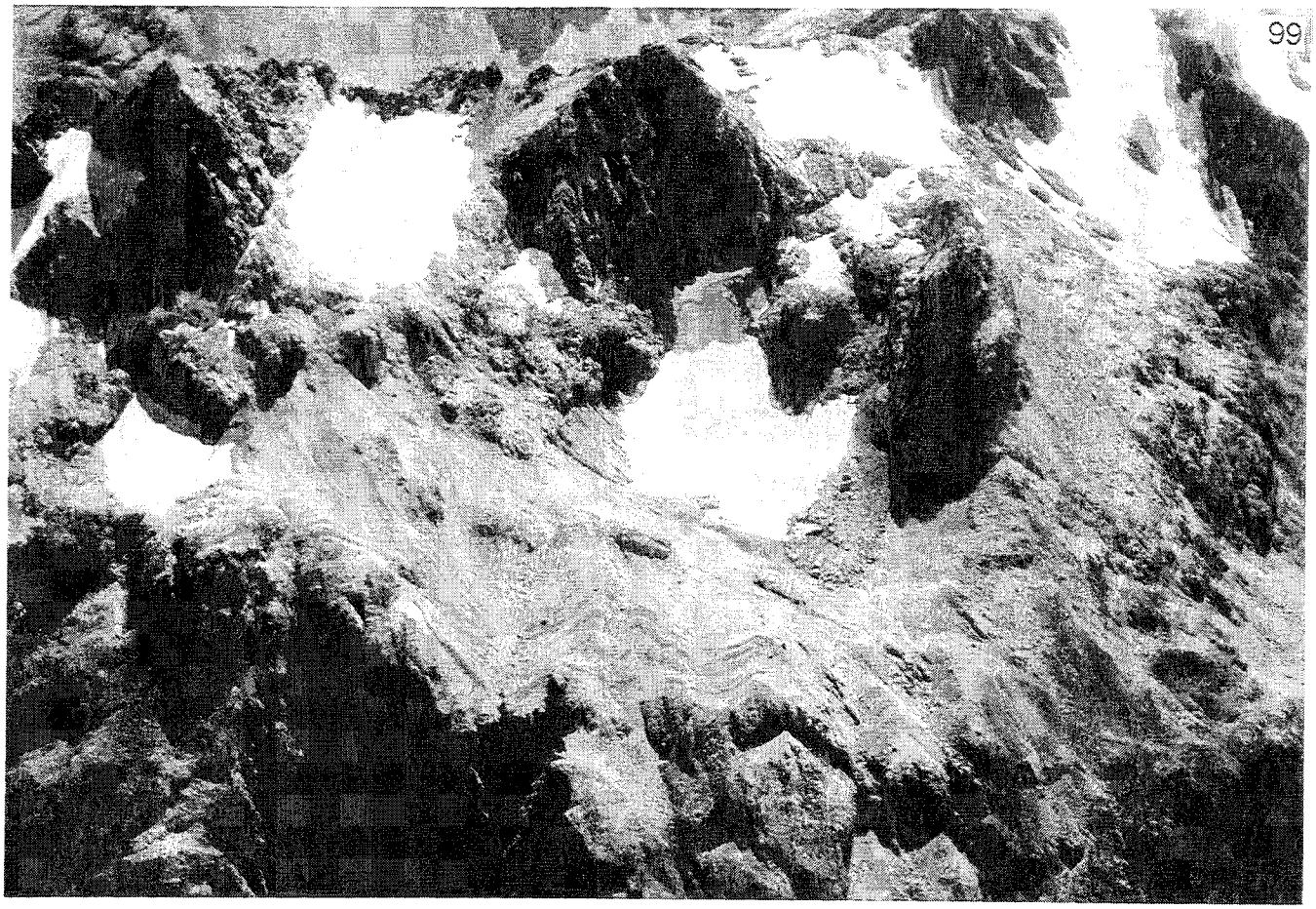
Below: Plot of all available annual snowline departures from the ELA for Rolleston Gl.



CARRINGTON PEAK



1999 accum. area = 2.94 ha



Carrington Peak

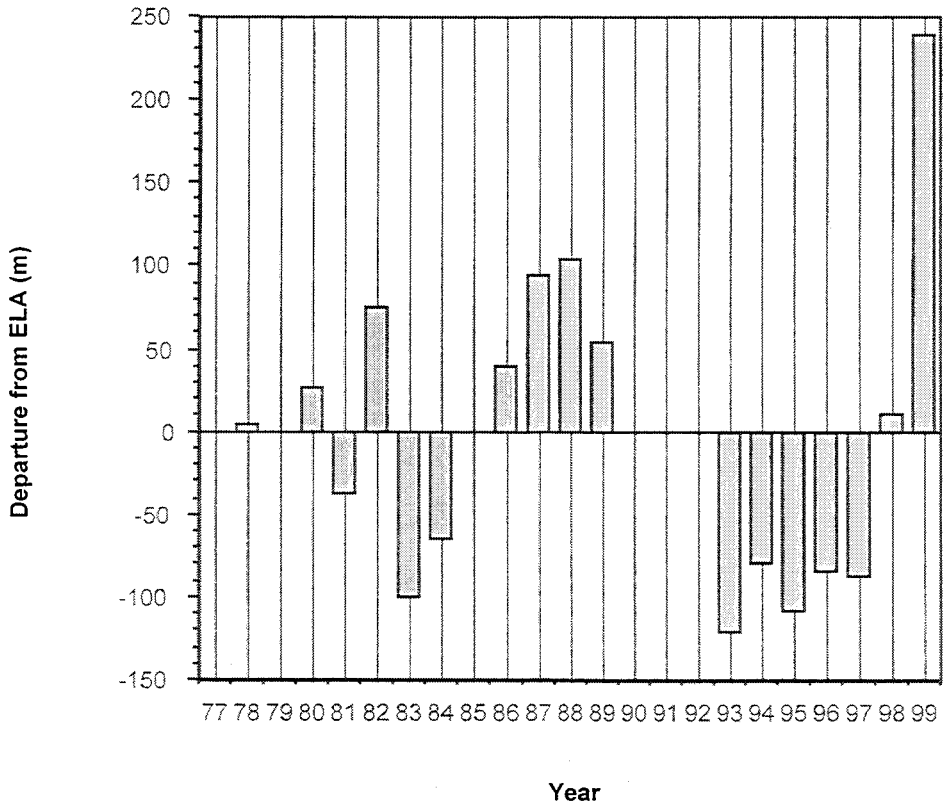
Inventory No. 646C/027
A small glacier to the north of Carrington Pk, Waimakariri R. catchment

Glacier Data	
Glacier area (ha)	15.5
Equilibrium line altitude (ELA)	1665
Maximum elevation (m)	1960
Minimum elevation (m)	1590
Mean elevation (m)	1775
Elevation range (m)	370
Maximum length (km)	0.7
Gradient	0.529

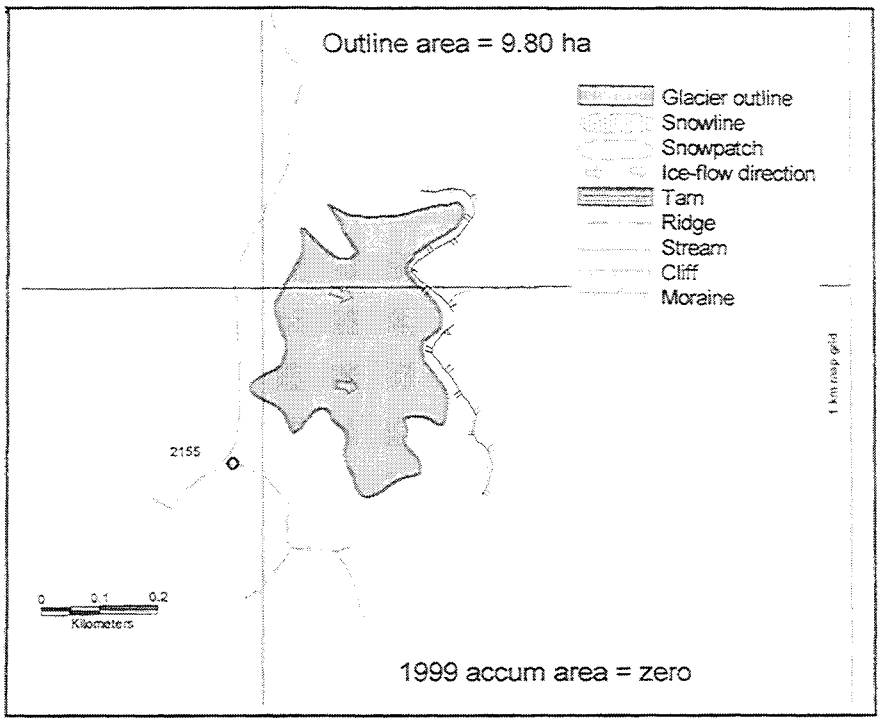
1999 Snowline Data	
1999 accumulation area (ha)	2.94
1999 snowline elevation (m)	1905
Snowline departure from ELA (m)	240
Accumulation area ratio (AAR)	0.19

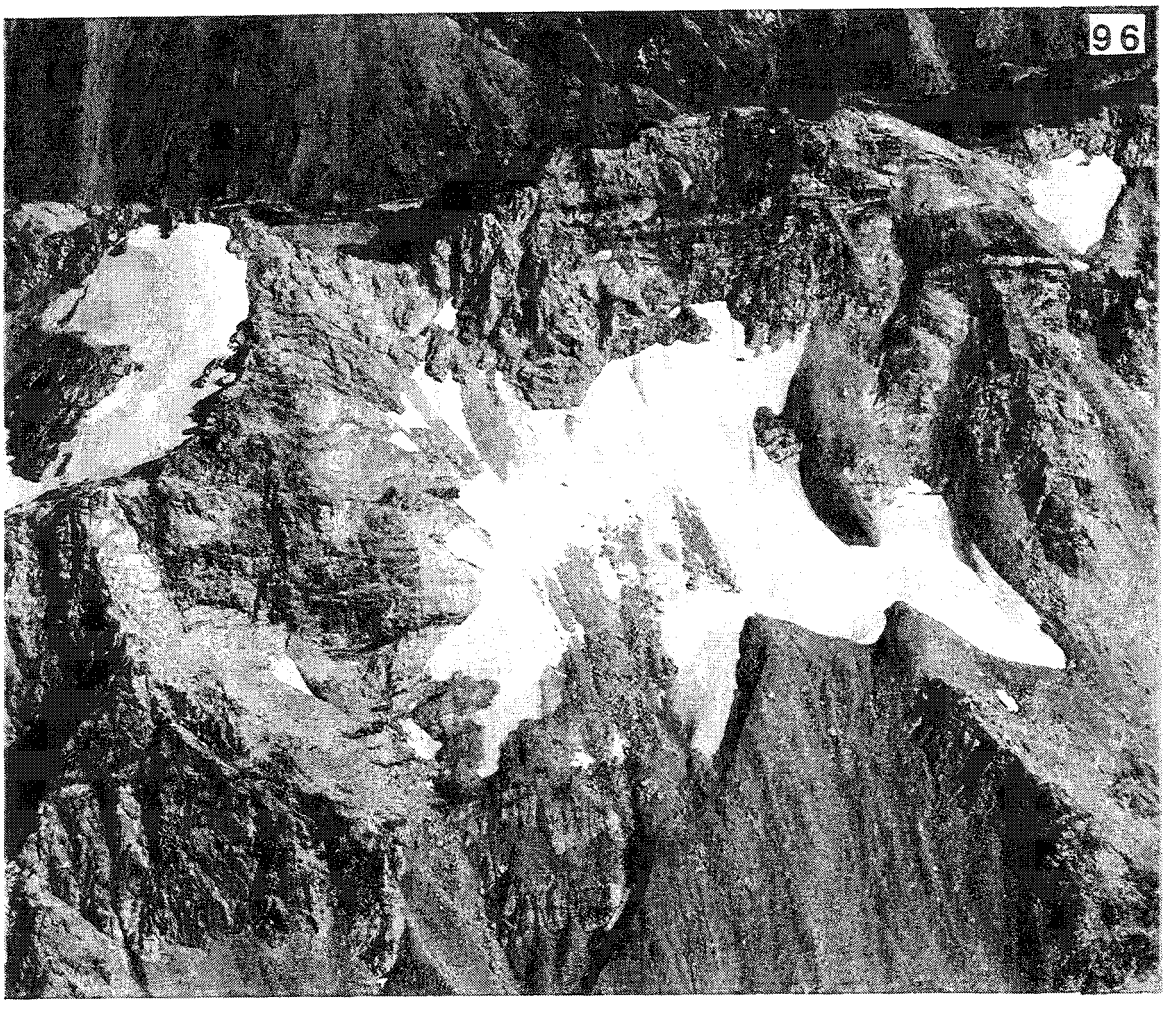
Left: Digitised map of Carrington Pk. for 1999 and oblique aerial photograph taken 1999.

Below: Plot of all available annual snowline departures from the ELA for Carrington Pk.



MOUNT AVOCA


Outline area = 9.80 ha
Glacier outline
Snowline
Snowpatch
Ice-flow direction
Tarn
Ridge
Stream
Cliff
Moraine
2155
0 0.1 0.2
Kilometers
1999 accum area = zero


96

Mount Avoca

Inventory No. 685F/004
A small glacierette to the south of Mt. Avoca, Rakaia R. catchment.
Location was near the epicentre of the 1994 Arthurs Pass earthquake.

Glacier Data

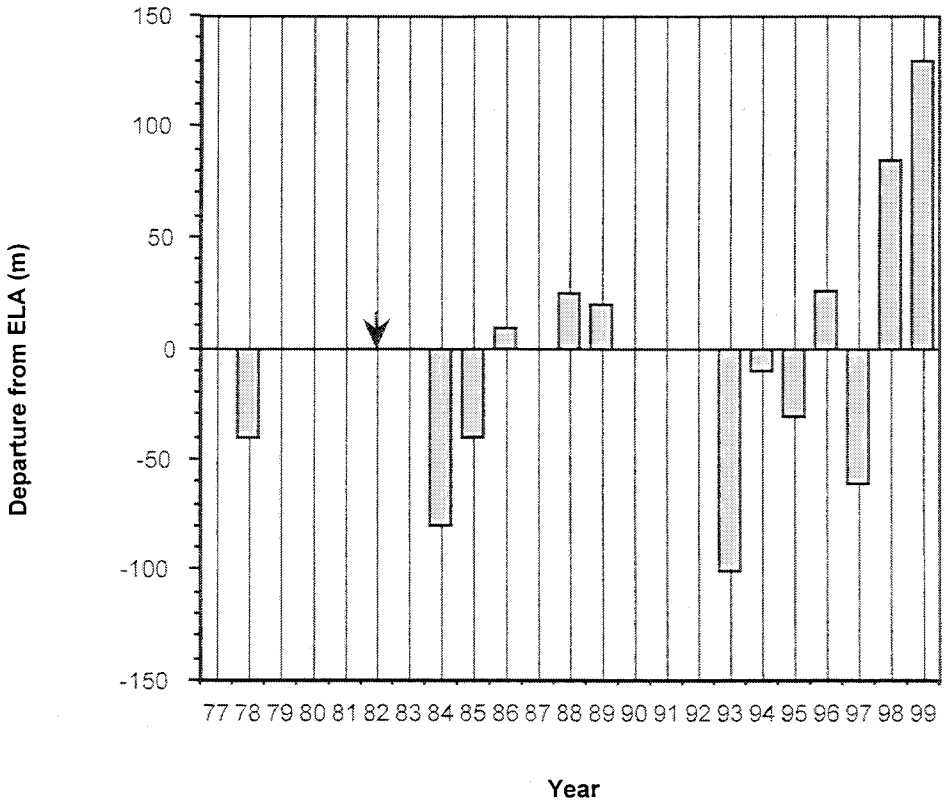
Glacier area (ha)	9.80
Equilibrium line altitude (ELA)	1950
Maximum elevation (m)	2080
Minimum elevation (m)	1890
Mean elevation (m)	1985
Elevation range (m)	190
Maximum length (km)	0.3
Gradient	0.633

1999 Snowline Data

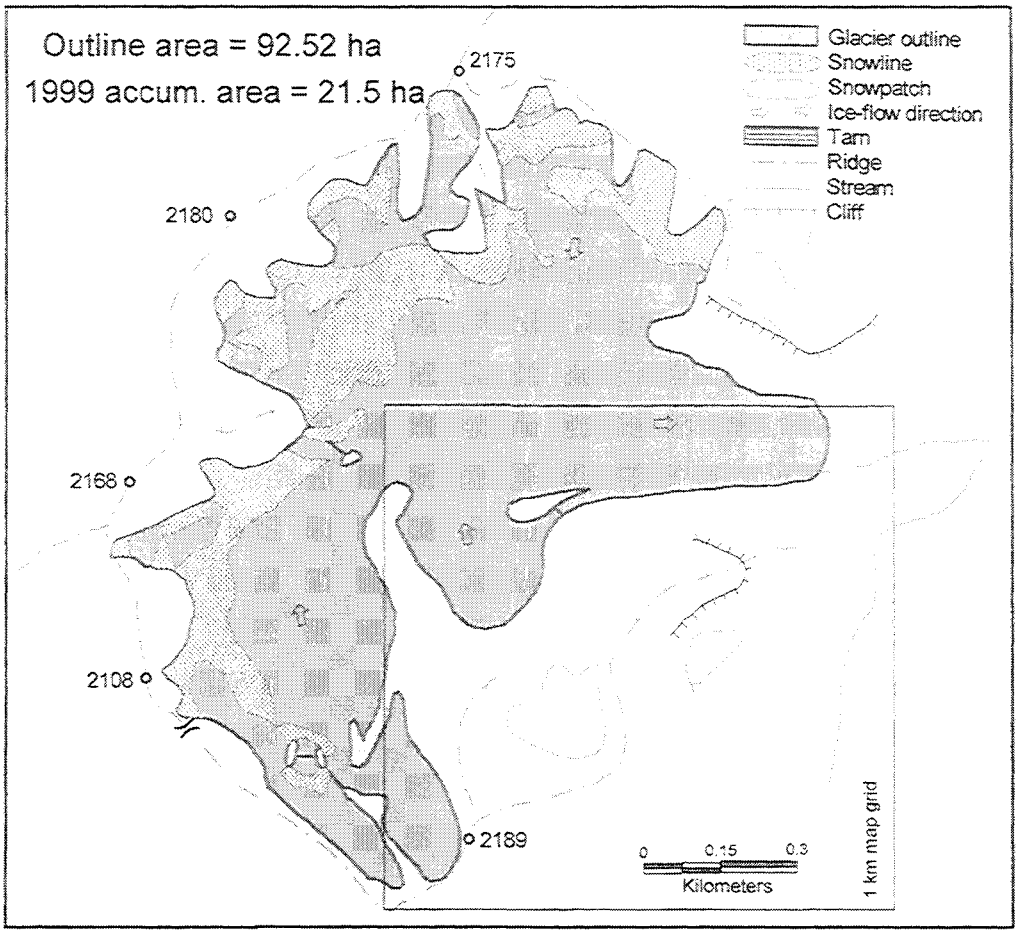
1999 accumulation area (ha)	0
1999 snowline elevation (m)	2080
Snowline departure from ELA (m)	130
Accumulation area ratio (AAR)	0

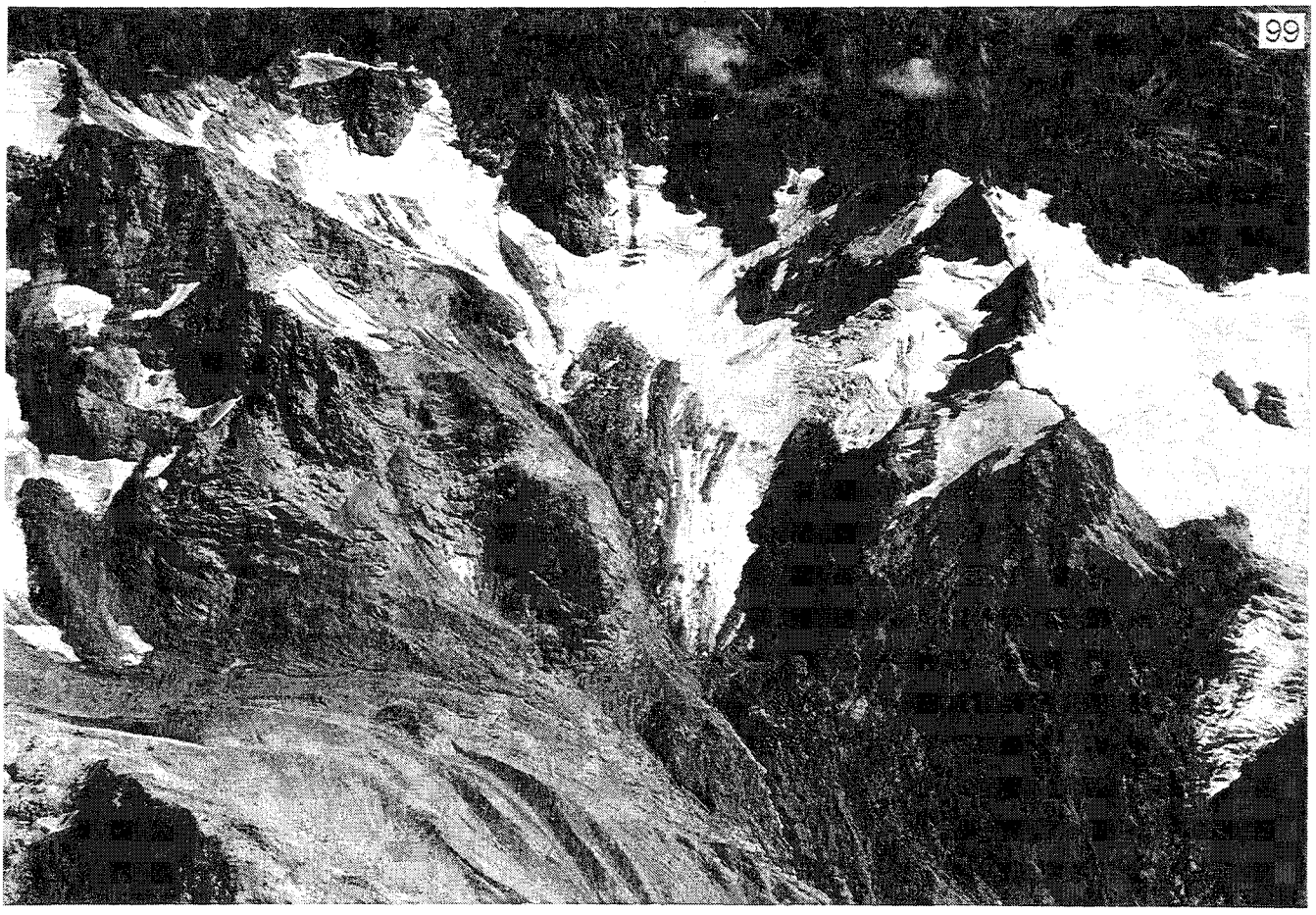
Left: Digitised map of Mt. Avoca and oblique aerial photograph taken 1996.

Below: Plot of all available annual snowline departures from the ELA for Mt. Avoca. Down arrow indicates zero value.



MARMADUKE DIXON GLACIER





Marmaduke Dixon Glacier

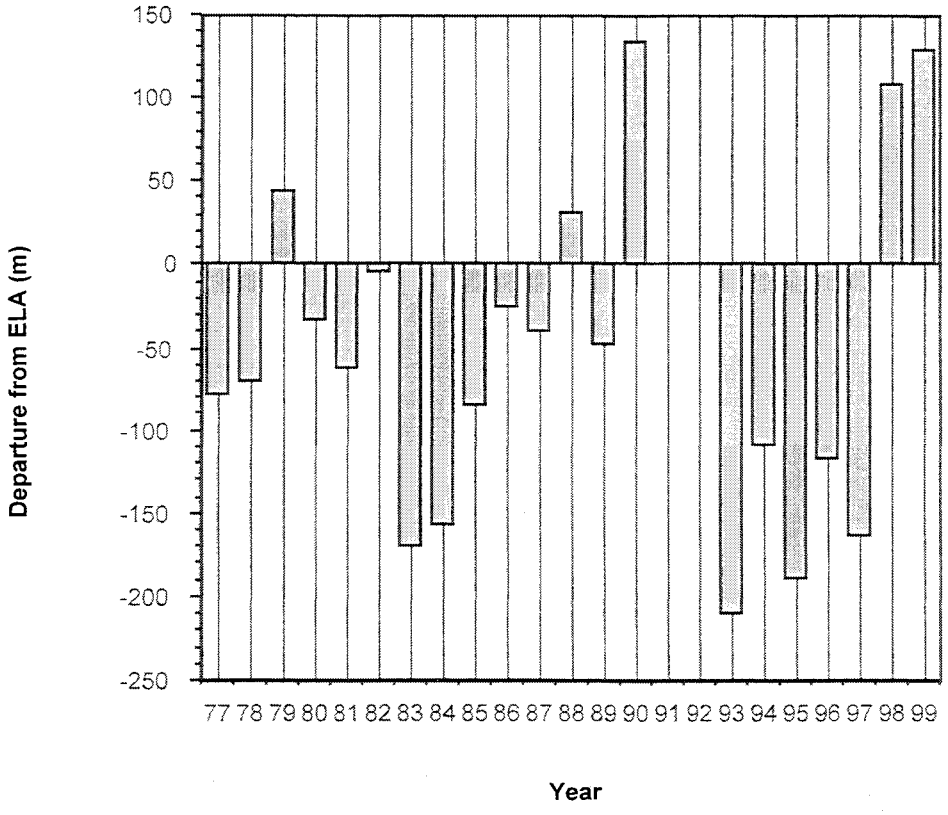
Inventory No. 664C/012
A small glacier at the head of White R, Waimakariri R. catchment.

Glacier Data	
Glacier area (ha)	92.52
Equilibrium line altitude (ELA)	1865
Maximum elevation (m)	2180
Minimum elevation (m)	1620
Mean elevation (m)	1858
Elevation range (m)	560
Maximum length (km)	1.7
Gradient	0.329

1999 Snowline Data	
1999 accumulation area (ha)	21.50
1999 snowline elevation (m)	1994
Snowline departure from ELA (m)	129
Accumulation area ratio (AAR)	0.23

Left: Digitised map of Marmaduke Dixon Gl. for 1999 and oblique aerial photograph taken 1999. Debris on the glacier is from the 1994 Arthurs Pass earthquake.

Below: Plot of all available annual snowline departures from the ELA for Marmaduke Dixon Gl.



Retreat Snowfield

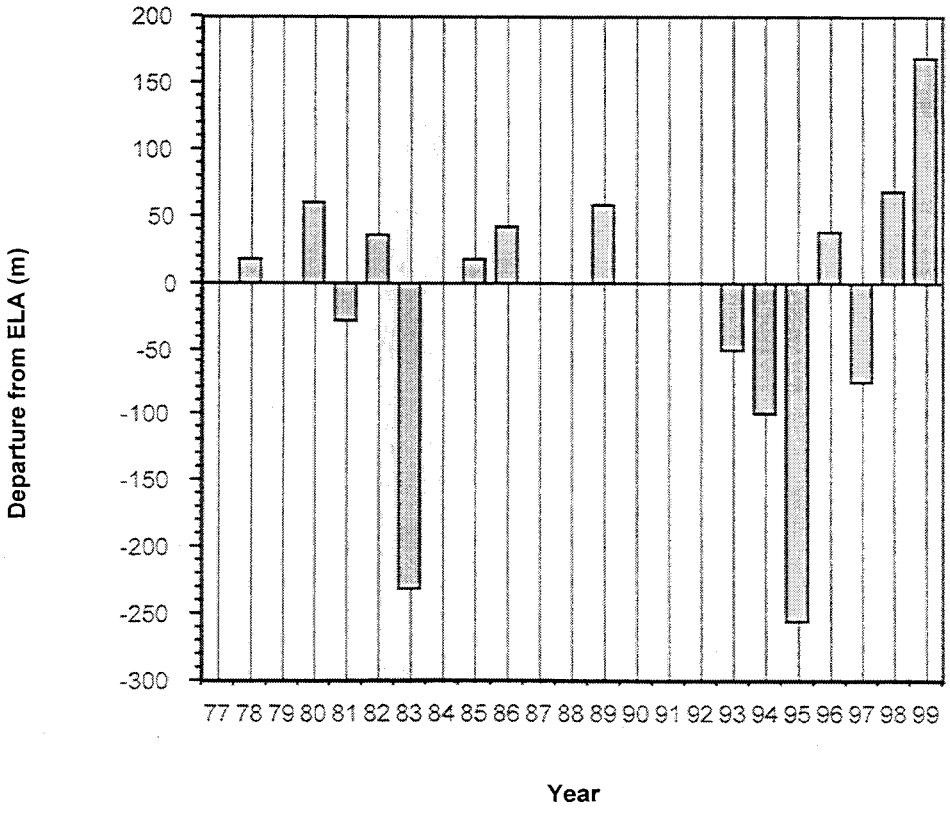
Inventory No. 906A/004
A small valley glacier flowing west from the Main Divide at the junction of the Kokatahi, Arahura and Wilberforce catchments.

Glacier Data	
Glacier area (ha)	28.7
Equilibrium line altitude (ELA)	1720
Maximum elevation (m)	2200
Minimum elevation (m)	1560
Mean elevation (m)	1880
Elevation range (m)	640
Maximum length (km)	1.05
Gradient	0.609

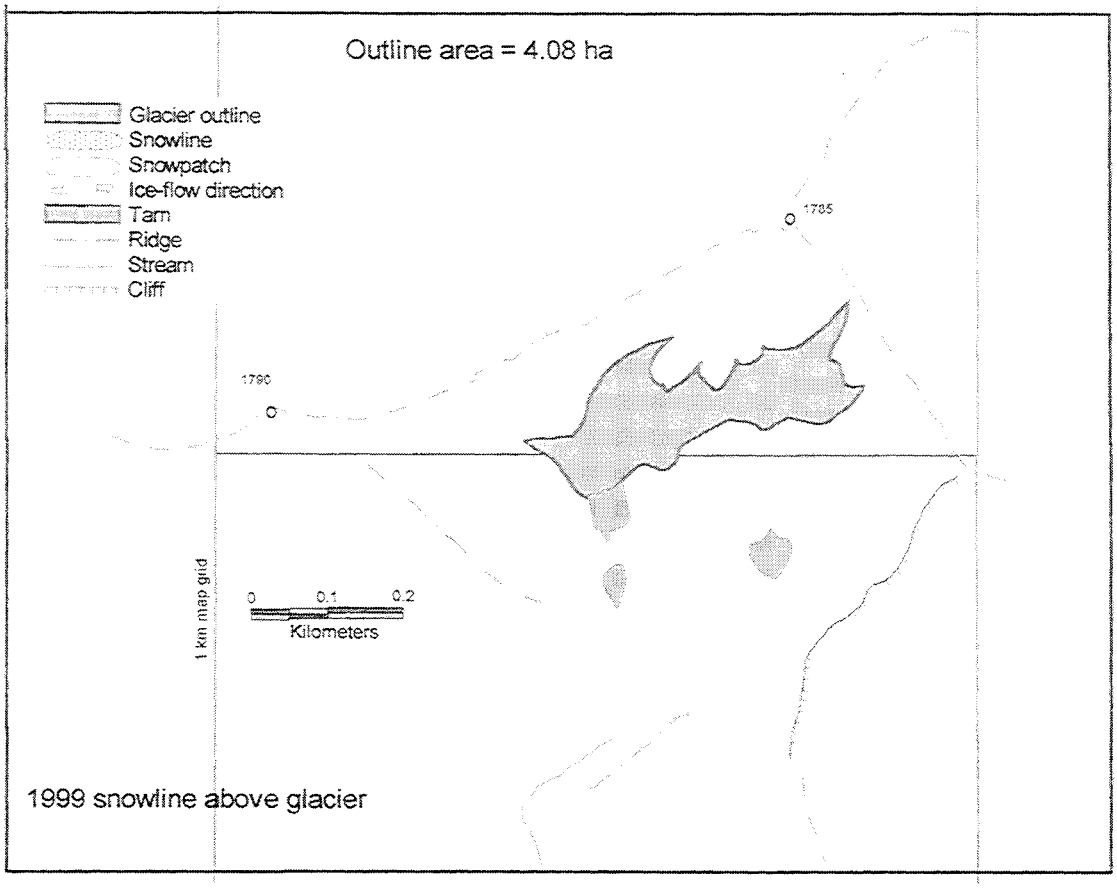
1999 Snowline Data	
1999 accumulation area (ha)	1.91
1999 snowline elevation (m)	1888
Snowline departure from ELA (m)	168
Accumulation area ratio (AAR)	0.07

Left: Digitised map of Retreat Snowfield for 1999 and oblique aerial photograph taken 1996.

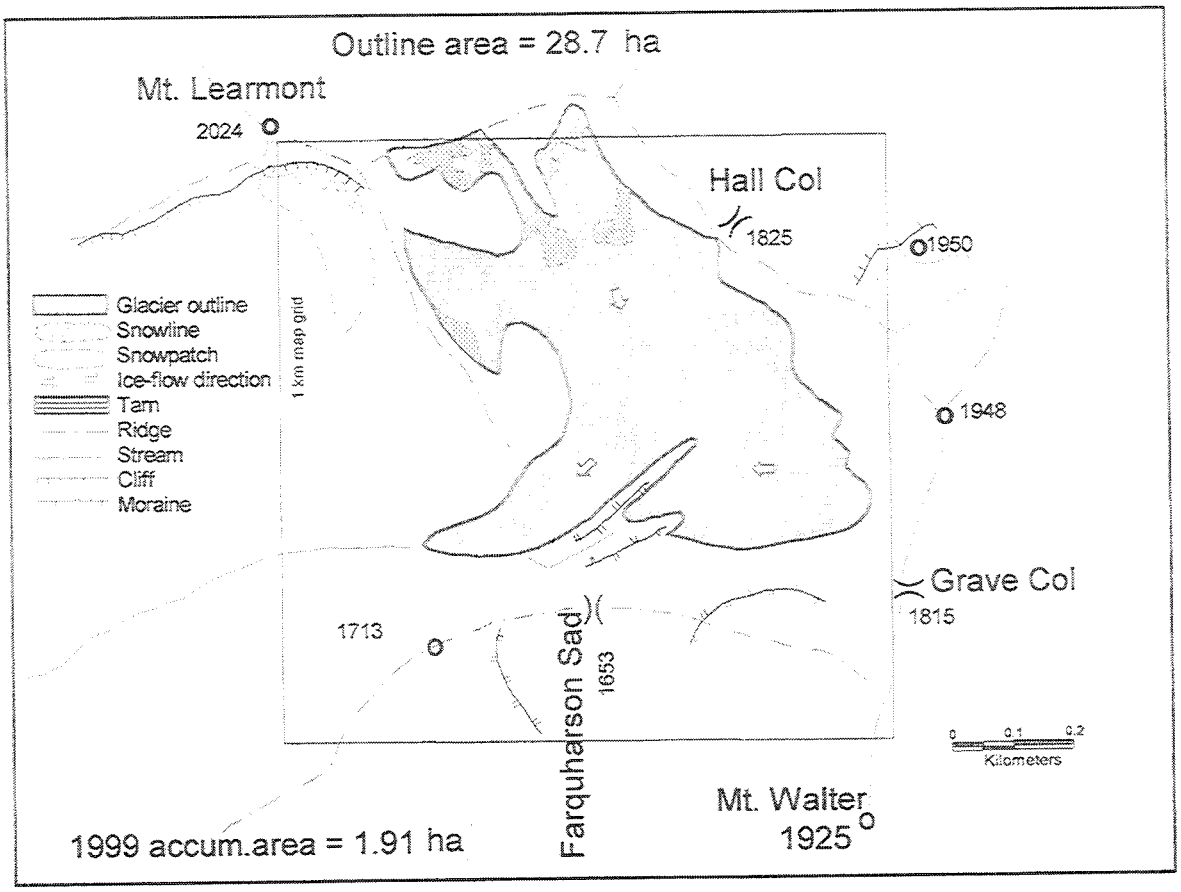
Below: Plot of all available annual snowline departures from the ELA for Retreat Snowfield.



BROWNING RANGE



RETREAT SNOWFIELD



Browning Range

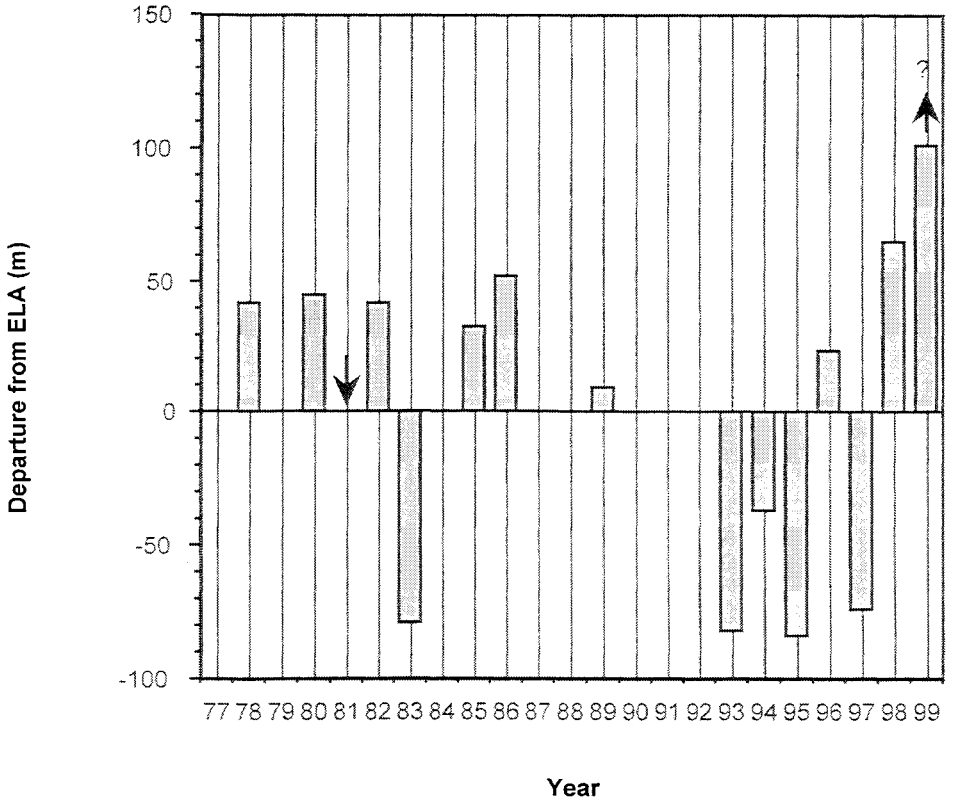
Inventory No. 906A/004
A glacierette in a small cirque on Browning Range, Kokatahi catchment.

Glacier Data	
Glacier area (ha)	4.08
Equilibrium line altitude (ELA)	1564
Maximum elevation (m)	1700
Minimum elevation (m)	1530
Mean elevation (m)	1615
Elevation range (m)	170
Maximum length (km)	0.15
Gradient	

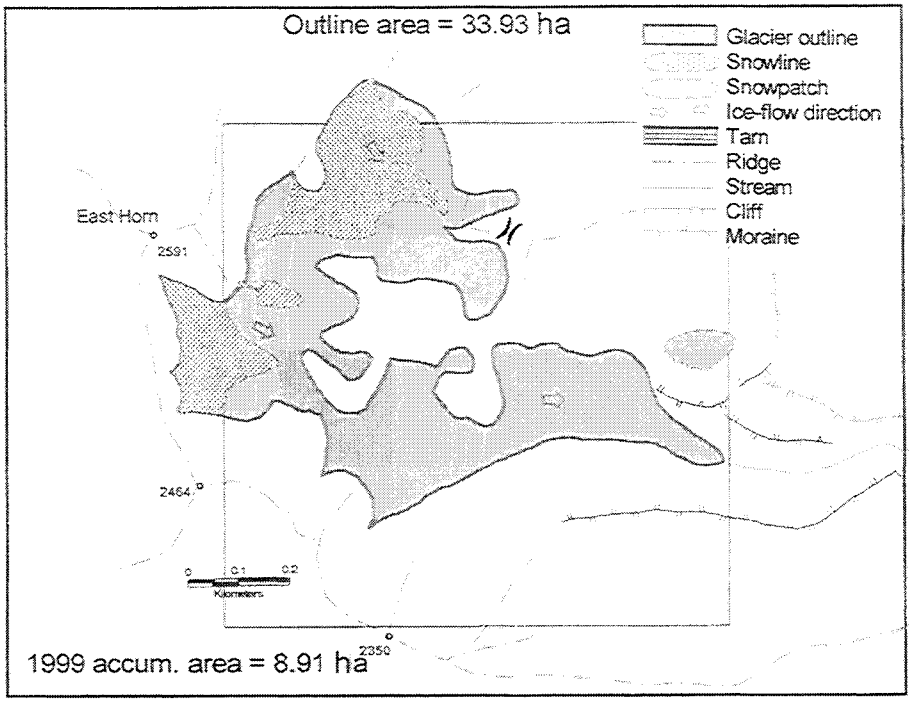
1999 Snowline Data	
1999 accumulation area (ha)	Above glacier
1999 snowline elevation (m)	-
Snowline departure from ELA (m)	-
Accumulation area ratio (AAR)	-

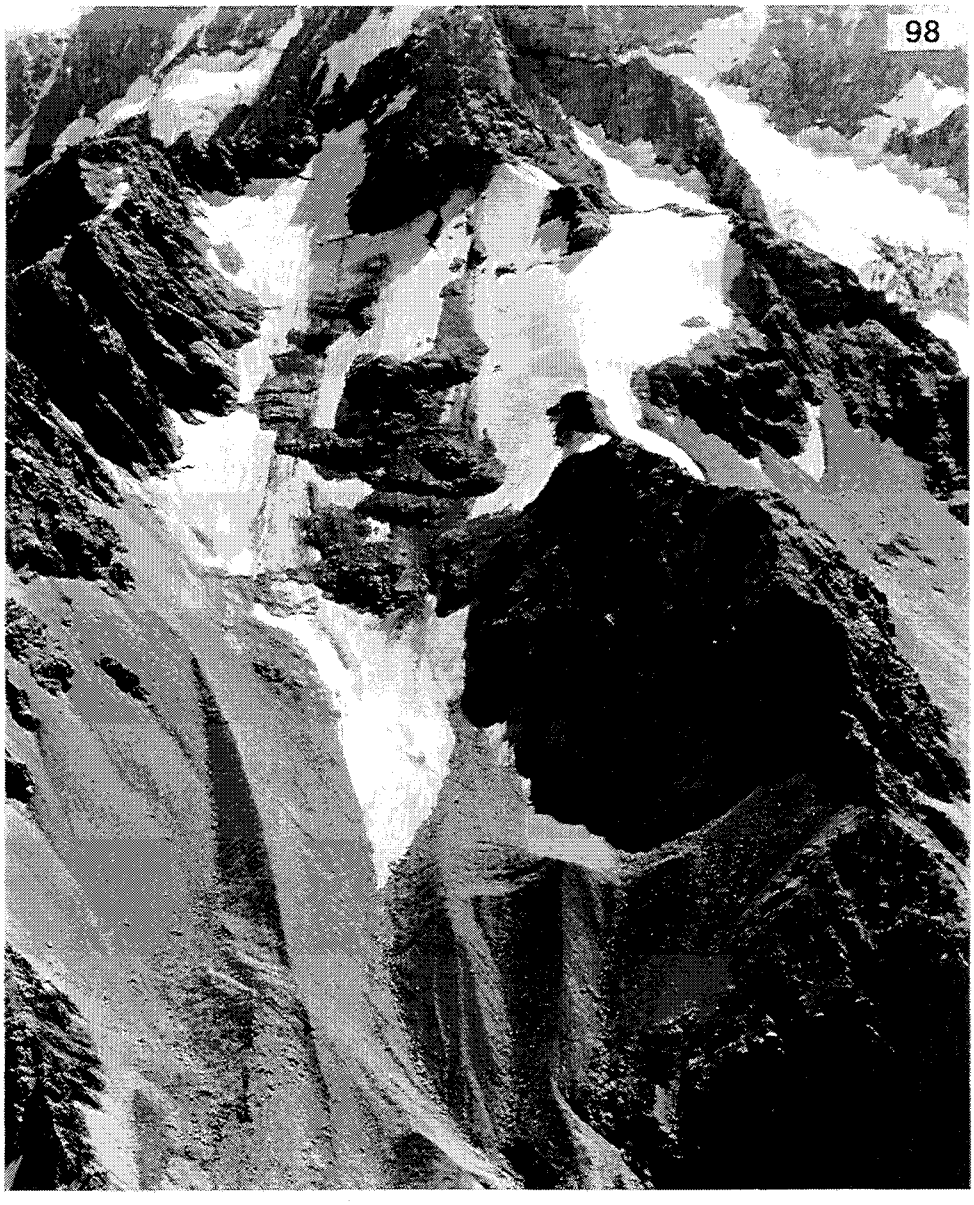
Left: Digitised map of Browning Range and oblique aerial photograph taken 1997.

Below: Plot of all available annual snowline departures from the ELA for Browning Ra. Down arrow indicates zero value.



DOUGLAS GLACIER





Douglas Glacier

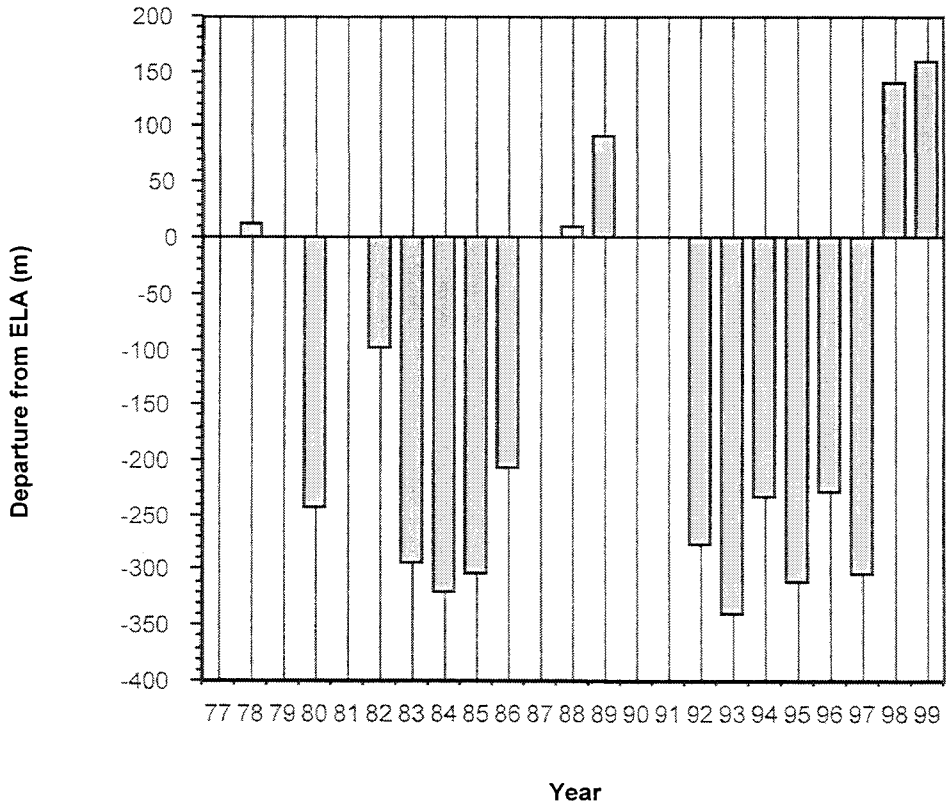
Inventory No. 685B/001
A thin, steep mountain glacier on the slopes of Mt. Arrowsmith, East Horn, Cameron catchment.

Glacier Data	
Glacier area (ha)	33.93
Equilibrium line altitude (ELA)	2120
Maximum elevation (m)	2480
Minimum elevation (m)	1820
Mean elevation (m)	2150
Elevation range (m)	660
Maximum length (km)	1.18
Gradient	0.559

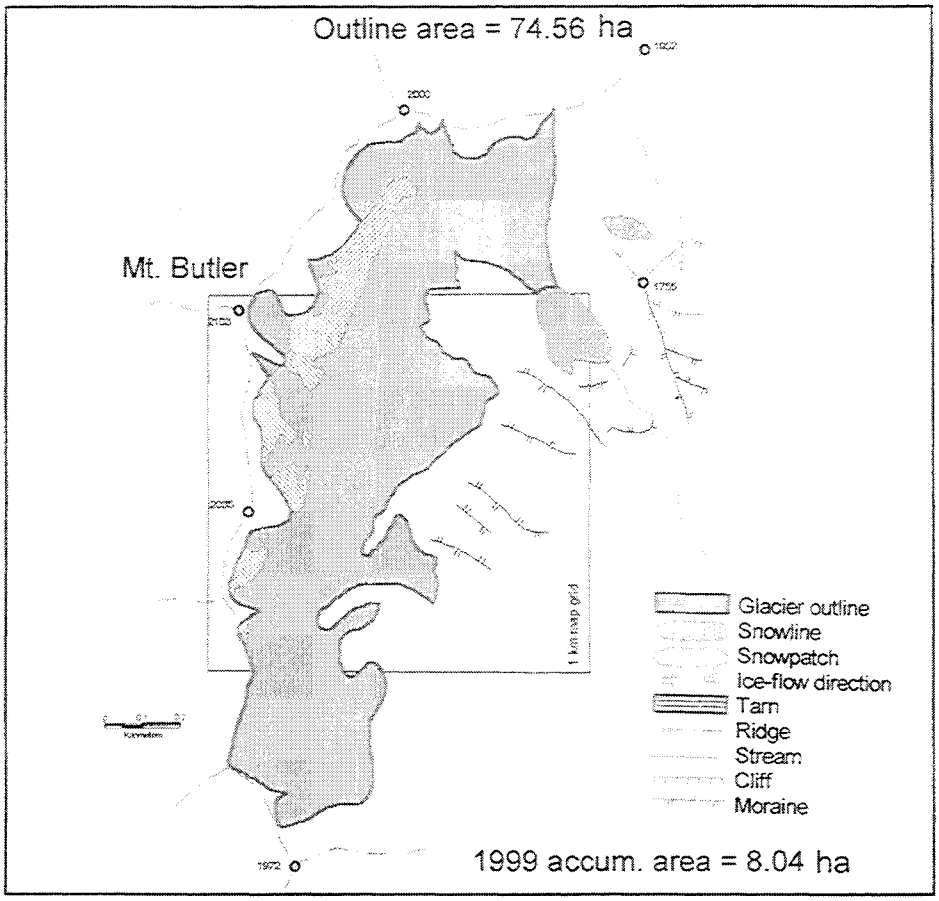
1999 Snowline Data	
1999 accumulation area (ha)	8.91
1999 snowline elevation (m)	2280
Snowline departure from ELA (m)	160
Accumulation area ratio (AAR)	0.26

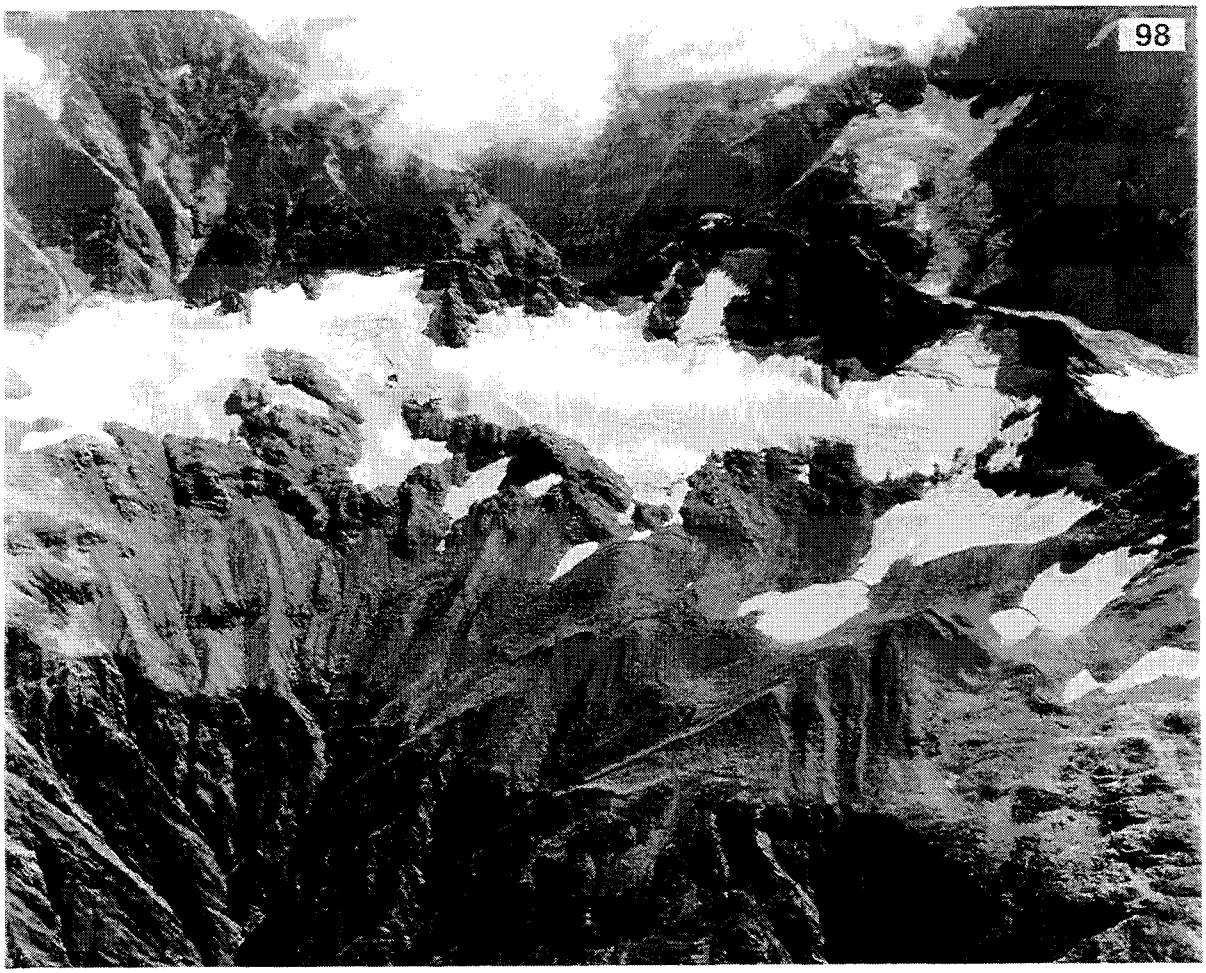
Left: Digitised map of Douglas Gl. for 1999 and oblique aerial photograph taken 1998.

Below: Plot of all available annual snowline departures from the ELA for Douglas Gl.



MOUNT BUTLER





Mount Butler

Inventory No. 685C/060

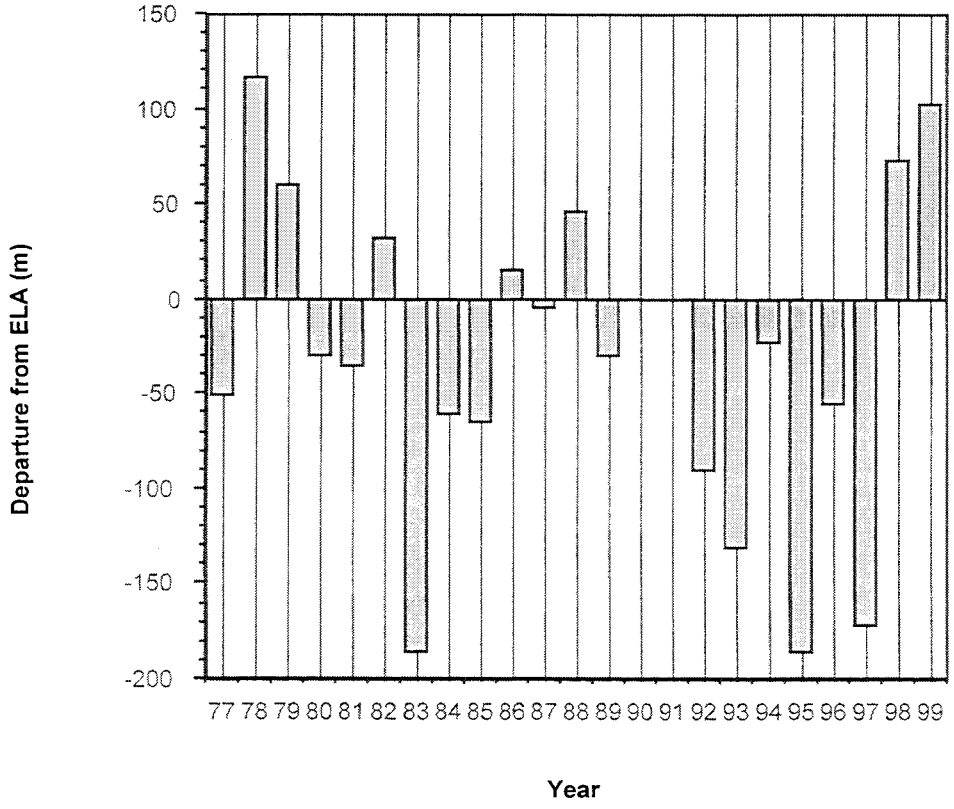
A wide mountain glacier on the E slopes of Mt. Butler, Whitcombe Pass, Rakaia R. catchment.

Glacier Data	
Glacier area (ha)	74.56
Equilibrium line altitude (ELA)	1835
Maximum elevation (m)	2100
Minimum elevation (m)	1680
Mean elevation (m)	1890
Elevation range (m)	420
Maximum length (km)	0.66
Gradient	0.636

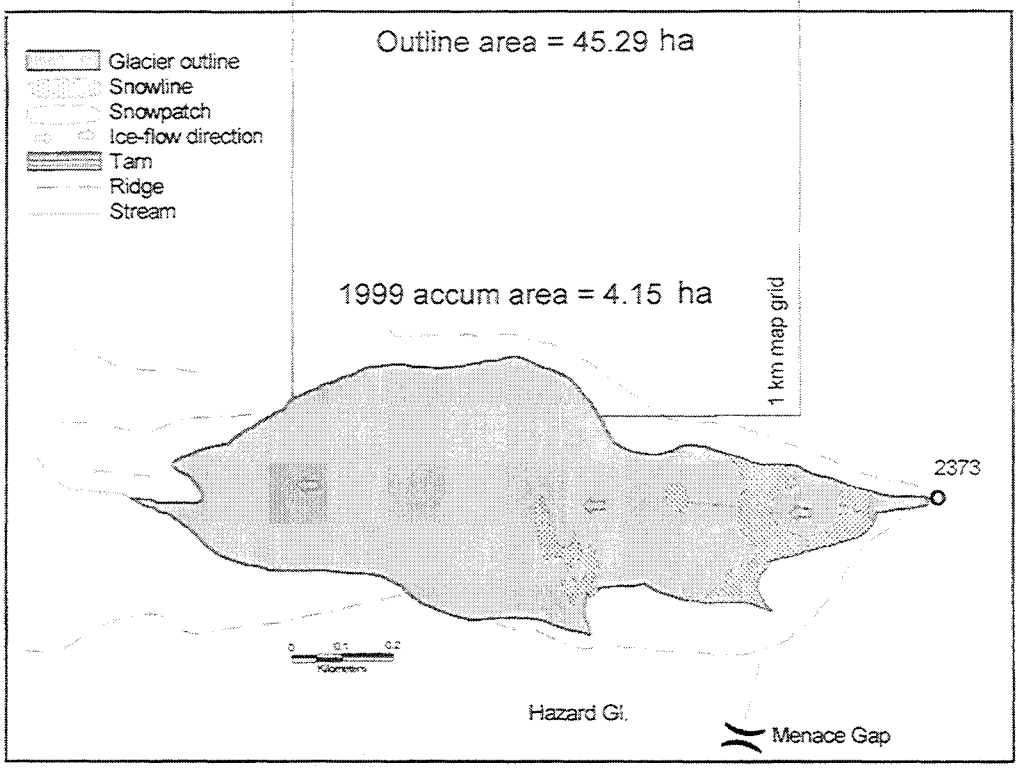
1999 Snowline Data	
1999 accumulation area (ha)	8.04
1999 snowline elevation (m)	1938
Snowline departure from ELA (m)	103
Accumulation area ratio (AAR)	0.11

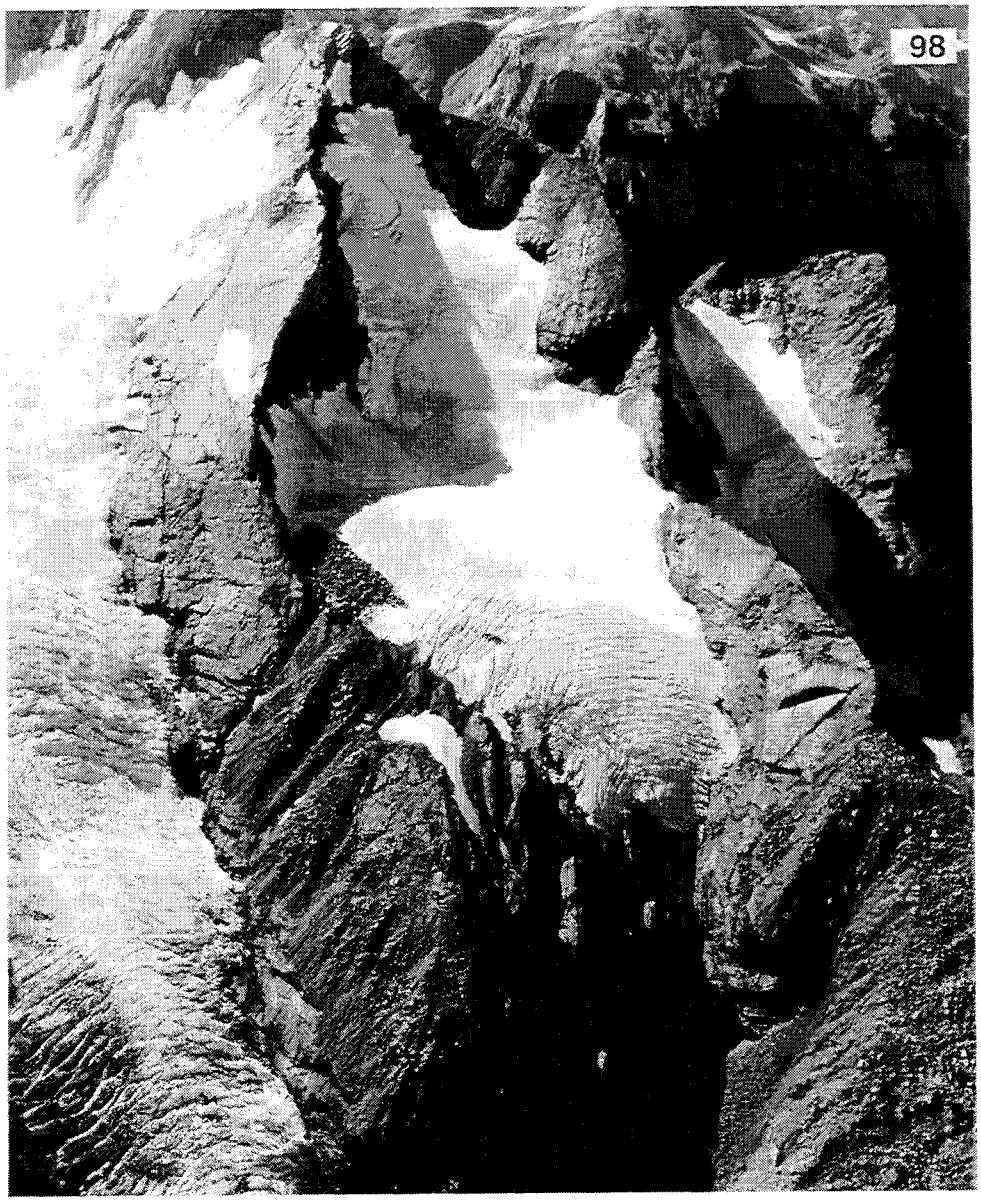
Left: Digitised map of Mt. Butler for 1999 and oblique aerial photograph taken 1998.

Below: Plot of all available annual snowline departures from the ELA for Mt Butler.



DAINTY GLACIER





Dainty Glacier

Inventory No. 685C/060

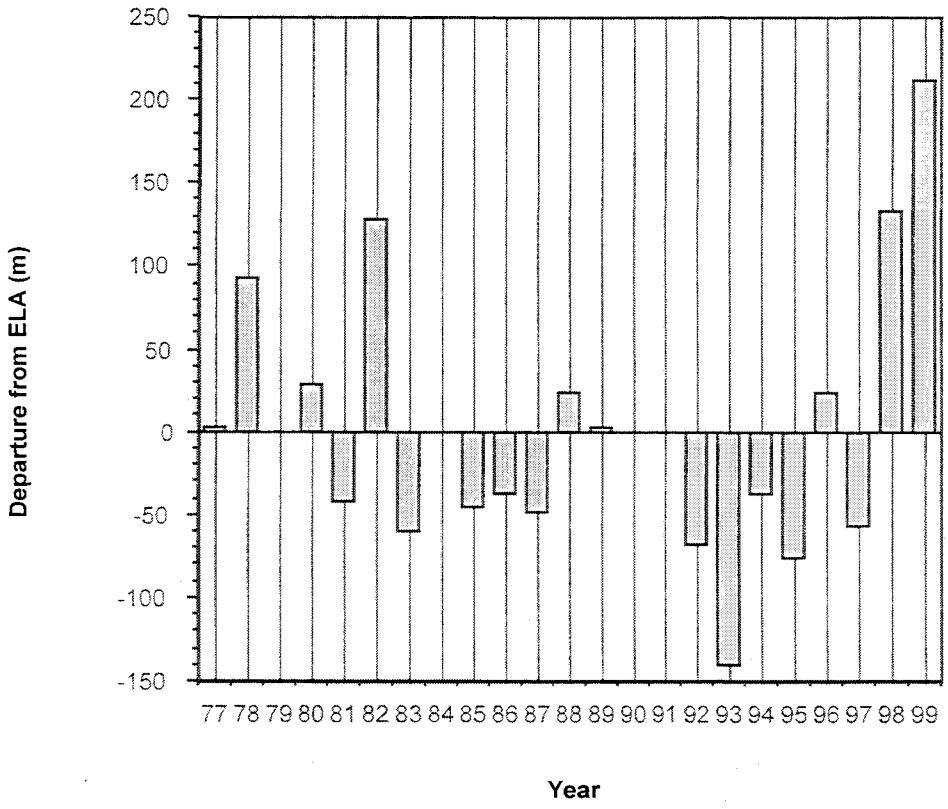
A west coast mountain glacier on the E slopes of Mt. Whitcombe massif, Wanganui R. catchment.

Glacier Data	
Glacier area (ha)	45.29
Equilibrium line altitude (ELA)	1918
Maximum elevation (m)	2370
Minimum elevation (m)	1700
Mean elevation (m)	2035
Elevation range (m)	670
Maximum length (km)	1.45
Gradient	0.462

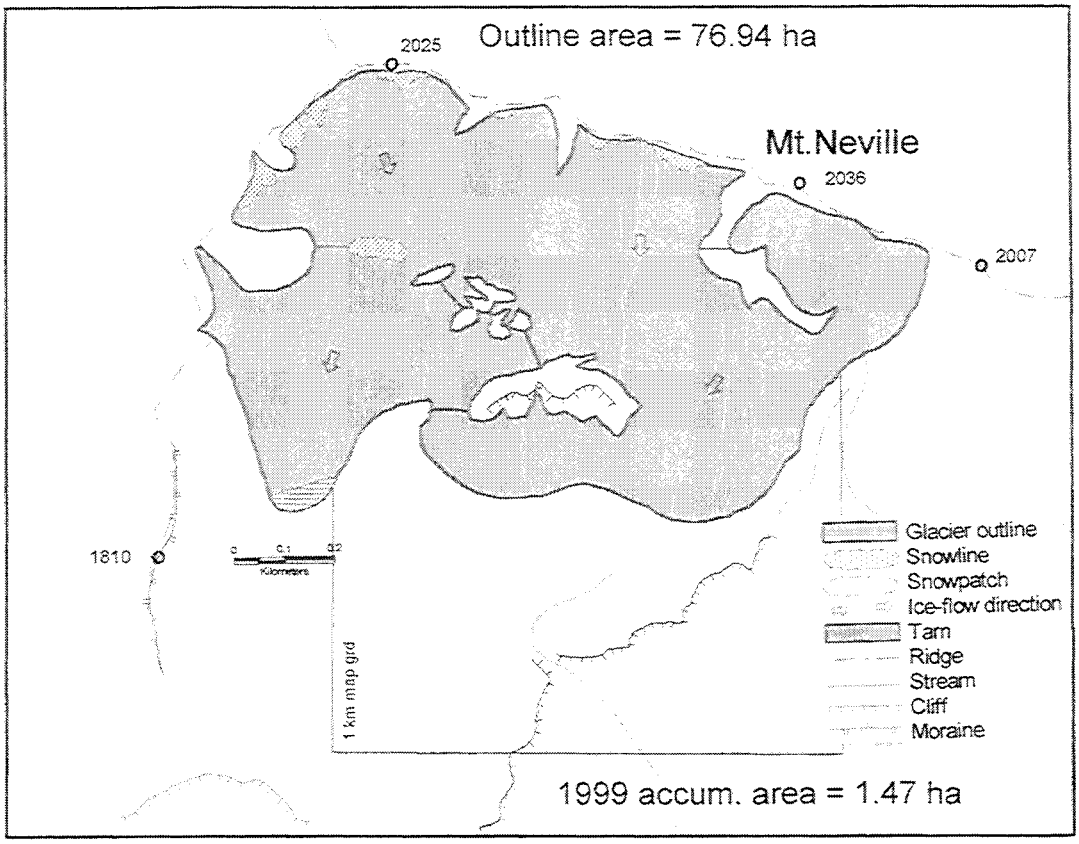
1999 Snowline Data	
1999 accumulation area (ha)	4.15
1999 snowline elevation (m)	2130
Snowline departure from ELA (m)	212
Accumulation area ratio (AAR)	0.09

Left: Digitised map of Dainty Gl. for 1999 and oblique aerial photograph taken 1998.

Below: Plot of all available annual snowline departures from the ELA for Dainty Gl.



KEA GLACIER


Outline area = 76.94 ha
2025
Mt.Neville
2036
2007
1810
0 0.1 0.2
Kilometers
1 km map grid
Glacier outline
Snowline
Snowpatch
Ice-flow direction
Tarn
Ridge
Stream
Cliff
Moraine
1999 accum. area = 1.47 ha


98

Kea Glacier

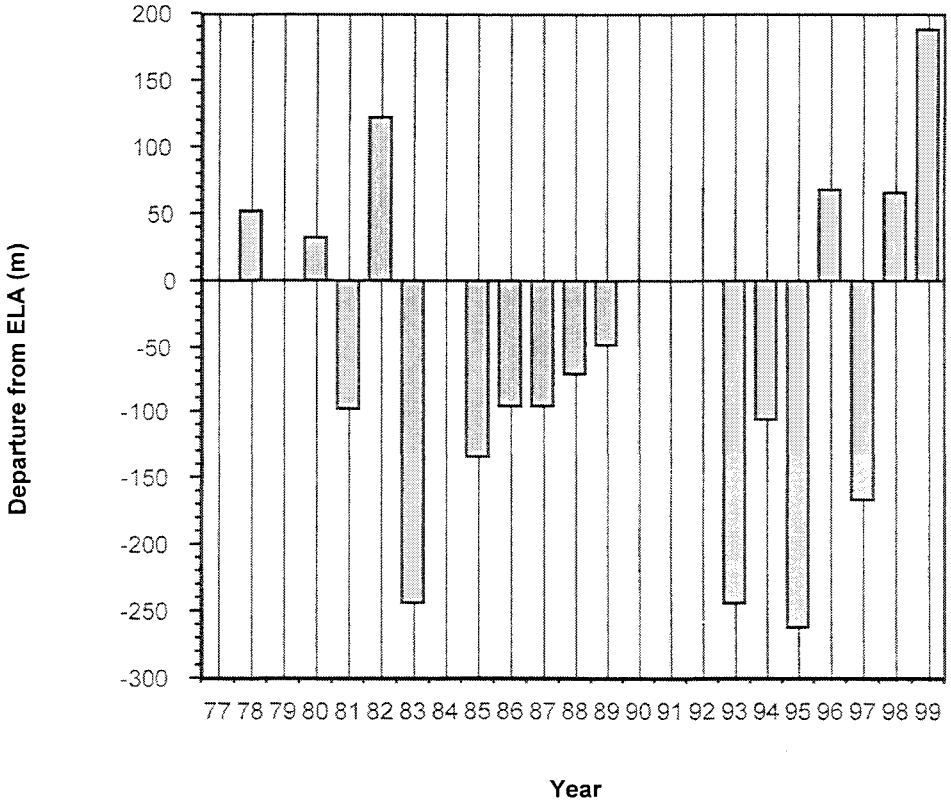
Inventory No. 897/007
A west coast cirque in the Wanganui R. catchment.

Glacier Data	
Glacier area (ha)	76.94
Equilibrium line altitude (ELA)	1832
Maximum elevation (m)	2030
Minimum elevation (m)	1650
Mean elevation (m)	1840
Elevation range (m)	670
Maximum length (km)	0.77
Gradient	0.494

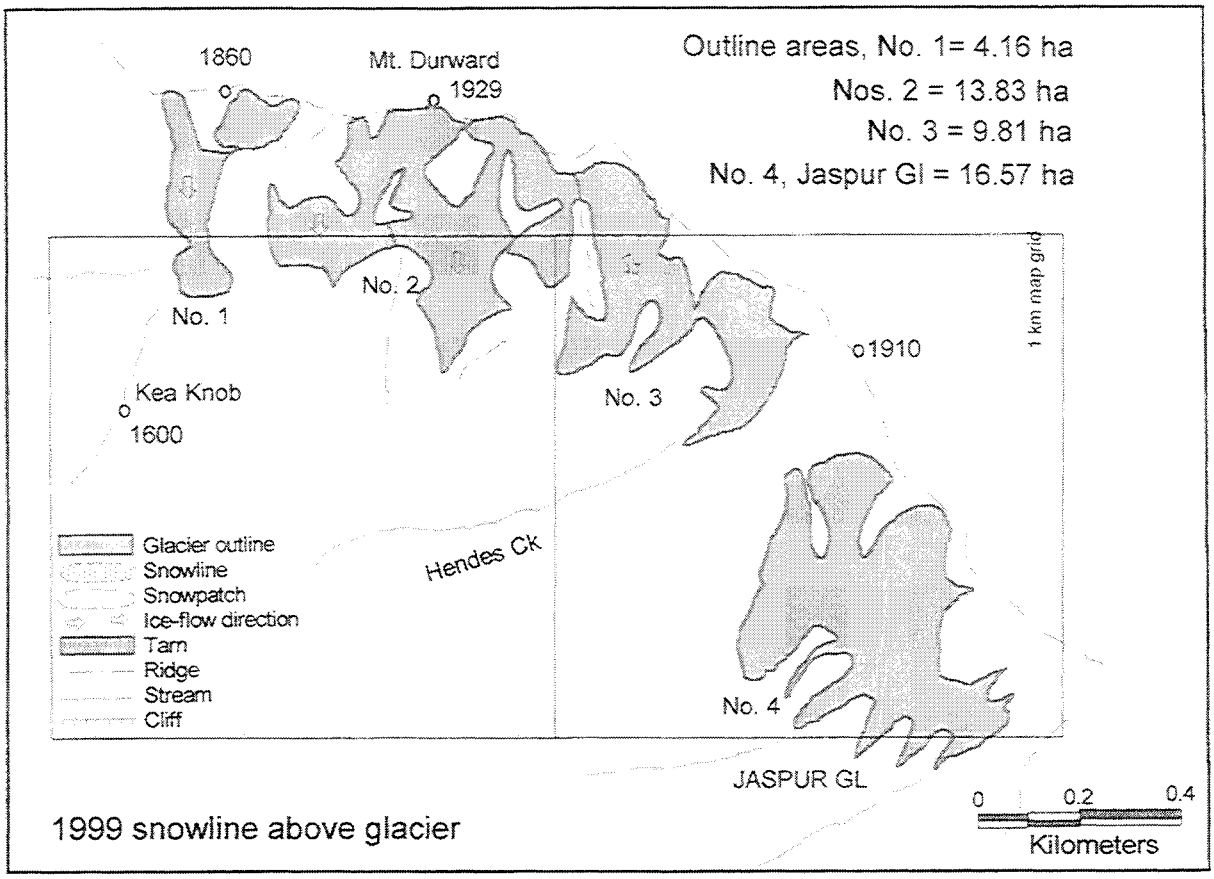
1999 Snowline Data	
1999 accumulation area (ha)	1.47
1999 snowline elevation (m)	2020
Snowline departure from ELA (m)	188
Accumulation area ratio (AAR)	0.02

Left: Digitised map of Kea Gl. for 1999 and oblique aerial photograph taken 1998.

Below: Plot of all available annual snowline departures from the ELA for Kea Gl.



JASPUR GLACIER



Jaspur Glacier

Inventory No. 897/004
A small west coast cirque glacierette in the Wanganui R. catchment and adjacent glacierettes Nos 1, 2 and 3 on Mt. Durward.

Glacier Data

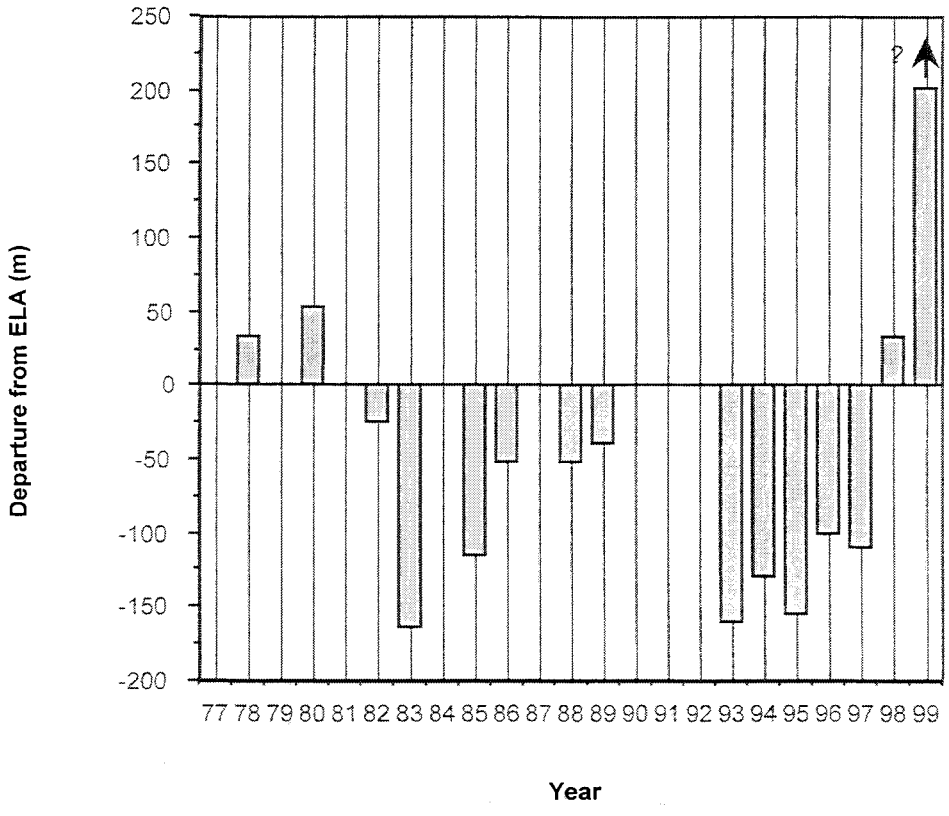
Glacier area, No.4 (ha)	16.57
(No. 1 = 4.16; No. 2 = 13.83; No. 3 = 9.81)	
Equilibrium line altitude (ELA)	1735
Maximum elevation (m)	1870
Minimum elevation (m)	1620
Mean elevation (m)	1745
Elevation range (m)	250
Maximum length (km)	0.44
Gradient	0.639

1999 Snowline Data

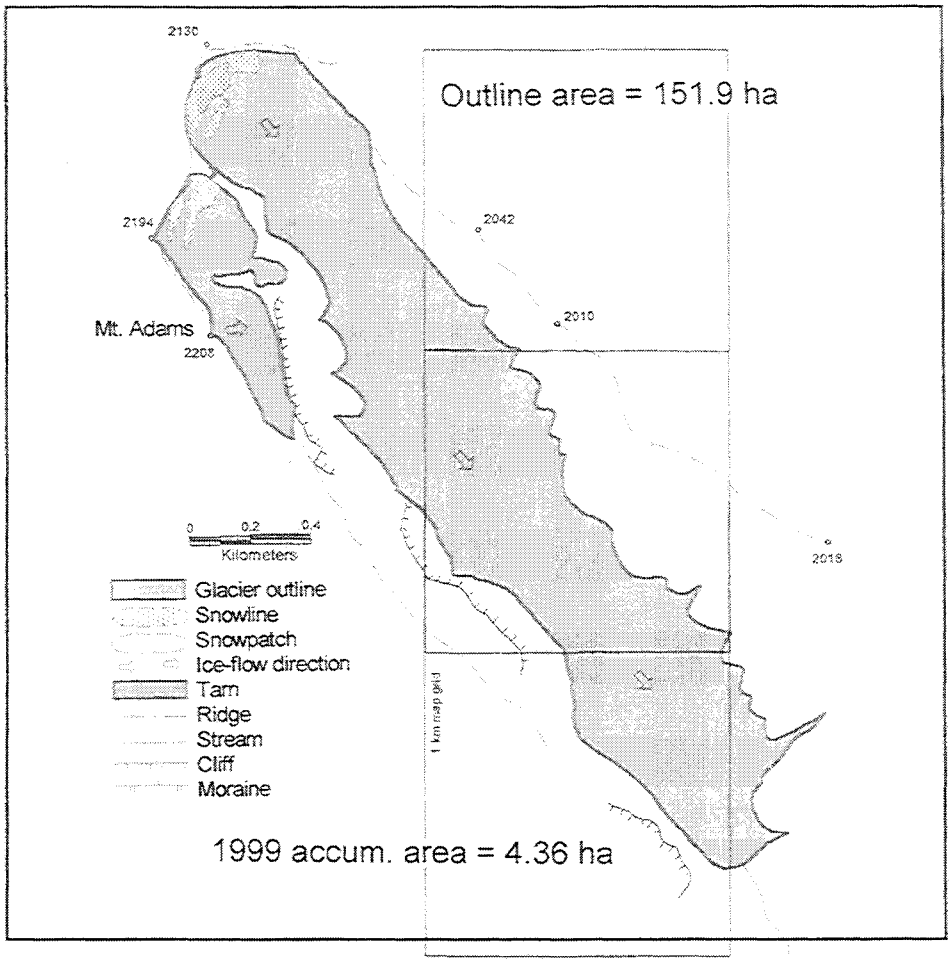
1999 accumulation area (ha)	0
1999 snowline elevation (m)	above glacier
Snowline departure from ELA (m)	over 200
Accumulation area ratio (AAR)	0

Left: Digitised map of Jaspur and associated glaciers and oblique aerial photograph taken 1997.

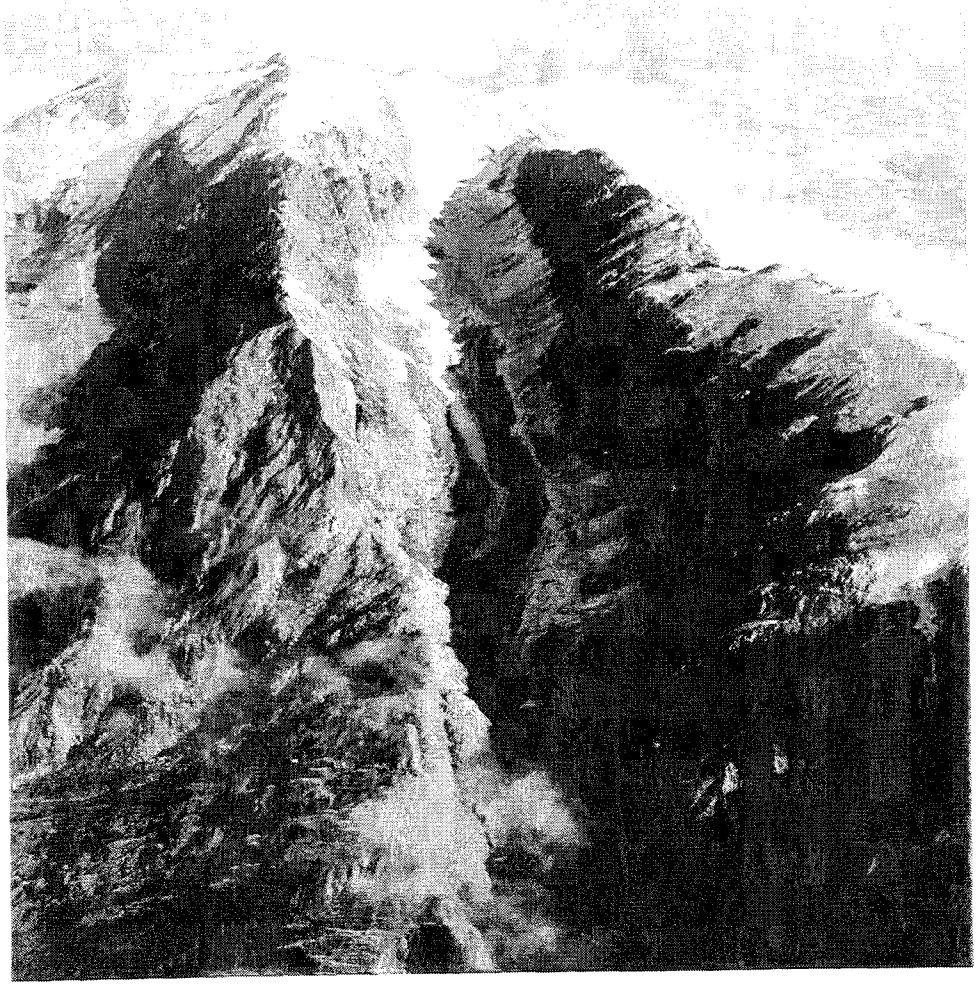
Below: Plot of all available annual snowline departures from the ELA for Jaspur Gl.



SIEGE GLACIER



98



Siege Glacier

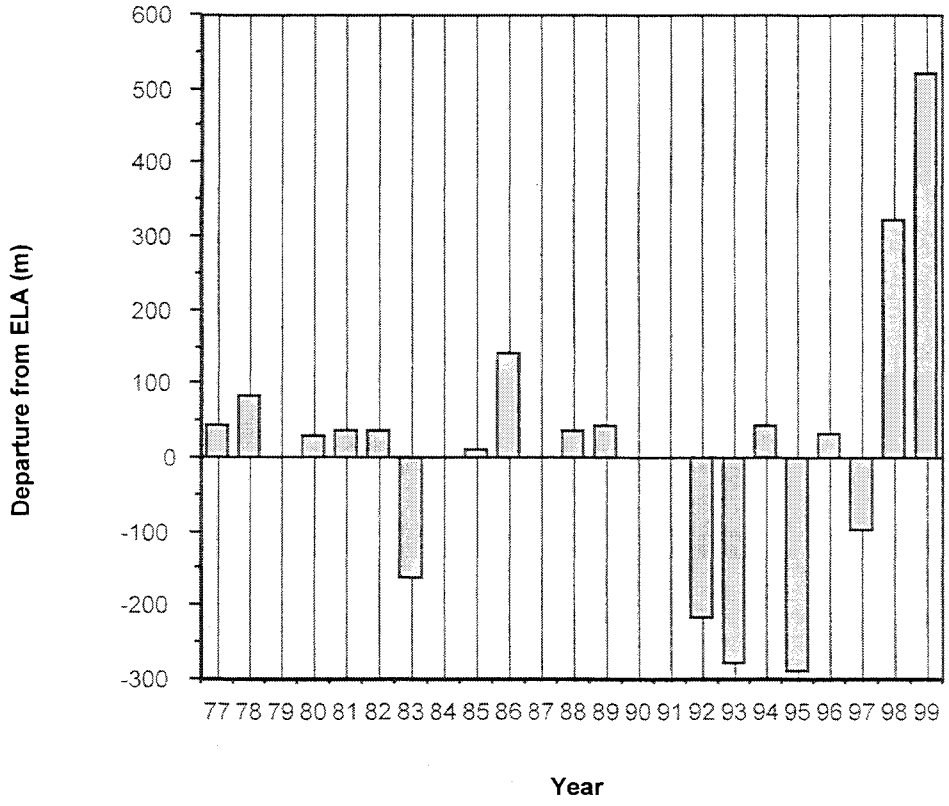
Inventory No. 893A/006
A narrow valley glacier on the SE side of Mt. Adams, Whataroa R. catchment.

Glacier Data	
Glacier area, (ha)	151.9
Equilibrium line altitude (ELA)	1630
Maximum elevation (m)	2200
Minimum elevation (m)	1360
Mean elevation (m)	1780
Elevation range (m)	840
Maximum length (km)	3.186
Gradient	0.239

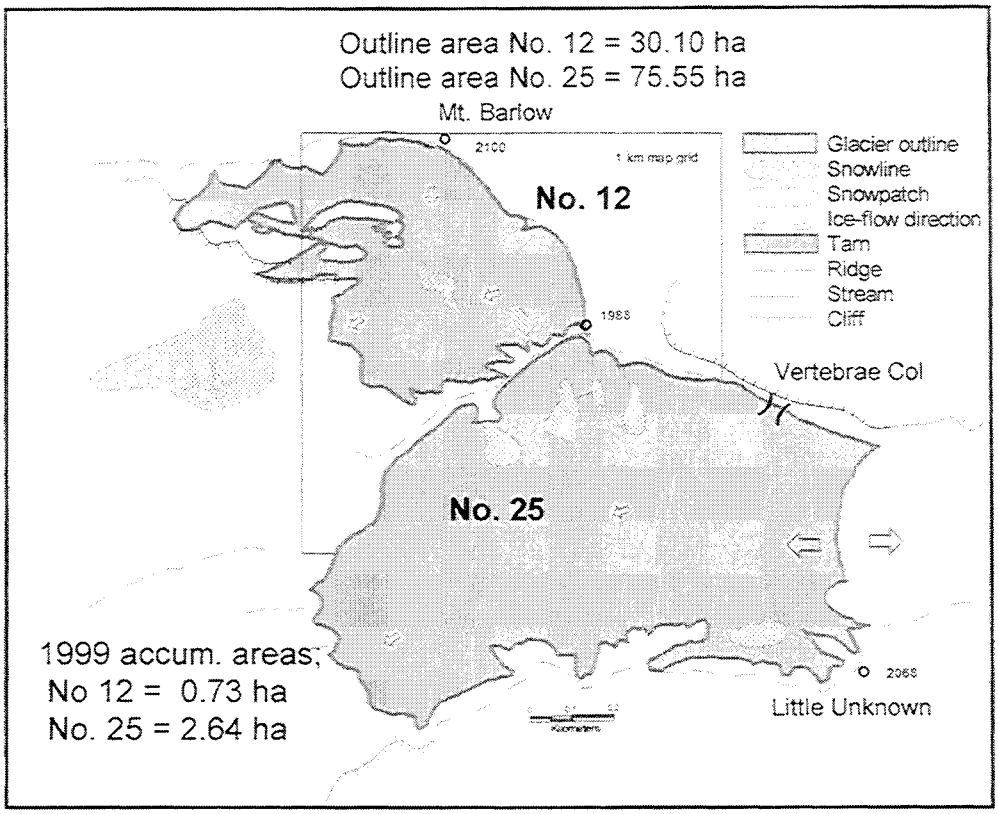
1999 Snowline Data	
1999 accumulation area (ha)	4.36
1999 snowline elevation (m)	2150
Snowline departure from ELA (m)	520
Accumulation area ratio (AAR)	0.03

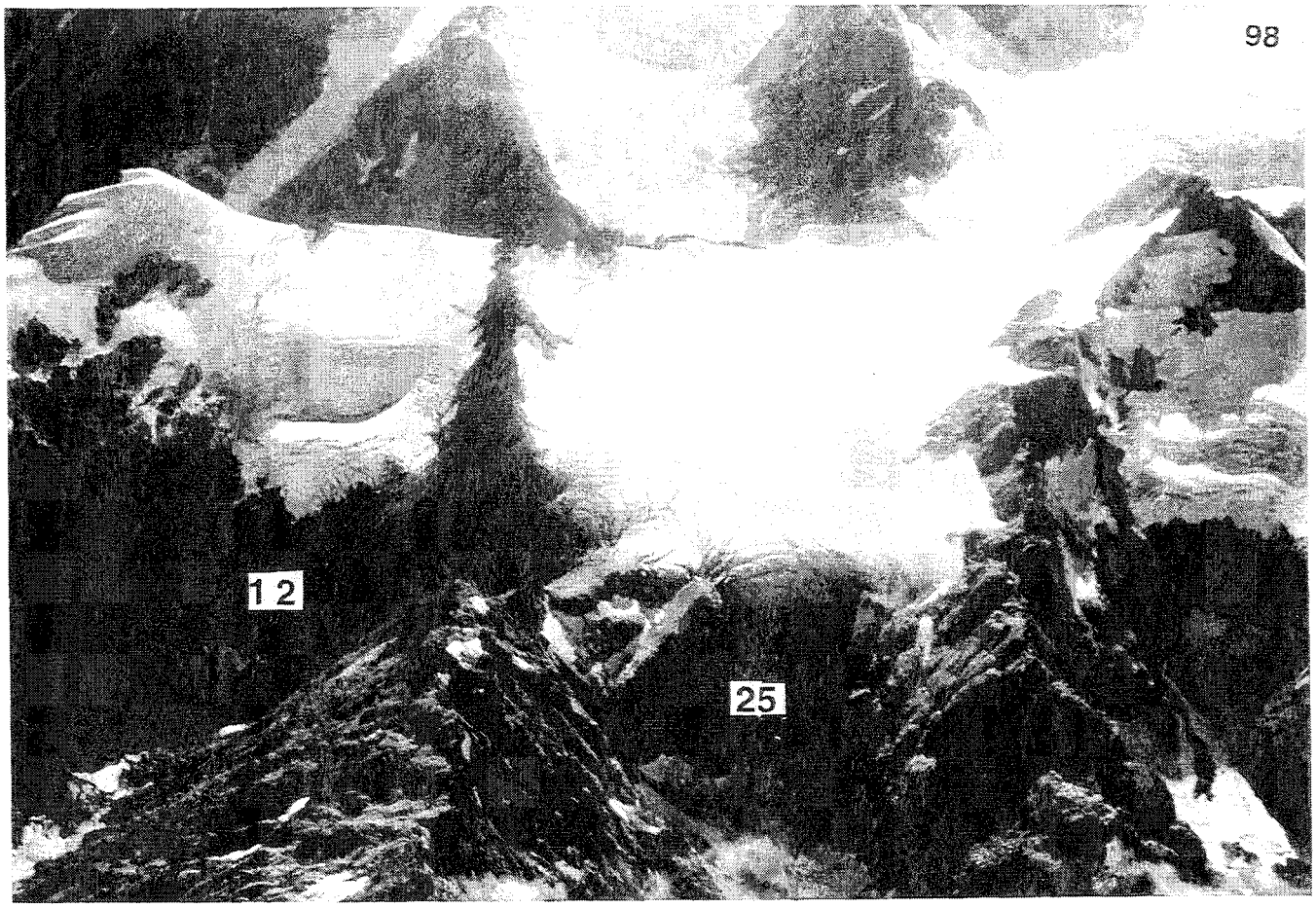
Left: Digitised map of Siege Glacier and oblique aerial photograph taken 1998.

Below: Plot of all available annual snowline departures from the ELA for Siege Gl.



VERTEBRAE COL





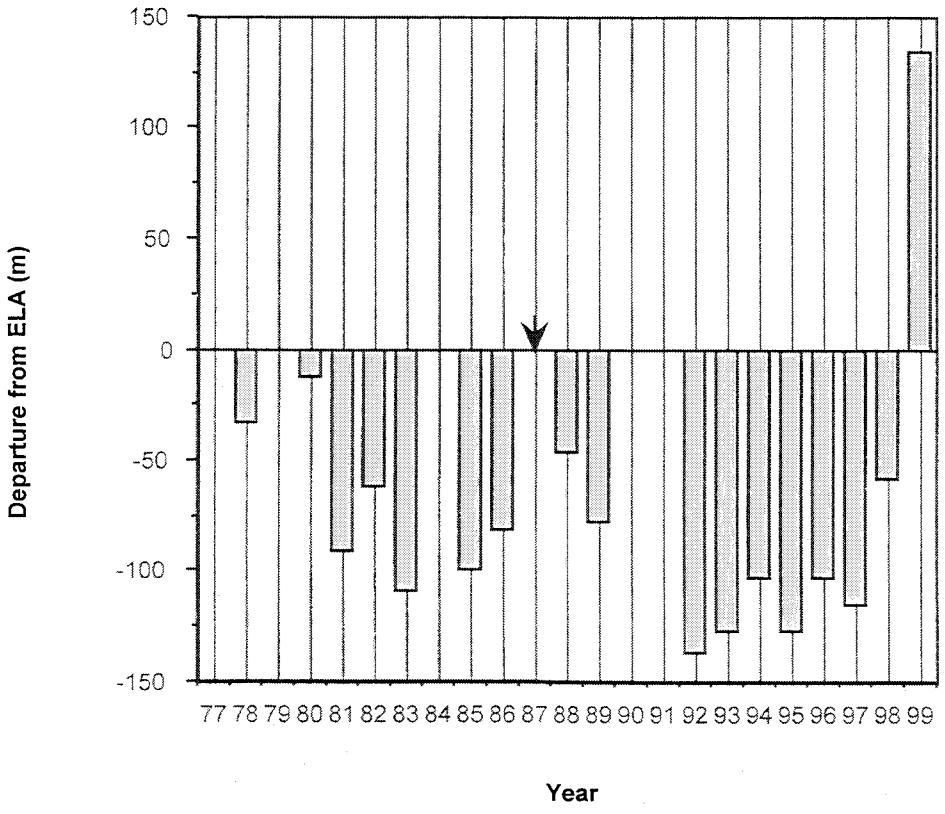
Vertebrae Col

Inventory Nos. 893A/012 & 893A/025
Two cirque glaciers at the SW end of the Garden of Eden icefield, Whataroa R. catchment.

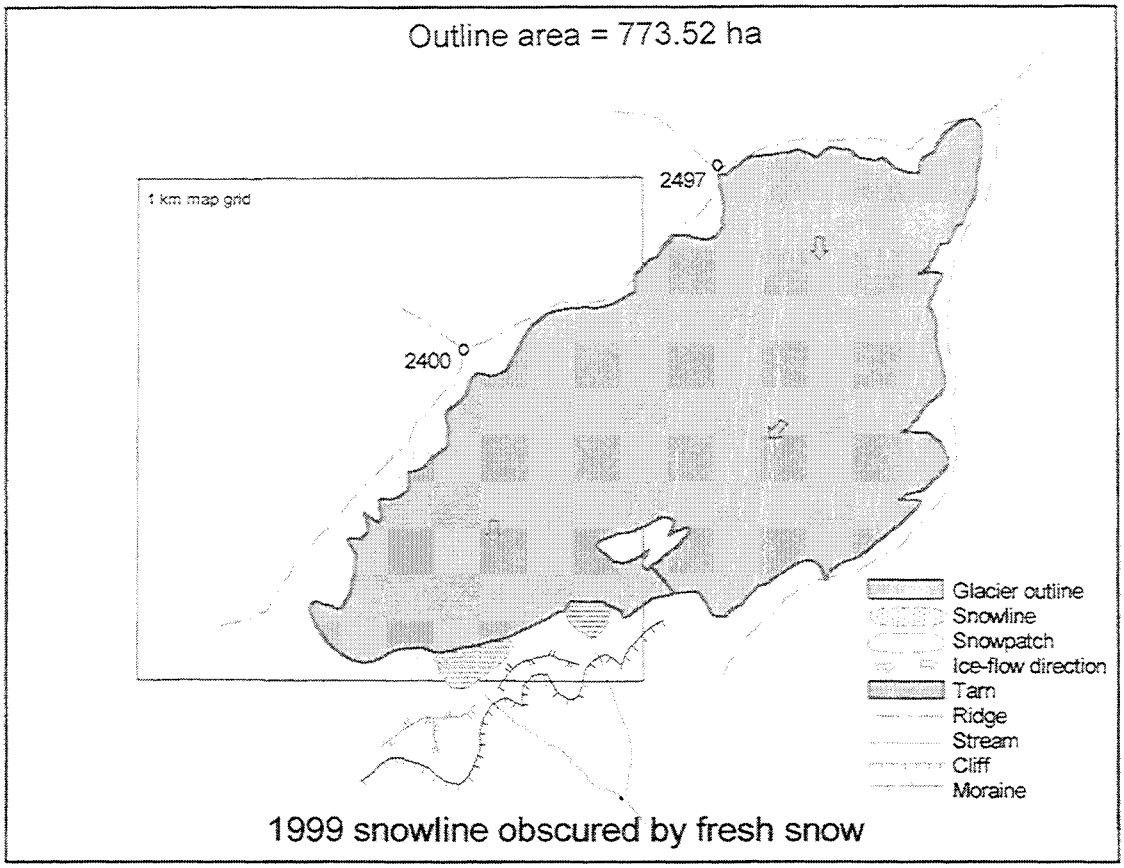
Glacier Data	**No. 25**	**No. 12**
Glacier area (ha)	75.55	30.10
Equilibrium line altitude (ELA)	1878	1908
Maximum elevation (m)	2060	2100
Minimum elevation (m)	1700	1730
Mean elevation (m)	1850	1915
Elevation range (m)	360	370
Maximum length (km)	1.15	0.625
Gradient	0.313	0.592
1999 Snowline Data		
1999 accumulation area (ha)	2.64	0.73
1999 snowline elevation (m)	1965	2090
Snowline departure from ELA (m)	87	182
Accumulation area ratio (AAR)	0.03	0.02

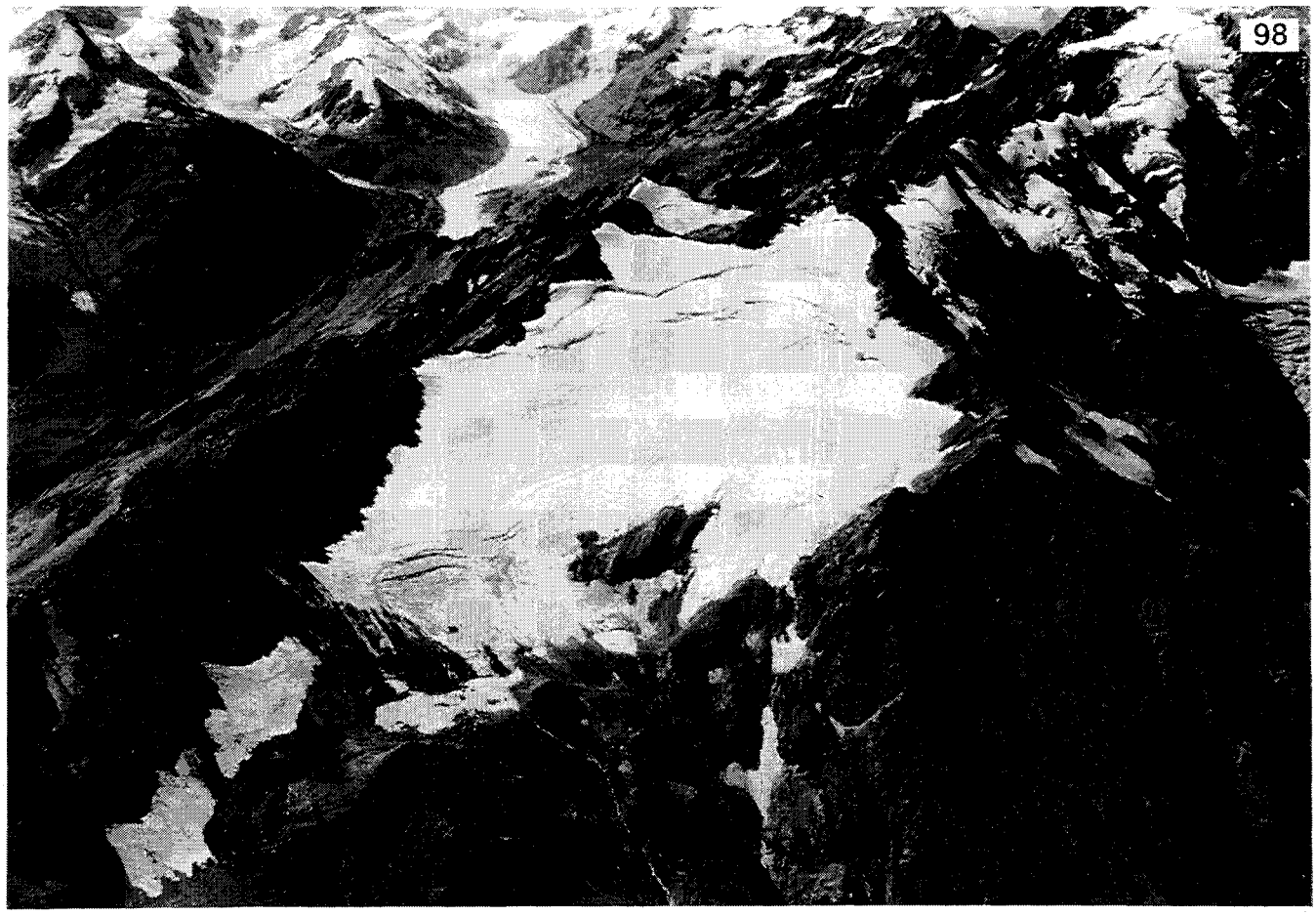
Left: Digitised map of Vertebrae Col glaciers and oblique aerial photograph taken 1998.

Below: Plot of all available annual snowline departures from the ELA for Vertebrae Col, given as a mean for both glaciers. Down arrow indicates zero value.



RIDGE GLACIER





Ridge Gl.

Inventory No. 711L/024

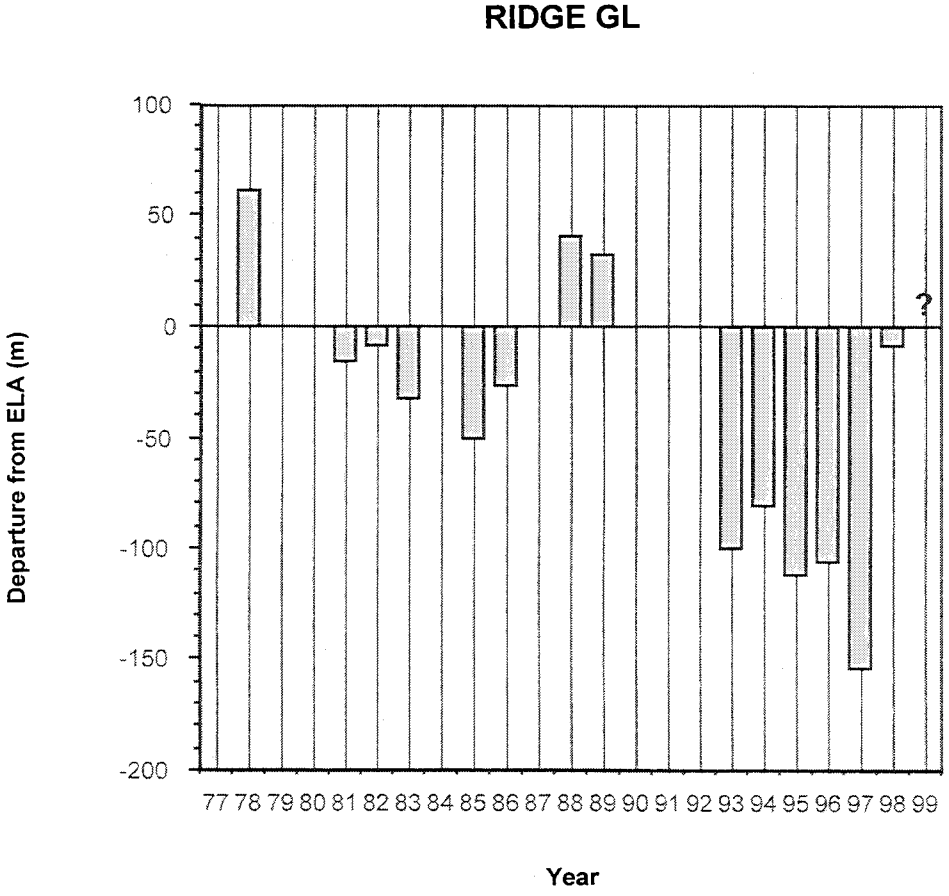
A cirque glacier on the ridge to the east of Murchison Glacier, draining into Jollie R. catchment.

Glacier Data	
Glacier area (ha)	73.52
Equilibrium line altitude (ELA)	2244
Maximum elevation (m)	2495
Minimum elevation (m)	2110
Mean elevation (m)	2303
Elevation range (m)	385
Maximum length (km)	1.04
Gradient	0.370

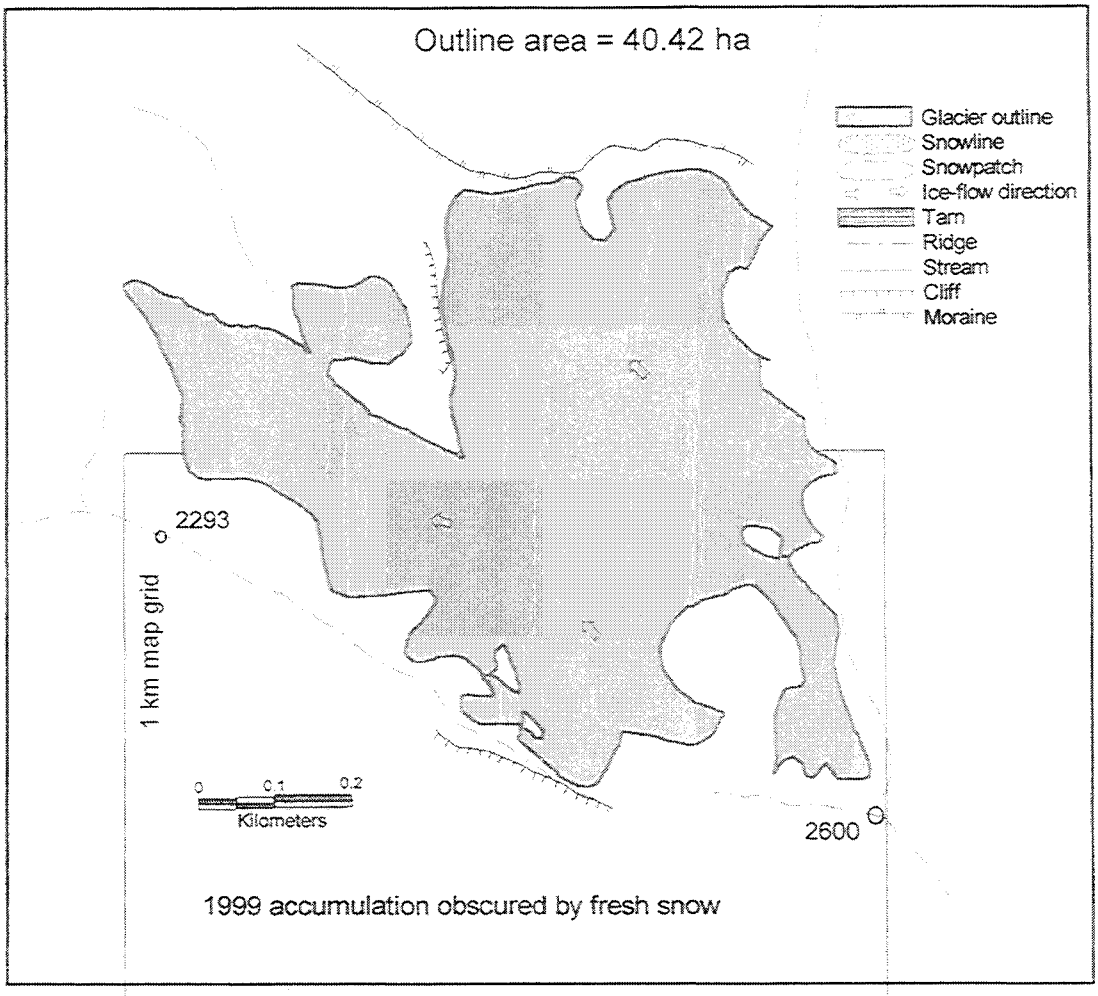
1999 Snowline Data	
1999 accumulation area (ha)	undetermined
1999 snowline elevation (m)	undetermined
Snowline departure from ELA (m)	-
Accumulation area ratio (AAR)	0

Left: Digitised map of Ridge Glacier and oblique aerial photograph taken 1998.

Below: Plot of all available annual snowline departures from the ELA for Ridge Gl.



LANGDALE GLACIER



Langdale Gl.

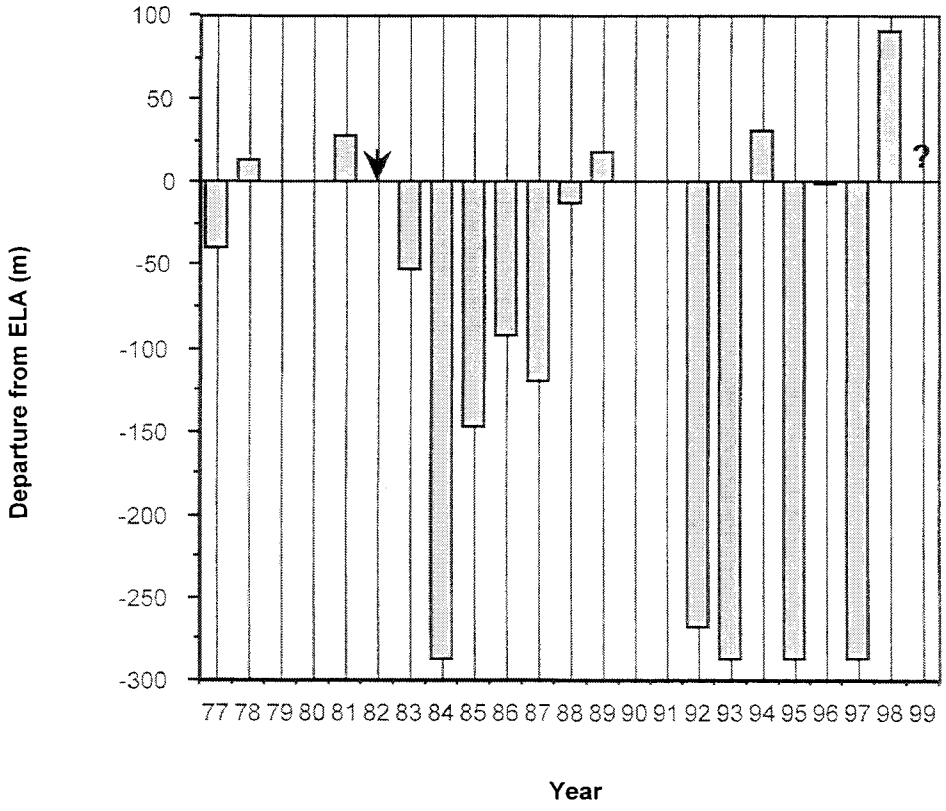
Inventory No. 711I/035
A cirque glacier on the Malte Brun Range above the Tasman Glacier.

Glacier Data	
Glacier area (ha)	40.42
Equilibrium line altitude (ELA)	2238
Maximum elevation (m)	2580
Minimum elevation (m)	2040
Mean elevation (m)	2310
Elevation range (m)	540
Maximum length (km)	1.03
Gradient	0.524

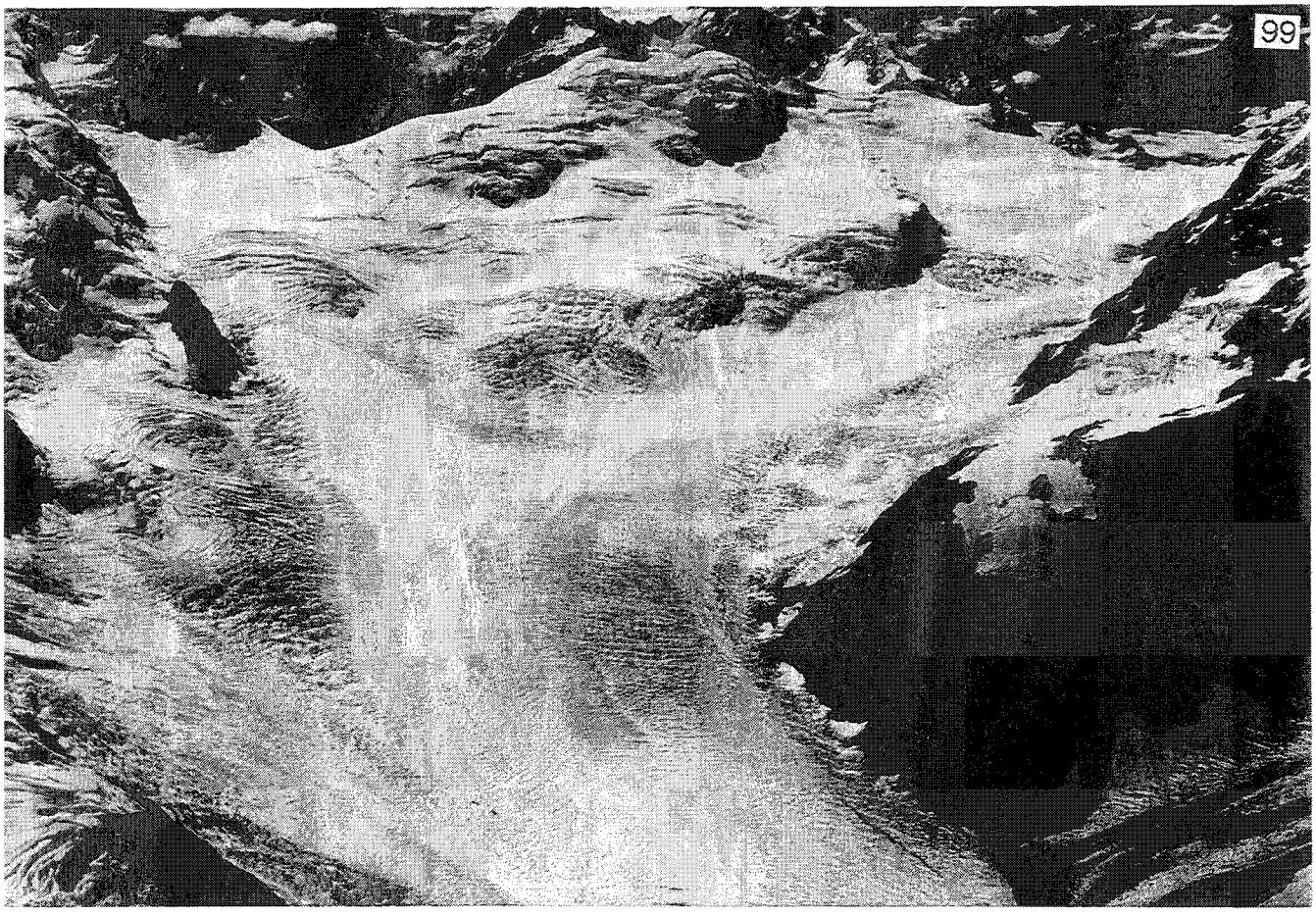
1999 Snowline Data	
1999 accumulation area (ha)	undetermined
1999 snowline elevation (m)	undetermined
Snowline departure from ELA (m)	undetermined
Accumulation area ratio (AAR)	0

Left: Digitised map of Langdale Glacier and oblique aerial photograph taken 1998.

Below: Plot of all available annual snowline departures from the ELA for Langdale Gl. Down arrow indicates zero value.




89


99

Tasman Gl.

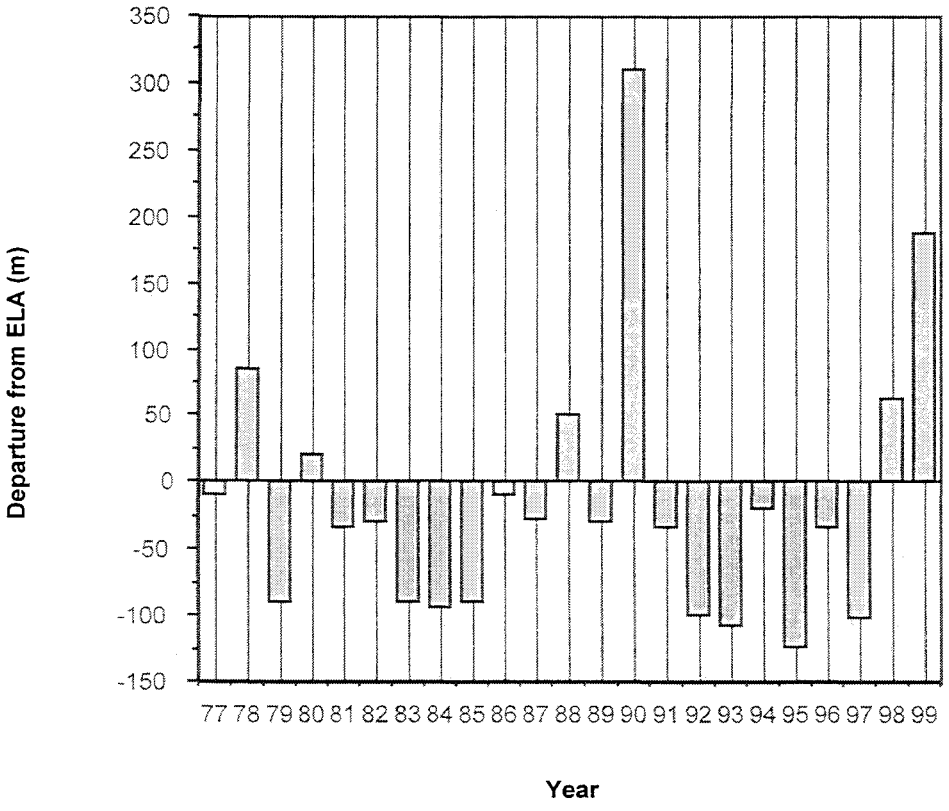
Inventory No. 711I/012
The largest valley glacier in New Zealand, accumulation areas not measured.

Glacier Data	
Glacier area (ha)	9834.1
Equilibrium line altitude (ELA)	1790
Maximum elevation (m)	3690
Minimum elevation (m)	730
Mean elevation (m)	2210
Elevation range (m)	2960
Maximum length (km)	28.5
Gradient (at ELA)	0.096

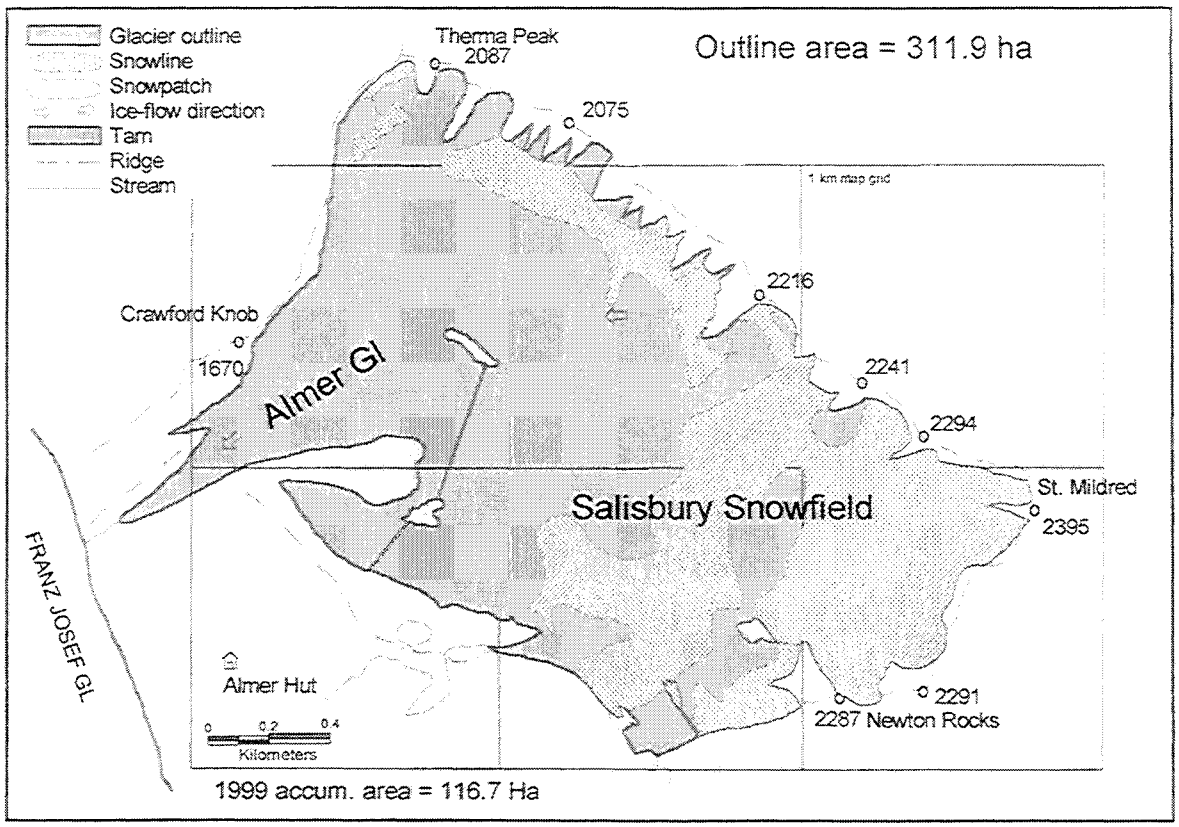
1999 Snowline Data	
1999 accumulation area (ha)	not measured
1999 snowline elevation (m)	1976
Snowline departure from ELA (m)	186
Accumulation area ratio (AAR)	not measured

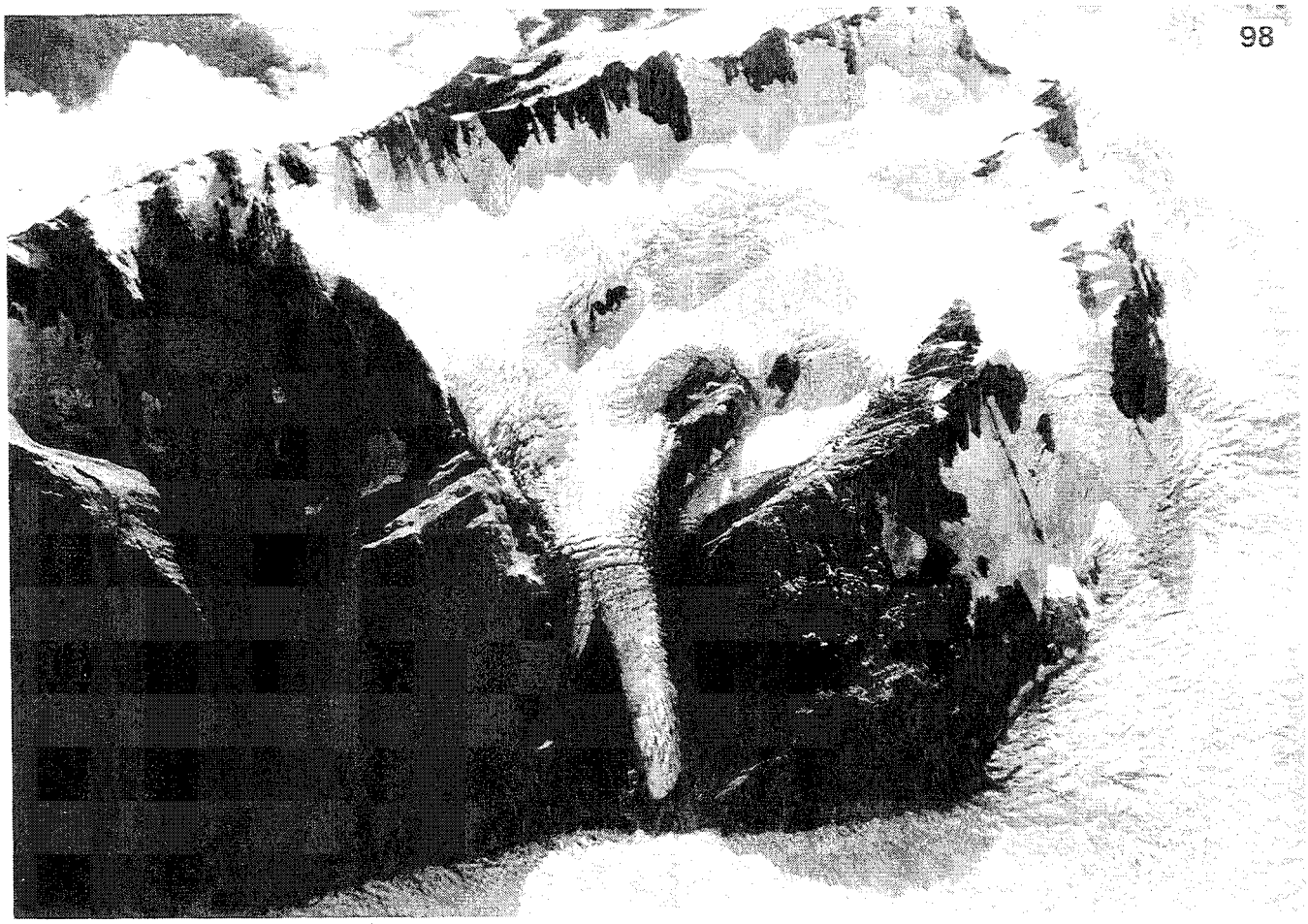
Upper left: Oblique aerial photograph of upper Tasman Glacier taken 1989.
Lower left: Oblique aerial photograph of the 1999 snowline on Tasman Glacier.

Below: Plot of annual snowline departures from the ELA for Tasman Gl. from 1977.



ALMER GLACIER





Almer Glacier – Salisbury Snowfield

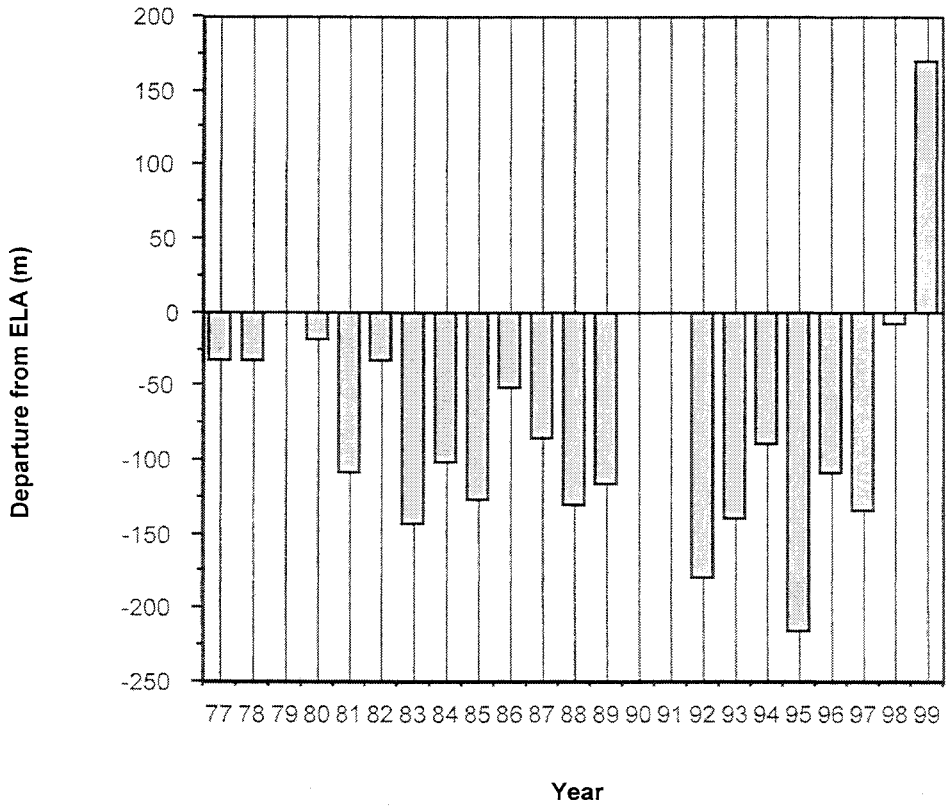
Inventory No. 888B/003
A mountain glacier on the ridge to NE of the Franz Josef Glacier trunk .

Glacier Data	
Glacier area (ha)	311.9
Equilibrium line altitude (ELA)	1860
Maximum elevation (m)	2390
Minimum elevation (m)	1300
Mean elevation (m)	1845
Elevation range (m)	1090
Maximum length (km)	1.03
Gradient	0.365

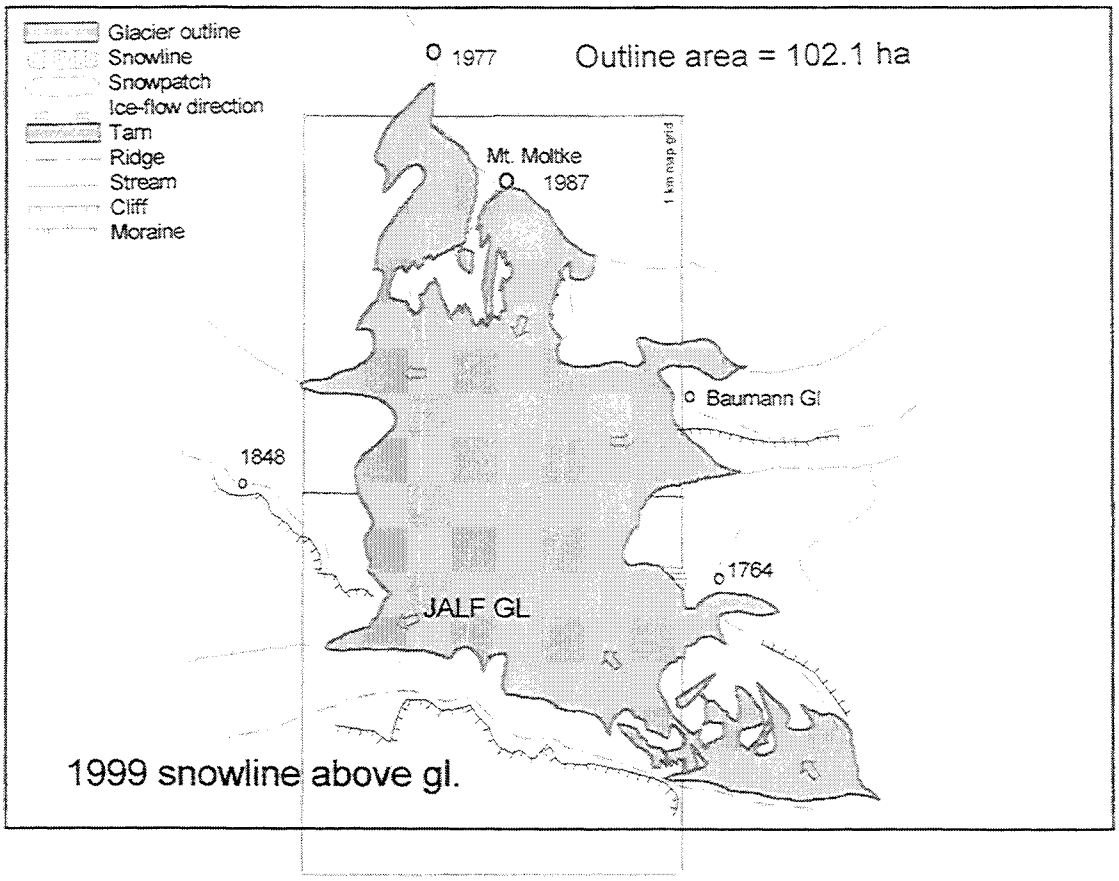
1999 Snowline Data	
1999 accumulation area (ha)	116.70
1999 snowline elevation (m)	2030
Snowline departure from ELA (m)	170
Accumulation area ratio (AAR)	0.37

Left: Digitised map of Almer Glacier-Salisbury Snowfield and oblique aerial photograph taken 1998.

Below: Plot of all available annual snowline departures from the ELA for Salisbury Snowfield.



JALF GLACIER



Jalf (& Baumann) Gl.

Inventory No. 886/002

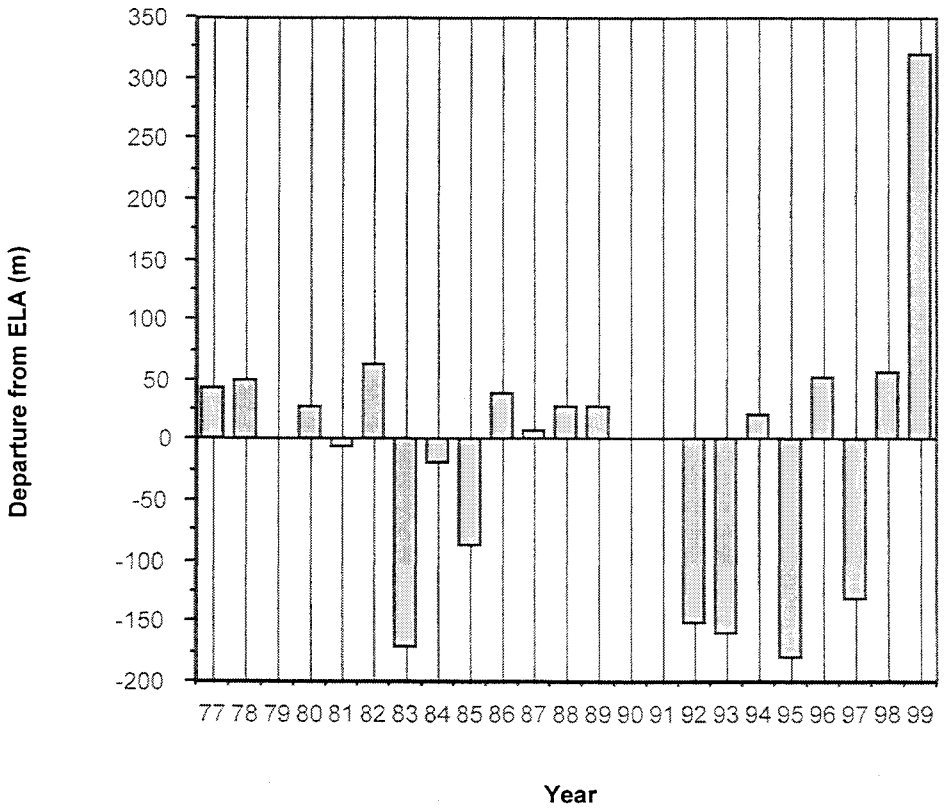
A small glacier with 3 outlets (one being Baumann Gl) occupying a saddle on the ridge to the SW of the Franz Josef Glacier trunk.

Glacier Data	
Glacier area (ha)	102.1
Equilibrium line altitude (ELA)	1732
Maximum elevation (m)	1980
Minimum elevation (m)	1580
Elevation range (m)	400
Maximum length (km)	na
Gradient	na

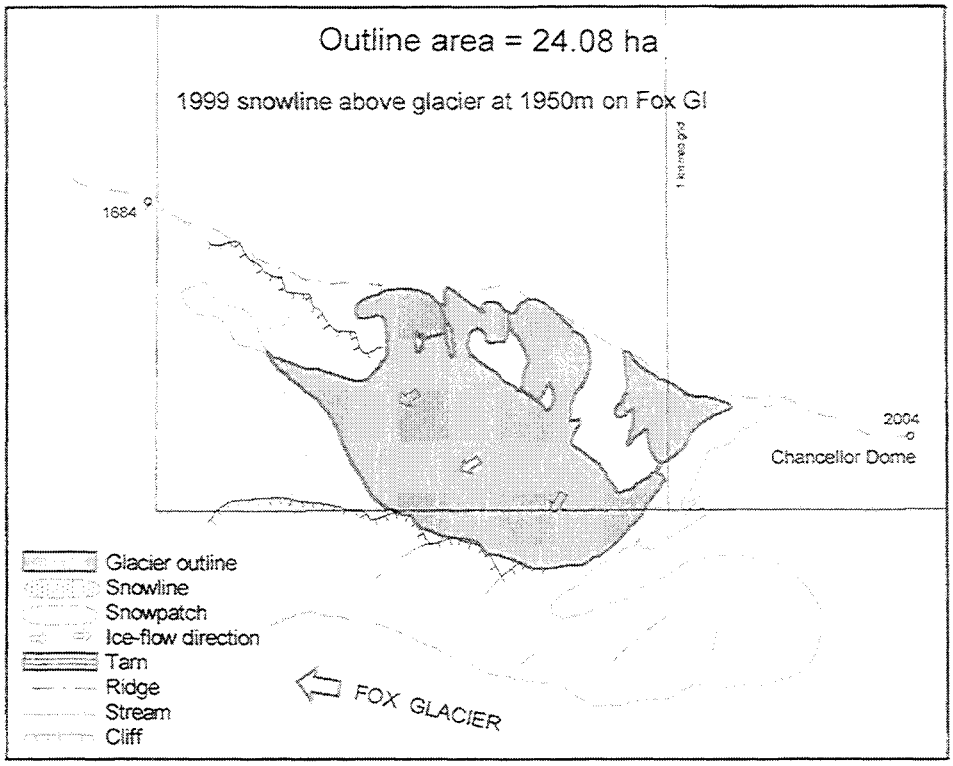
1999 Snowline Data	
1999 accumulation area (ha)	0
1999 snowline elevation (m)	2050, on ridge above glacier.
Snowline departure from ELA (m)	318
Accumulation area ratio (AAR)	na

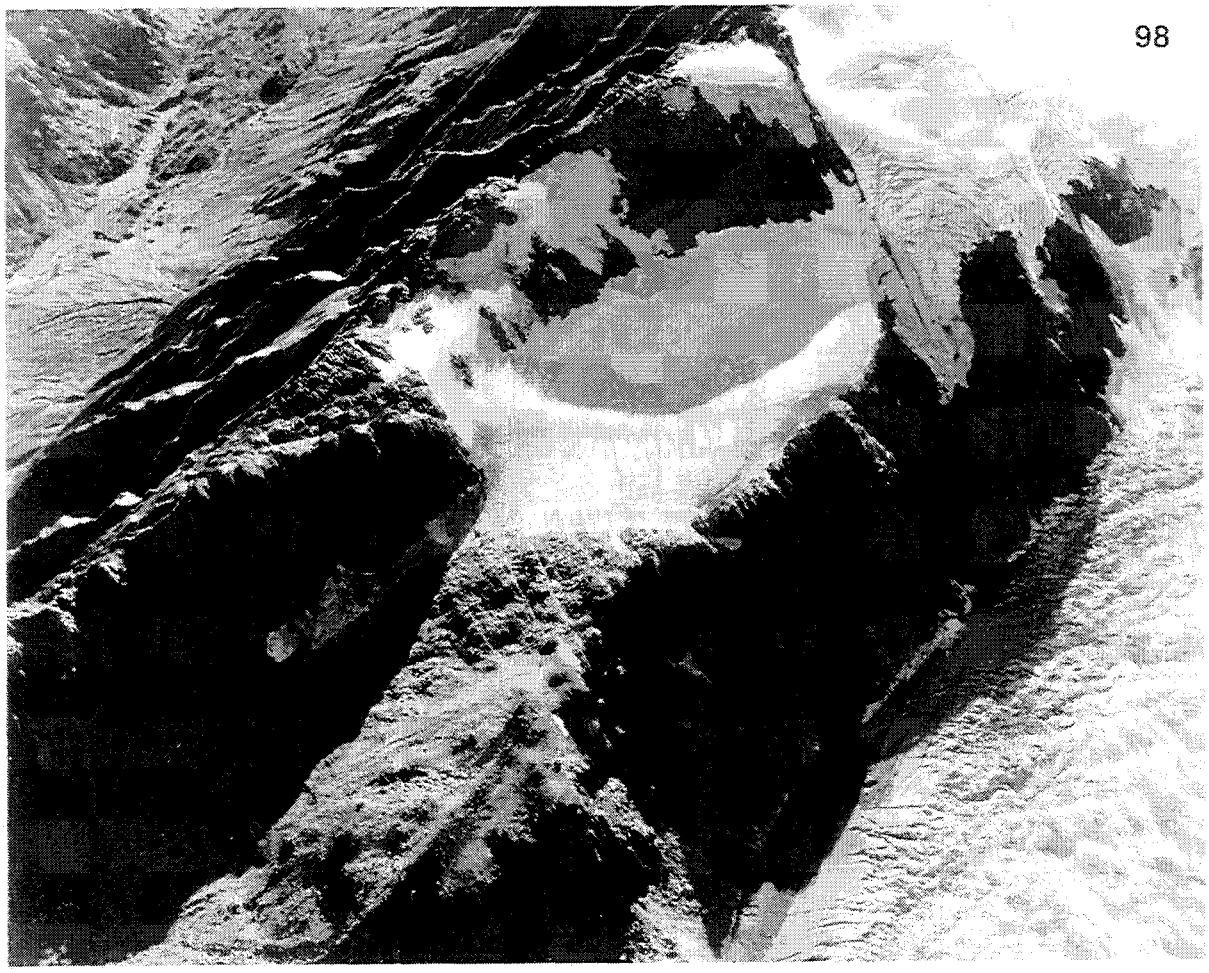
Left: Digitised map of Jalf Glacier and oblique aerial photograph taken 1997.

Below: Plot of all available annual snowline departures from the ELA for Jalf Gl.



CHANCELLOR DOME





Chancellor Dome

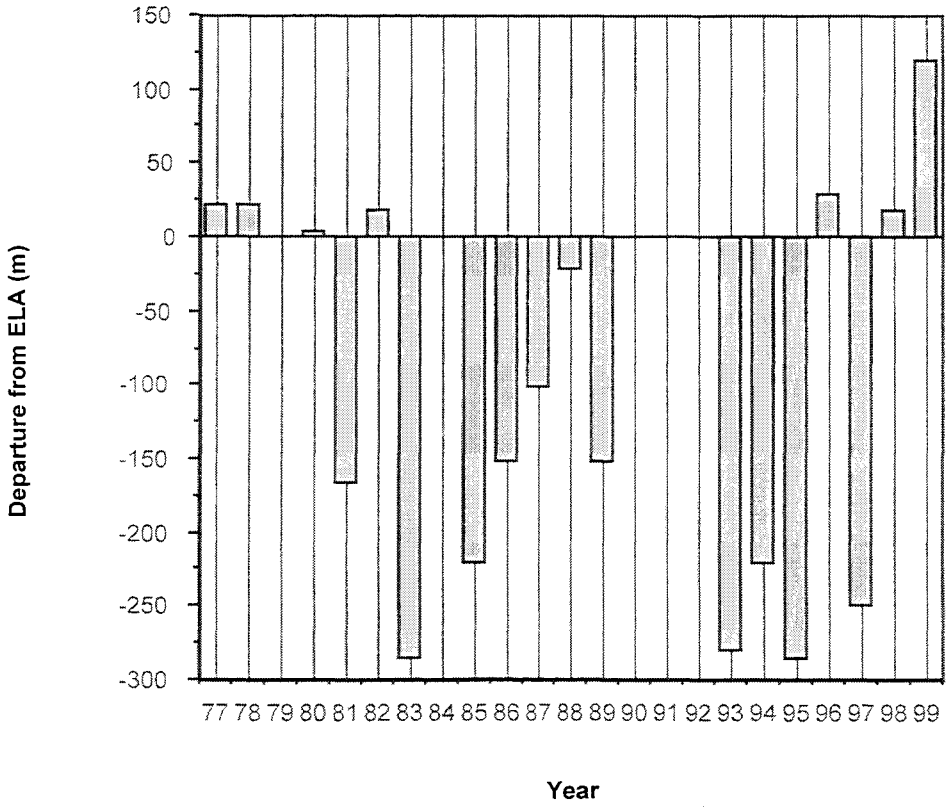
Inventory No. 886/002
A small cirque glacier on Chancellor Dome above the trunk of Fox Glacier.

Glacier Data	
Glacier area (ha)	24.08
Equilibrium line altitude (ELA)	1830
Maximum elevation (m)	1960
Minimum elevation (m)	1580
Mean elevation (m)	1770
Elevation range (m)	380
Maximum length (km)	0.55
Gradient	0.691

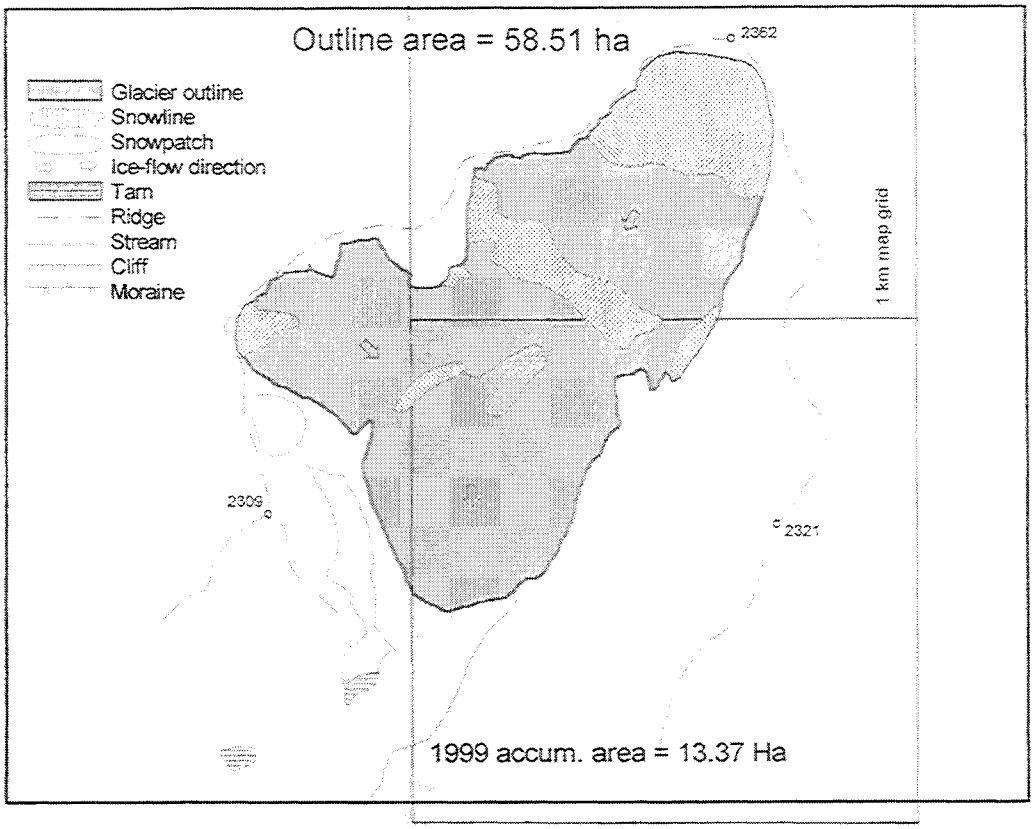
1999 Snowline Data	
1999 accumulation area (ha)	0
1999 snowline elevation (m)	1950, on ridge above glacier.
Snowline departure from ELA (m)	120
Accumulation area ratio (AAR)	0

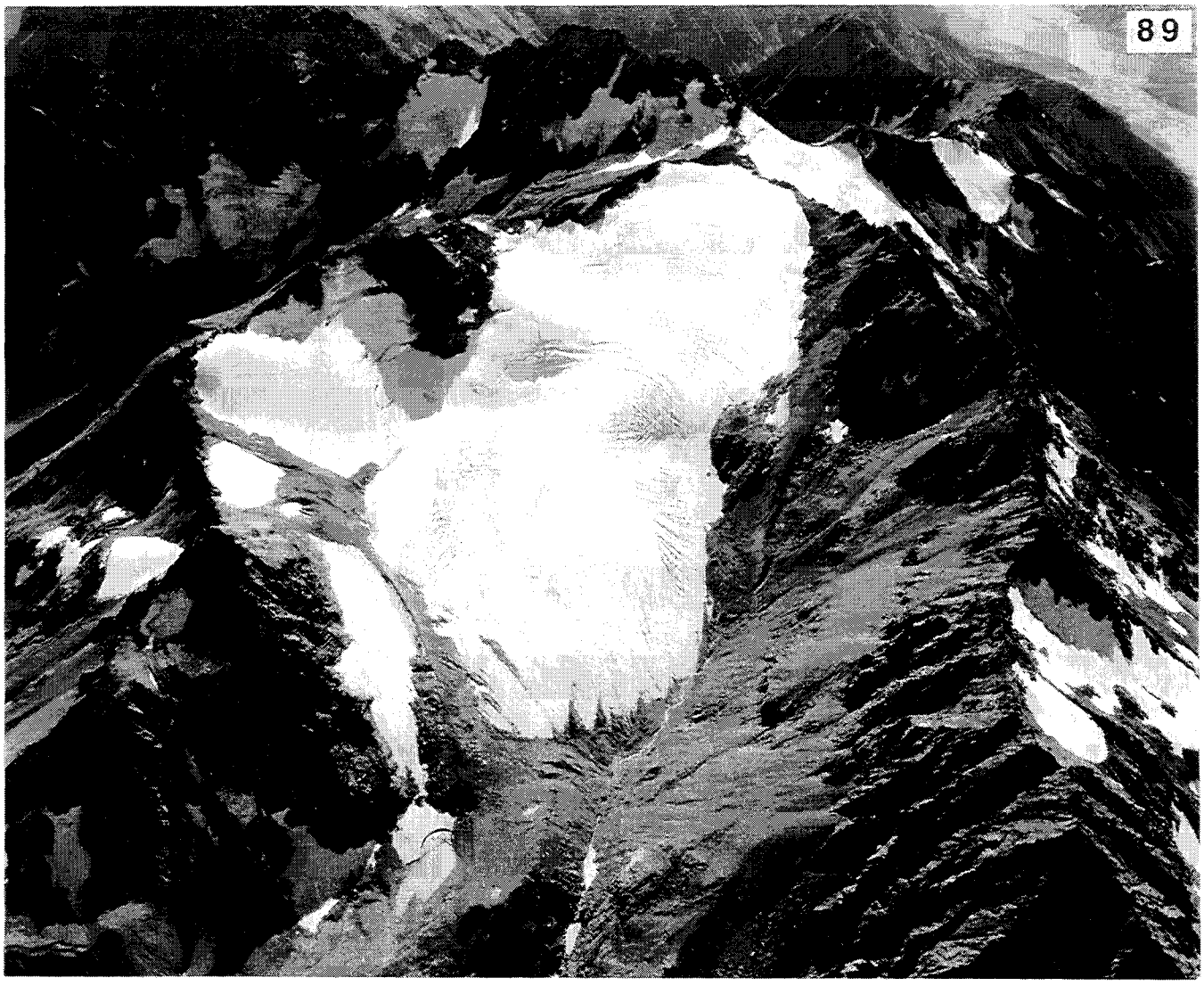
Left: Digitised map of Chancellor Dome and oblique aerial photograph taken 1998.

Below: Plot of all available annual snowline departures from the ELA for Chancellor Dome.



GLENMARY GLACIER





Glenmary Glacier

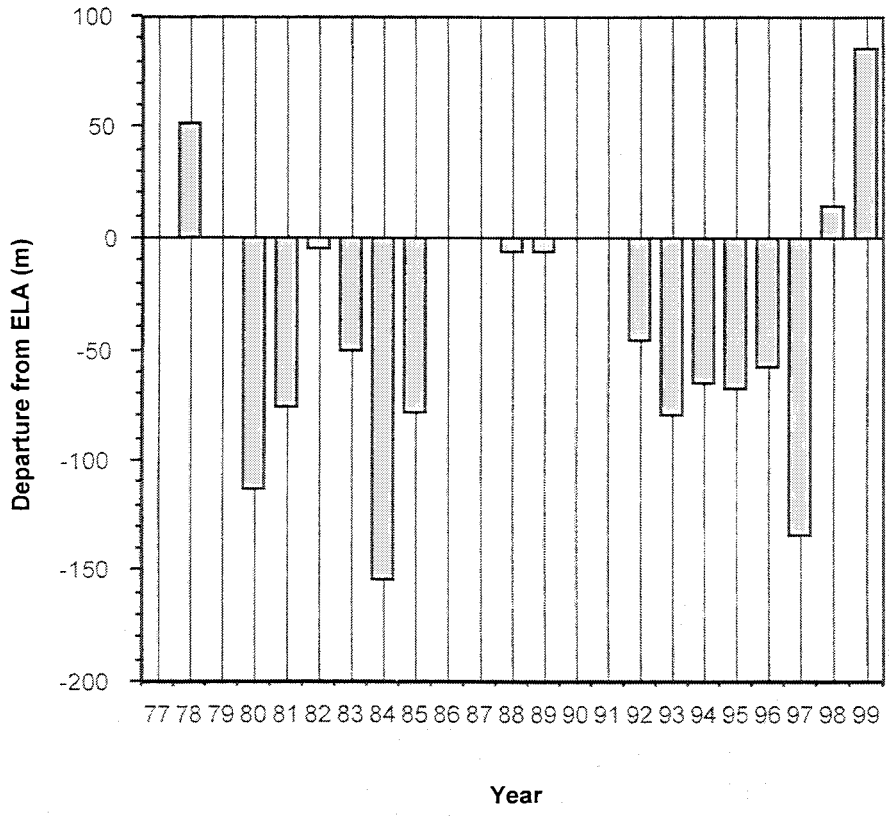
Inventory No. 711F/006
A well formed cirque glacier to the S of Mt. Glenmary, near the confluence of the Hopkins and Dobson Rivers.

Glacier Data	
Glacier area (ha)	58.51
Equilibrium line altitude (ELA)	2186
Maximum elevation (m)	2380
Minimum elevation (m)	2015
Mean elevation (m)	2198
Elevation range (m)	365
Maximum length (km)	1.19
Gradient	0.307

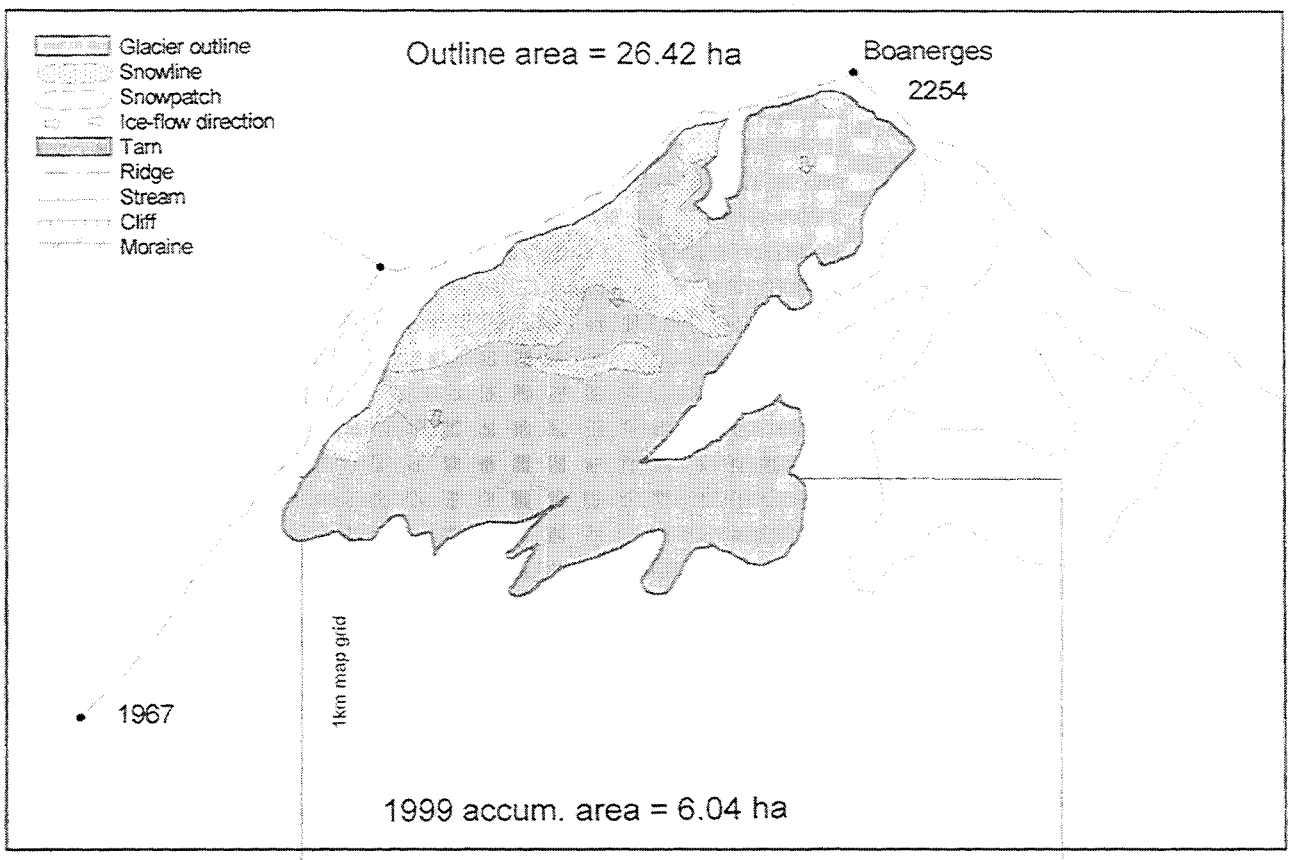
1999 Snowline Data	
1999 accumulation area (ha)	13.37
1999 snowline elevation (m)	2272
Snowline departure from ELA (m)	86
Accumulation area ratio (AAR)	0.23

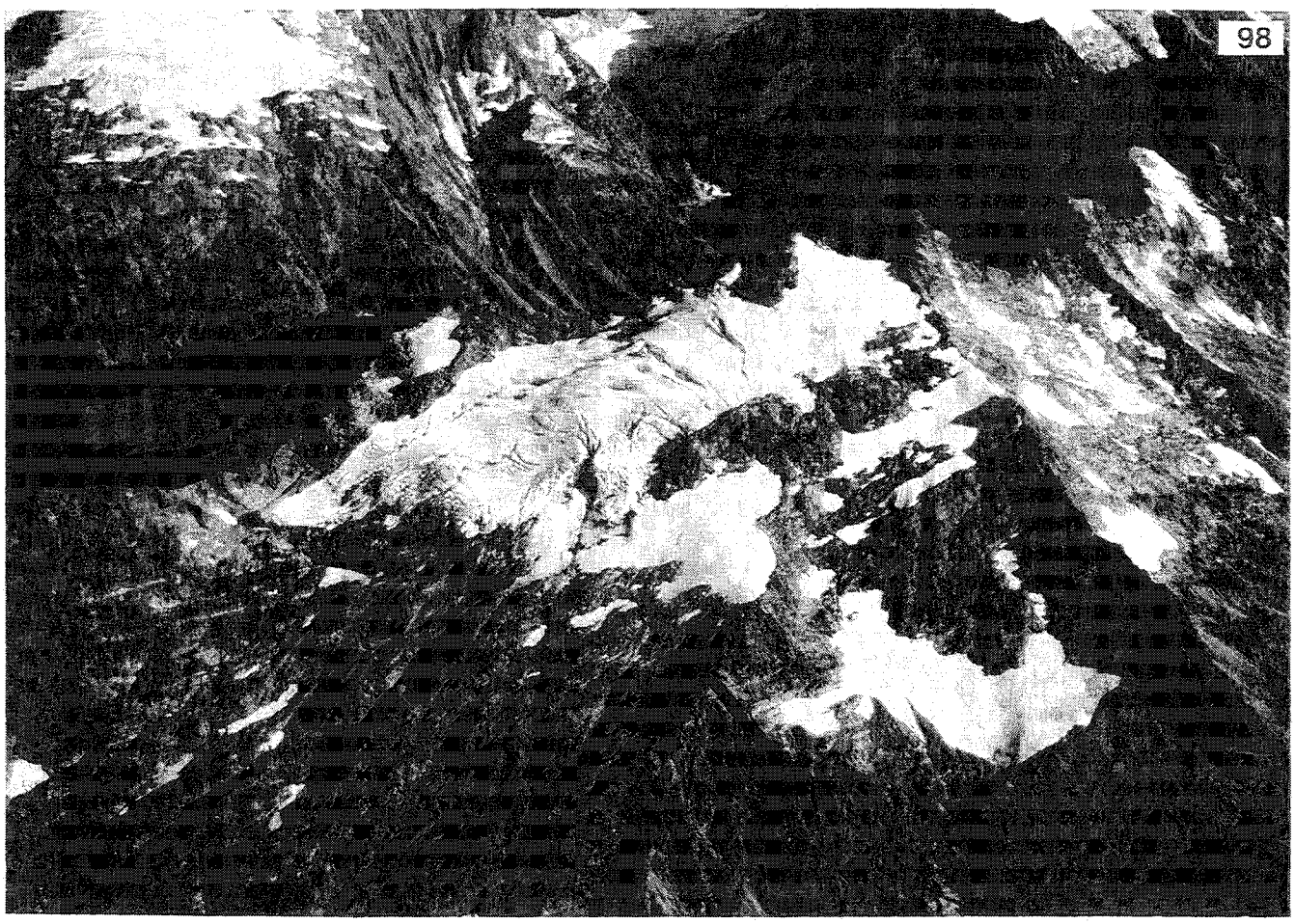
Left: Digitised map of Glenmary Gl for 1999 and oblique aerial photograph taken 1989.

Below: Plot of all available annual snowline departures from the ELA for Glenmary Gl.



BLAIR GLACIER





Blair Glacier

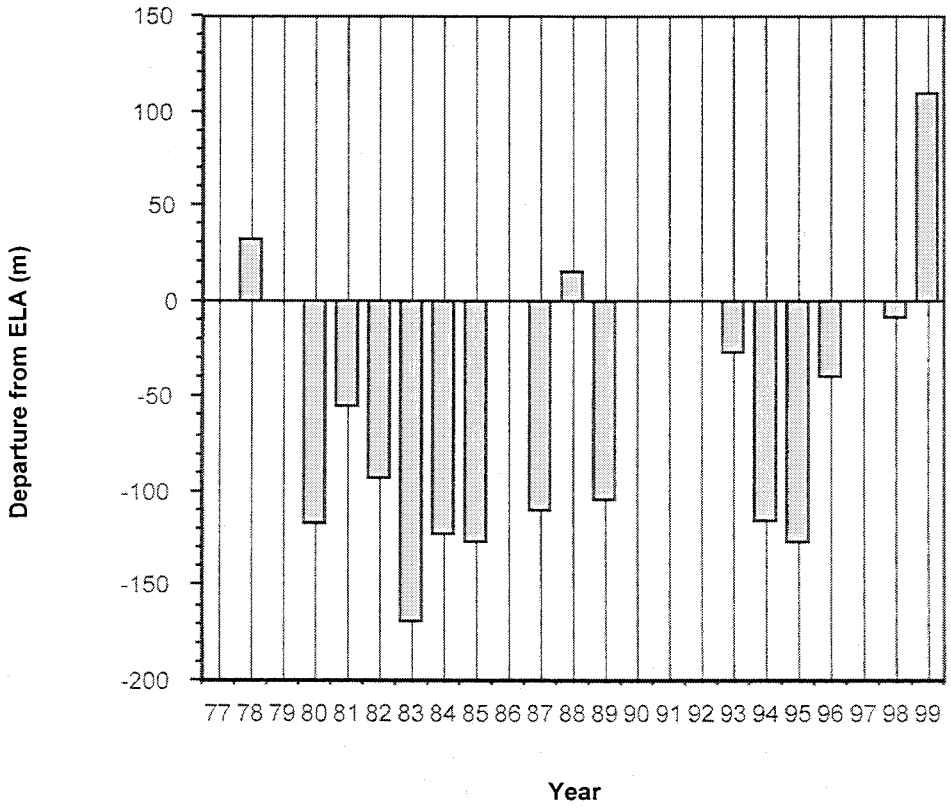
Inventory No. 711D/038
A small mountain glacier on Mt. Boanerges, between Huxley and Hopkins Rivers.

Glacier Data	
Glacier area (ha)	26.42
Equilibrium line altitude (ELA)	1980
Maximum elevation (m)	2240
Minimum elevation (m)	1790
Mean elevation (m)	2015
Elevation range (m)	450
Maximum length (km)	0.63
Gradient	0.714

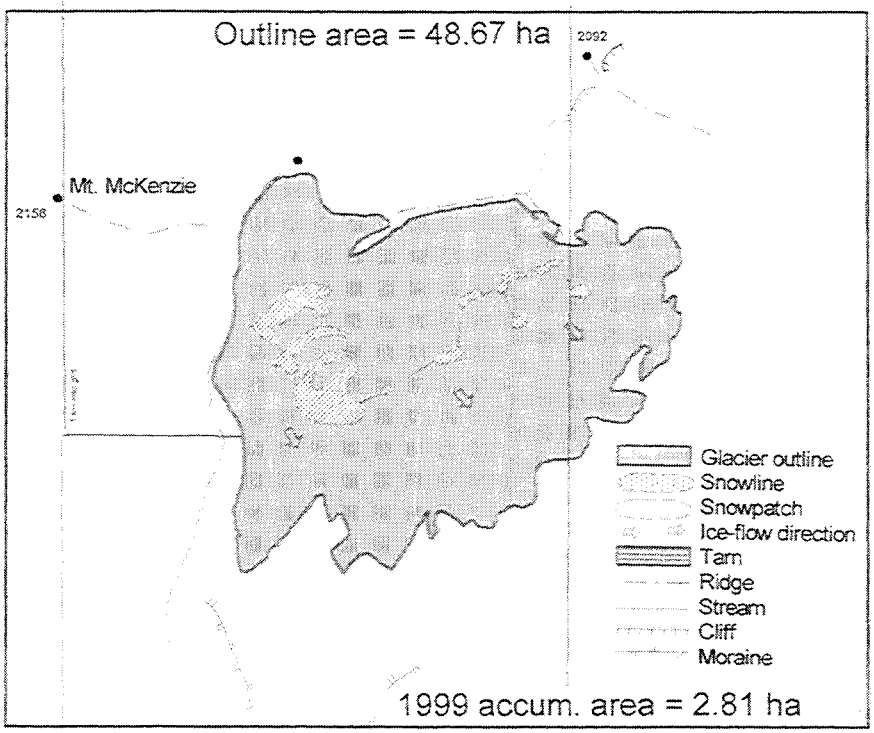
1999 Snowline Data	
1999 accumulation area (ha)	6.04
1999 snowline elevation (m)	2090
Snowline departure from ELA (m)	110
Accumulation area ratio (AAR)	0.23

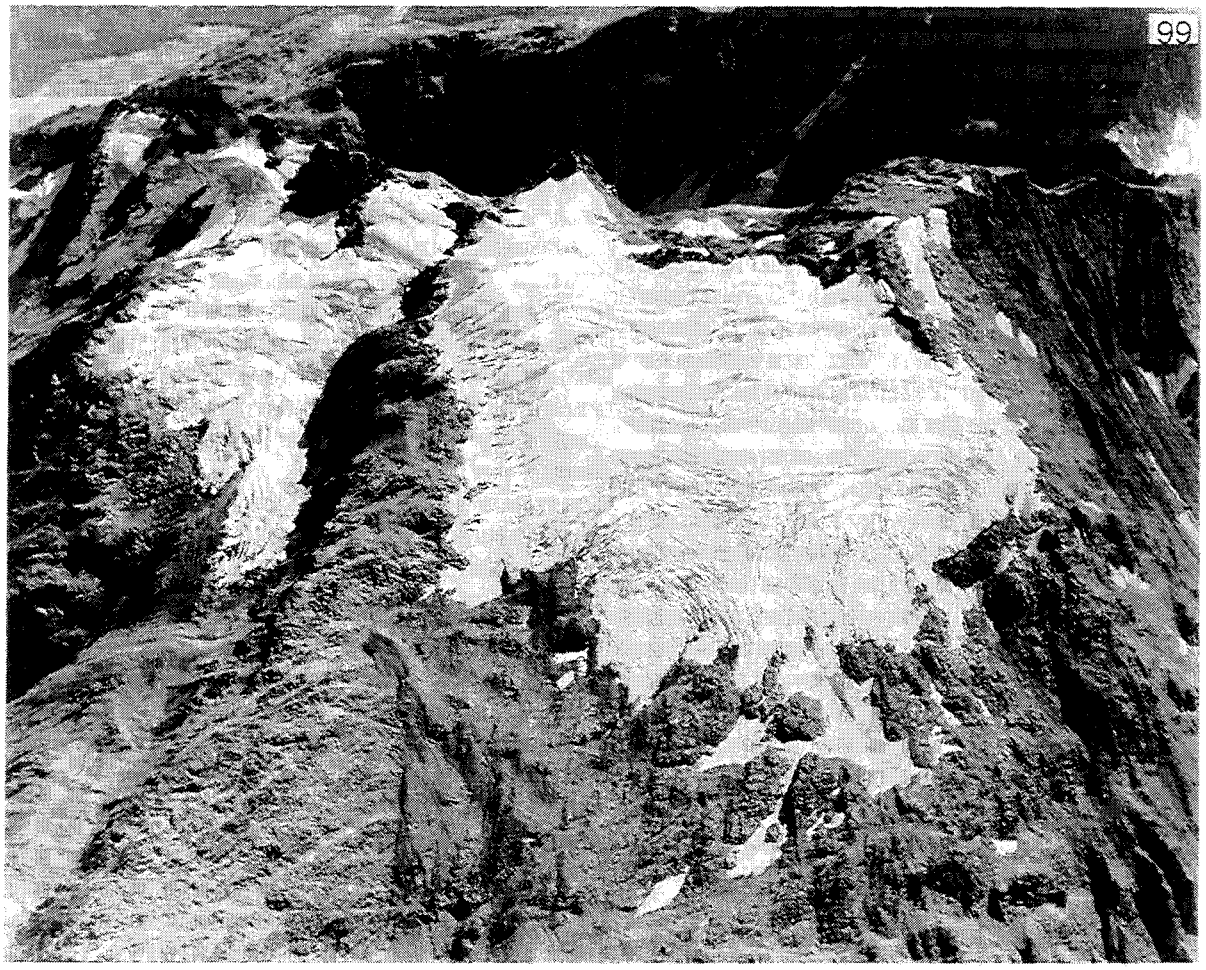
Left: Digitised map of Blair Gl for 1999 and oblique aerial photograph taken 1998. (McKenzie index glacier in background).

Below: Plot of all available annual snowline departures from the ELA for Blair Gl.



MOUNT McKENZIE





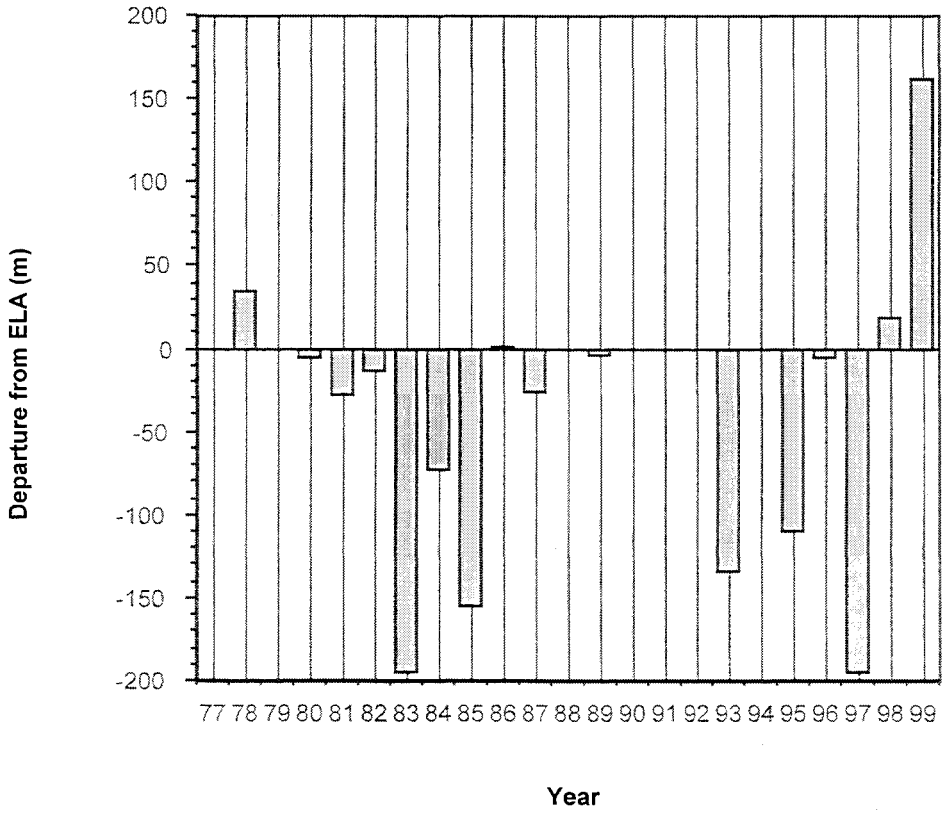
Mount McKenzie

Inventory No. 711D/021
A small mountain glacier on Mt. McKenzie, beside Brodrick Pass, Hopkins R. catchment.

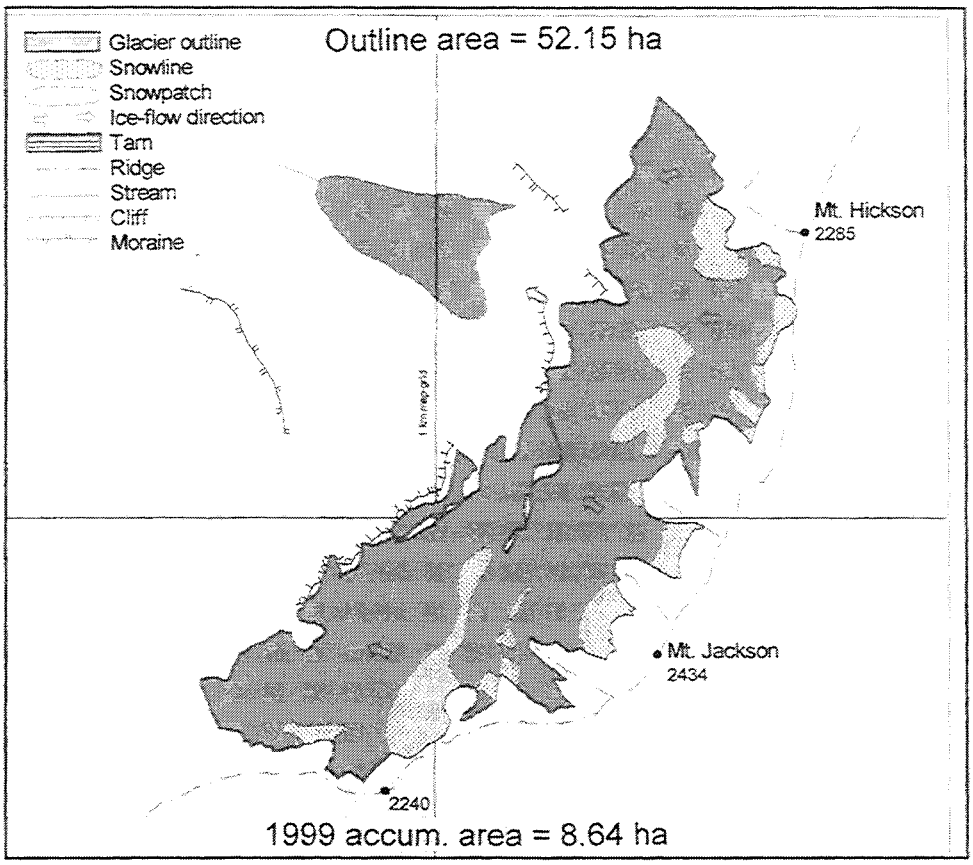
Glacier Data	
Glacier area (ha)	48.67
Equilibrium line altitude (ELA)	1915
Maximum elevation (m)	2100
Mean elevation (m)	1930
Elevation range (m)	340
Maximum length (km)	0.69
Gradient	0.493
1999 Snowline Data	
1999 accumulation area (ha)	2.81
1999 snowline elevation (m)	2078
Snowline departure from ELA (m)	163
Accumulation area ratio (AAR)	0.06

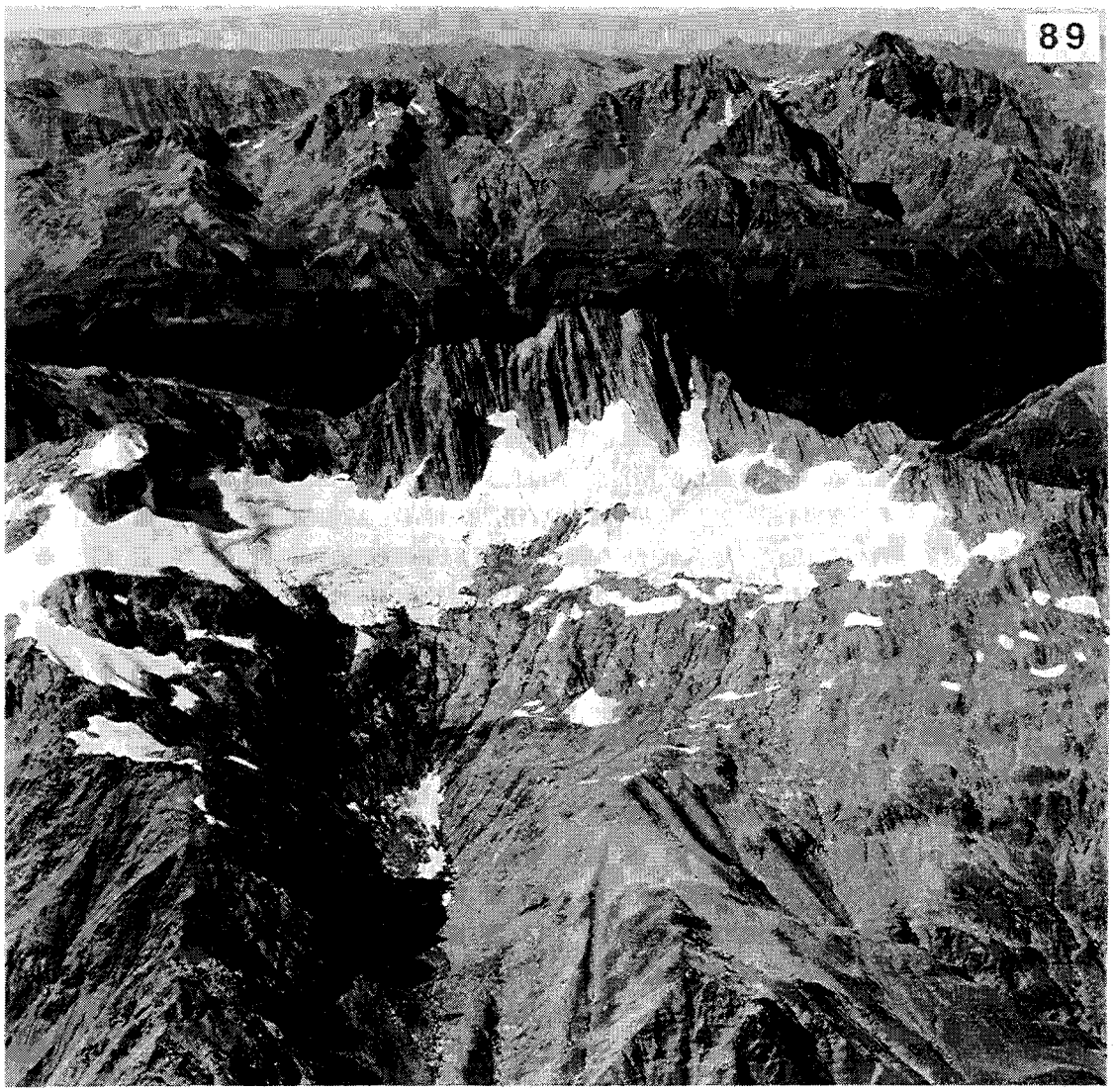
Left: Digitised map of Mt. McKenzie for 1999 and oblique aerial photograph taken 1999.

Below: Plot of all available annual snowline departures from the ELA for Mt. McKenzie.



JACKSON GLACIER





Jackson Glacier

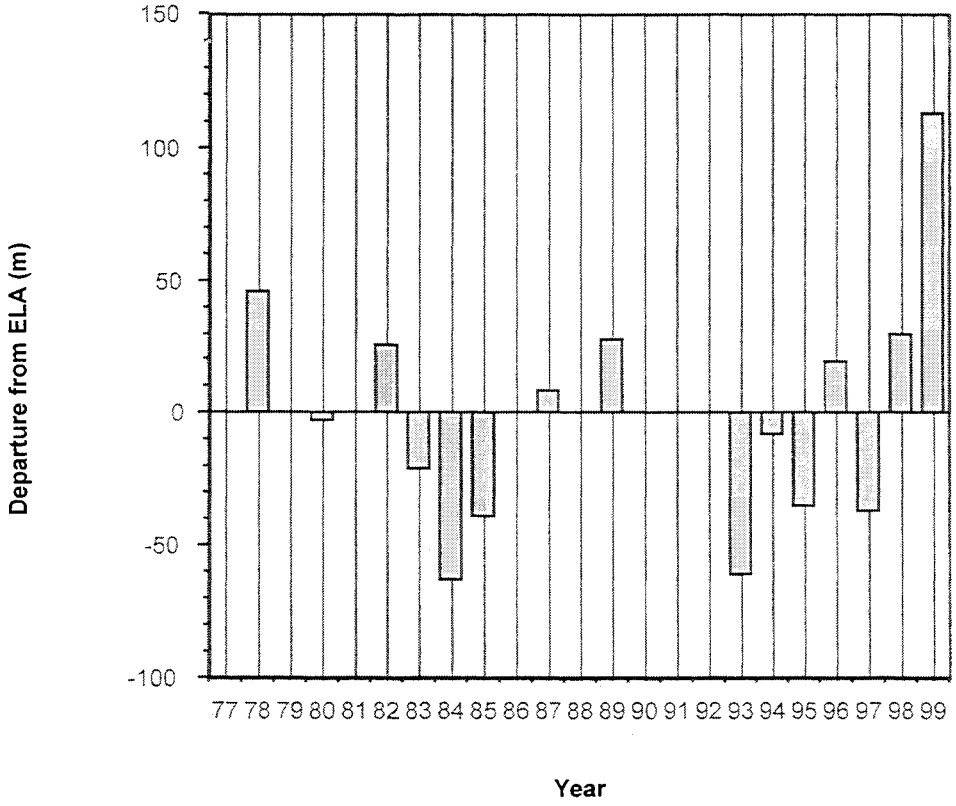
Inventory No. 868B/094
A wide mountain glacier on Mt. Jackson, Landsborough R. catchment.

Glacier Data	
Glacier area (ha)	52.15
Equilibrium line altitude (ELA)	2053
Maximum elevation (m)	2300
Minimum elevation (m)	1920
Mean elevation (m)	2110
Elevation range (m)	380
Maximum length (km)	0.5
Gradient	0.76

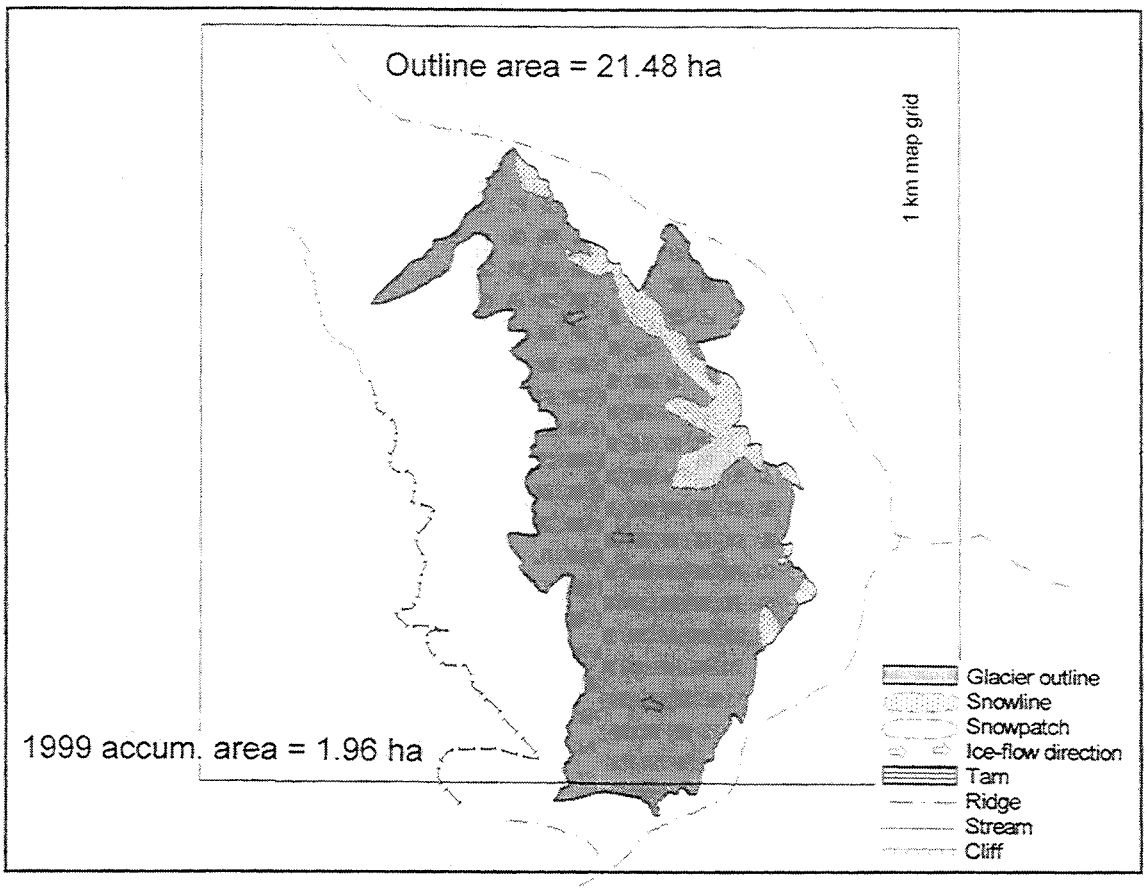
1999 Snowline Data	
1999 accumulation area (ha)	8.64
1999 snowline elevation (m)	2165
Snowline departure from ELA (m)	112
Accumulation area ratio (AAR)	0.15

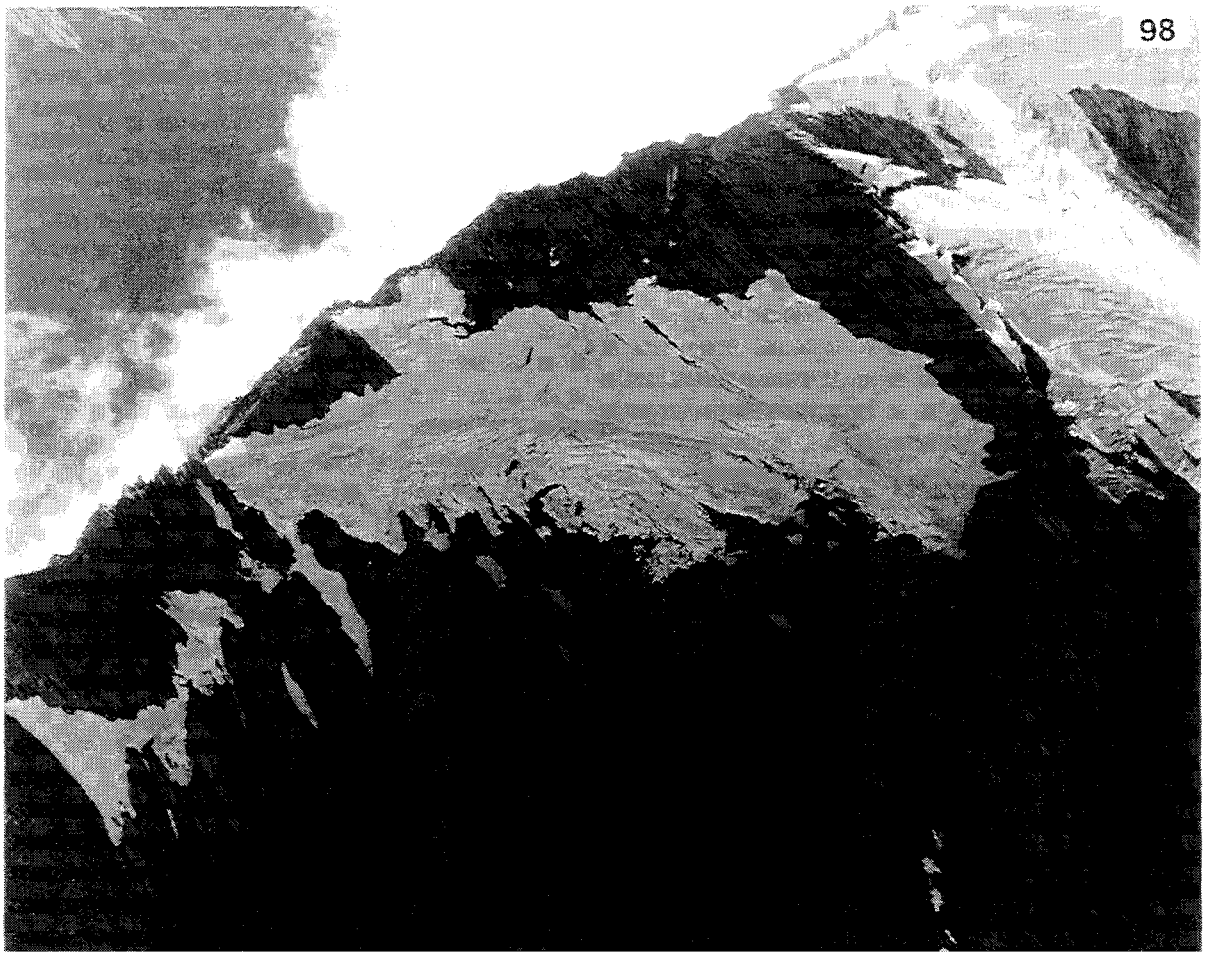
Left: Digitised map of Jackson Glacier for 1999 and oblique aerial photograph taken 1989.

Below: Plot of all available annual snowline departures from the ELA for Jackson Glacier.



JACK GLACIER





Jack Glacier

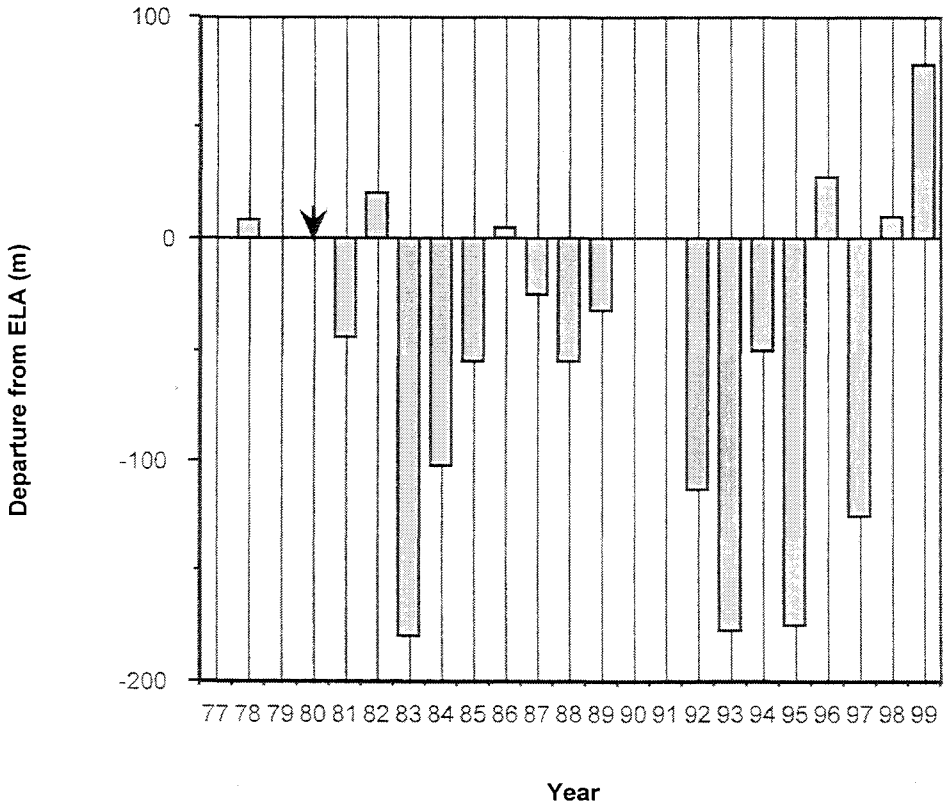
Inventory No. 875/015
A small cirque glacier on W ridge of Mt. Hooker, Paringa R. catchment.

Glacier Data	
Glacier area (ha)	21.48
Equilibrium line altitude (ELA)	1930
Maximum elevation (m)	2080
Minimum elevation (m)	1750
Mean elevation (m)	1915
Elevation range (m)	330
Maximum length (km)	0.337
Gradient	0.979

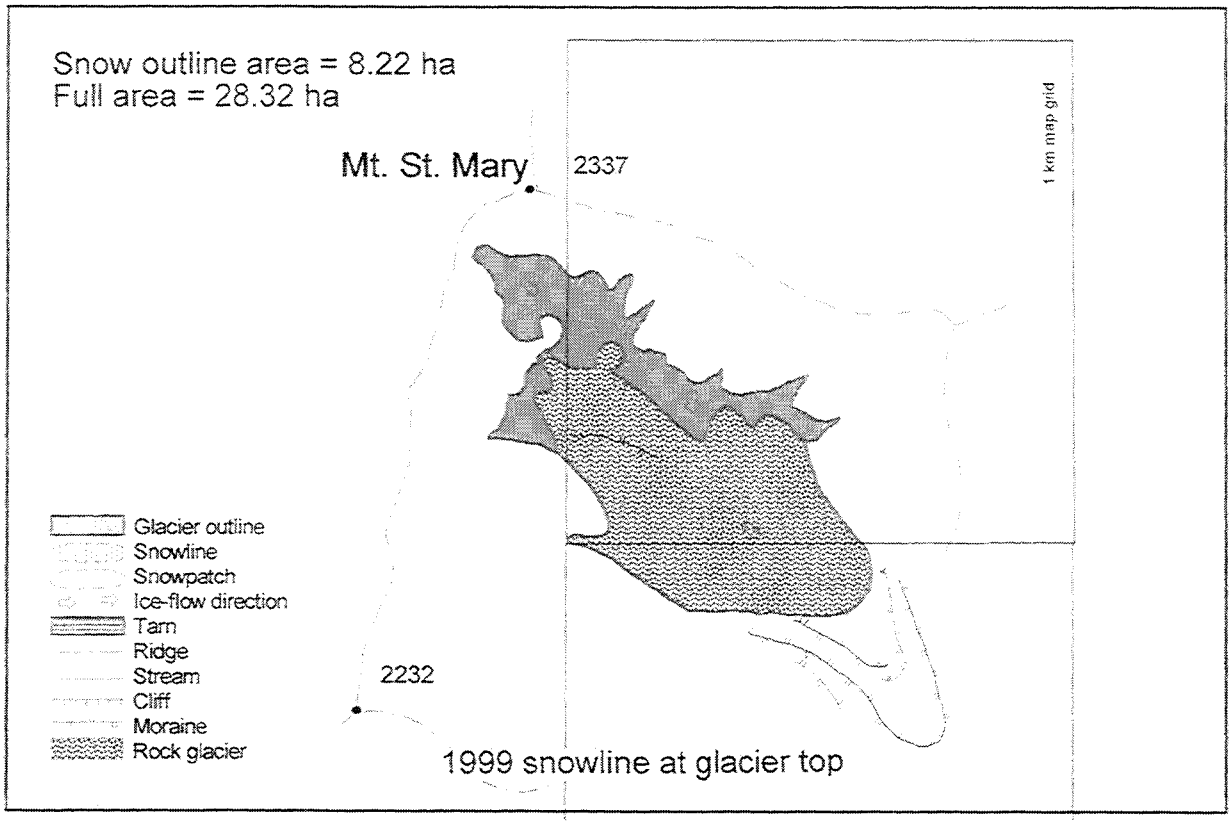
1999 Snowline Data	
1999 accumulation area (ha)	1.96
1999 snowline elevation (m)	2008
Snowline departure from ELA (m)	78
Accumulation area ratio (AAR)	0.09

Left: Digitised map of Jack Glacier for 1999 and oblique aerial photograph taken 1998.

Below: Plot of all available annual snowline departures from the ELA for Jack Glacier. Down arrow indicates zero value.



MOUNT ST MARY



Mount St. Mary

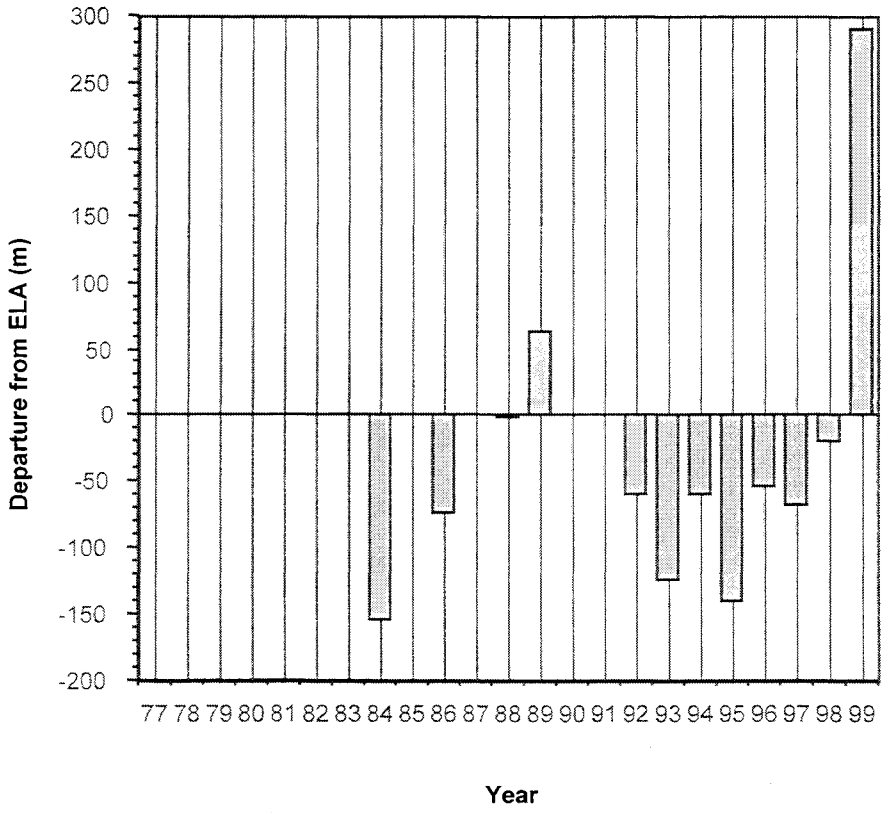
Inventory No. 711B/039
A rock glacier on Mt. St. Mary, Ahuriri R. catchment.

Glacier Data	
Full rock glacier area (ha)	28.32
Exposed ice area (ha)	8.22
Equilibrium line altitude (ELA)	1910
Maximum elevation (m)	2200
Minimum elevation (m)	1760
Mean elevation (m)	1980
Elevation range (m)	440
Maximum length (km)	0.7
Gradient	0.629

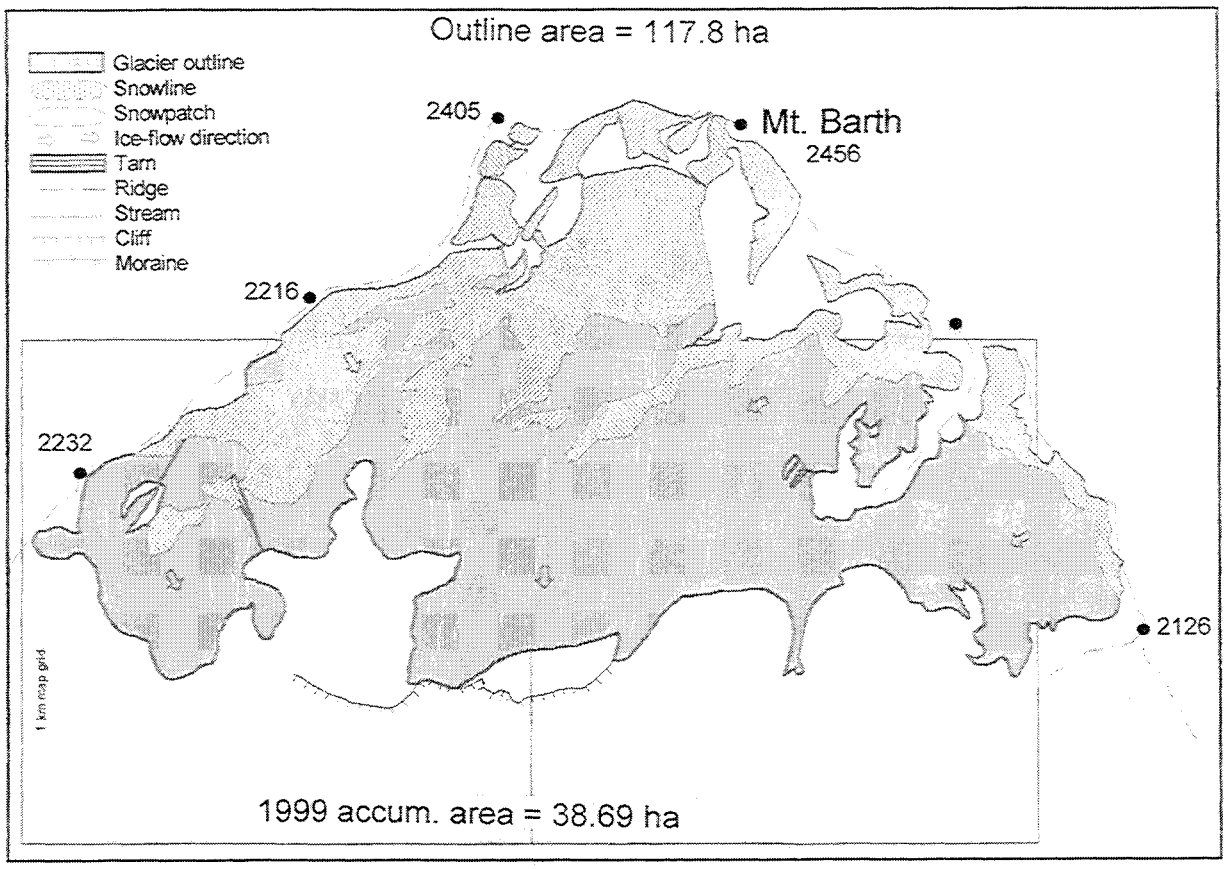
1999 Snowline Data	
1999 accumulation area (ha)	0, snowline equal to or above glacier
1999 snowline elevation (m)	2200
Snowline departure from ELA (m)	290
Accumulation area ratio (AAR)	0

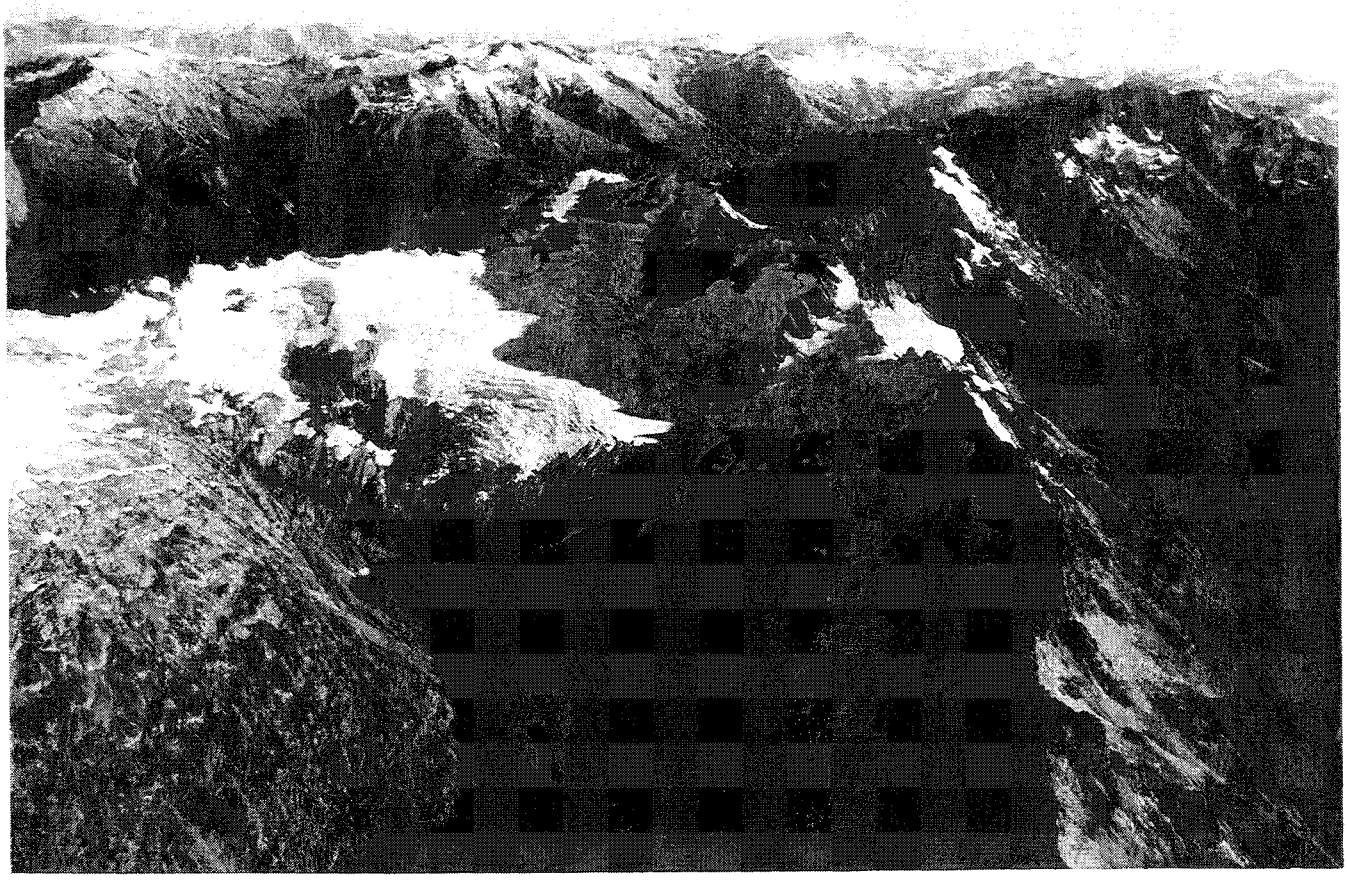
Left: Digitised map of Mt St. Mary and oblique aerial photograph taken 1998.

Below: Plot of all available annual snowline departures from the ELA for Mt. St. Mary.



THURNEYSON GLACIER





Thurneyson Glacier

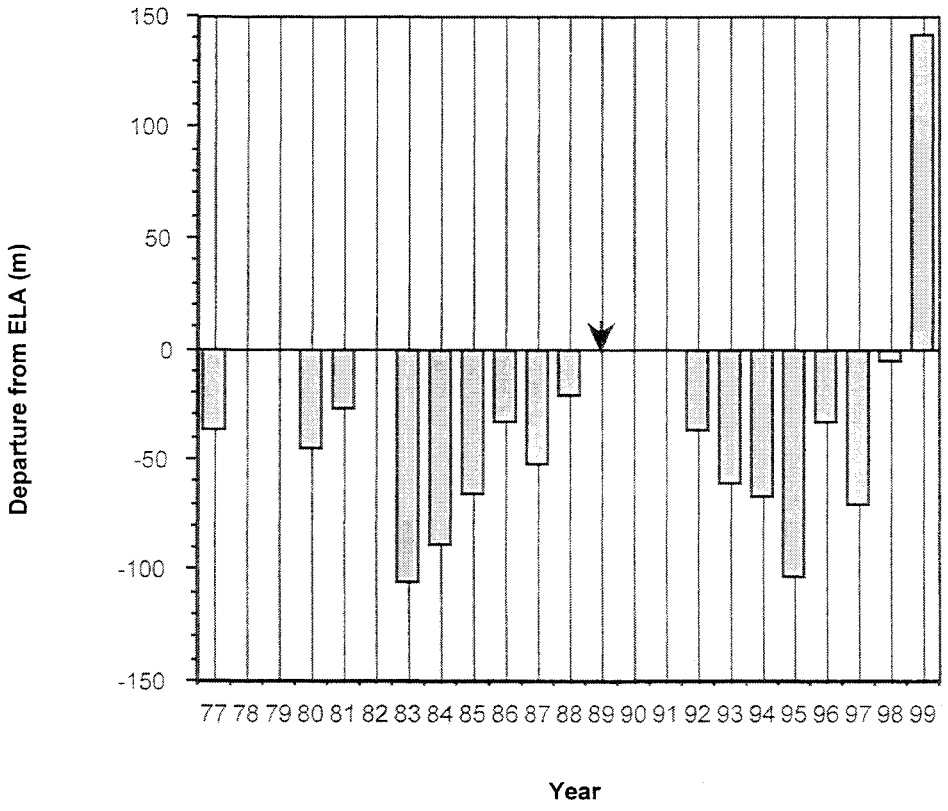
Inventory No. 711B/012
A mountain glacier on the Canyon Ck side of Mt. Bath, Ahuriri R. catchment.

Glacier Data	
Glacier area, (ha)	117.8
Equilibrium line altitude (ELA)	2020
Maximum elevation (m)	2450
Minimum elevation (m)	1720
Mean elevation (m)	2085
Elevation range (m)	730
Maximum length (km)	1.228
Gradient	0.57

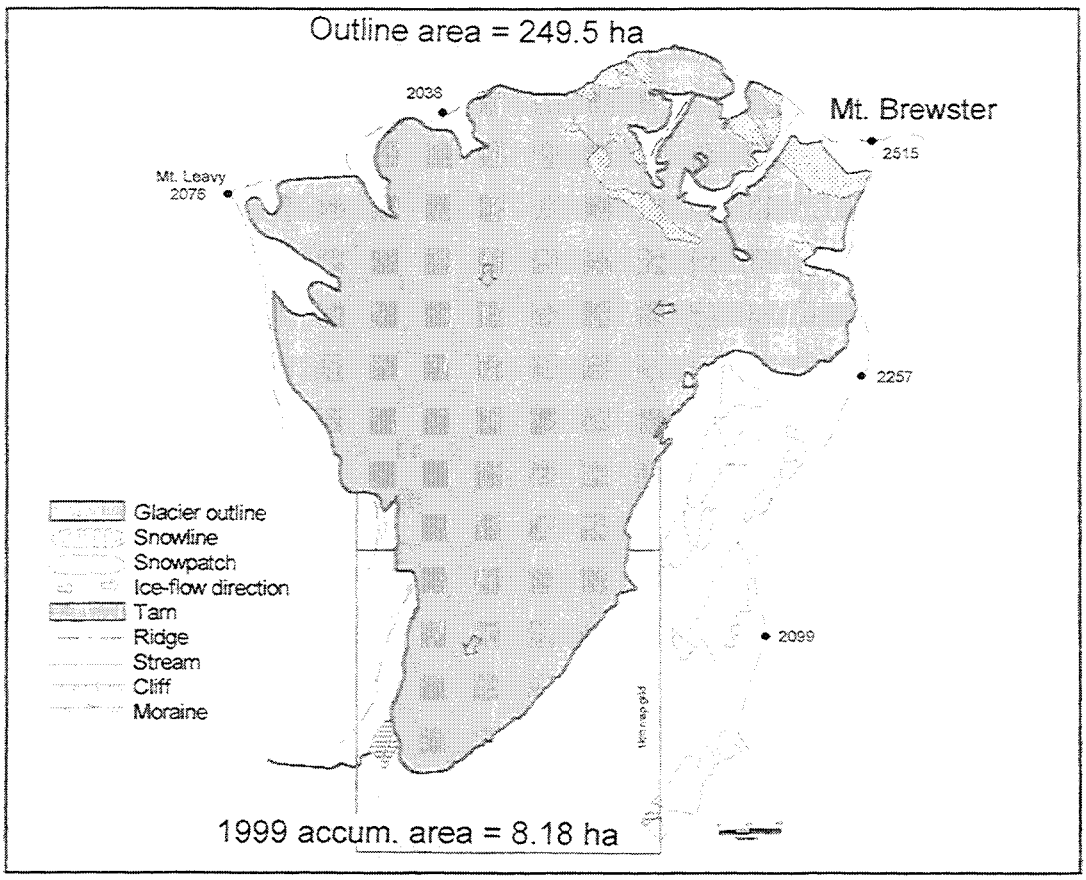
1999 Snowline Data	
1999 accumulation area (ha)	38.69
1999 snowline elevation (m)	2112
Snowline departure from ELA (m)	142
Accumulation area ratio (AAR)	0.33

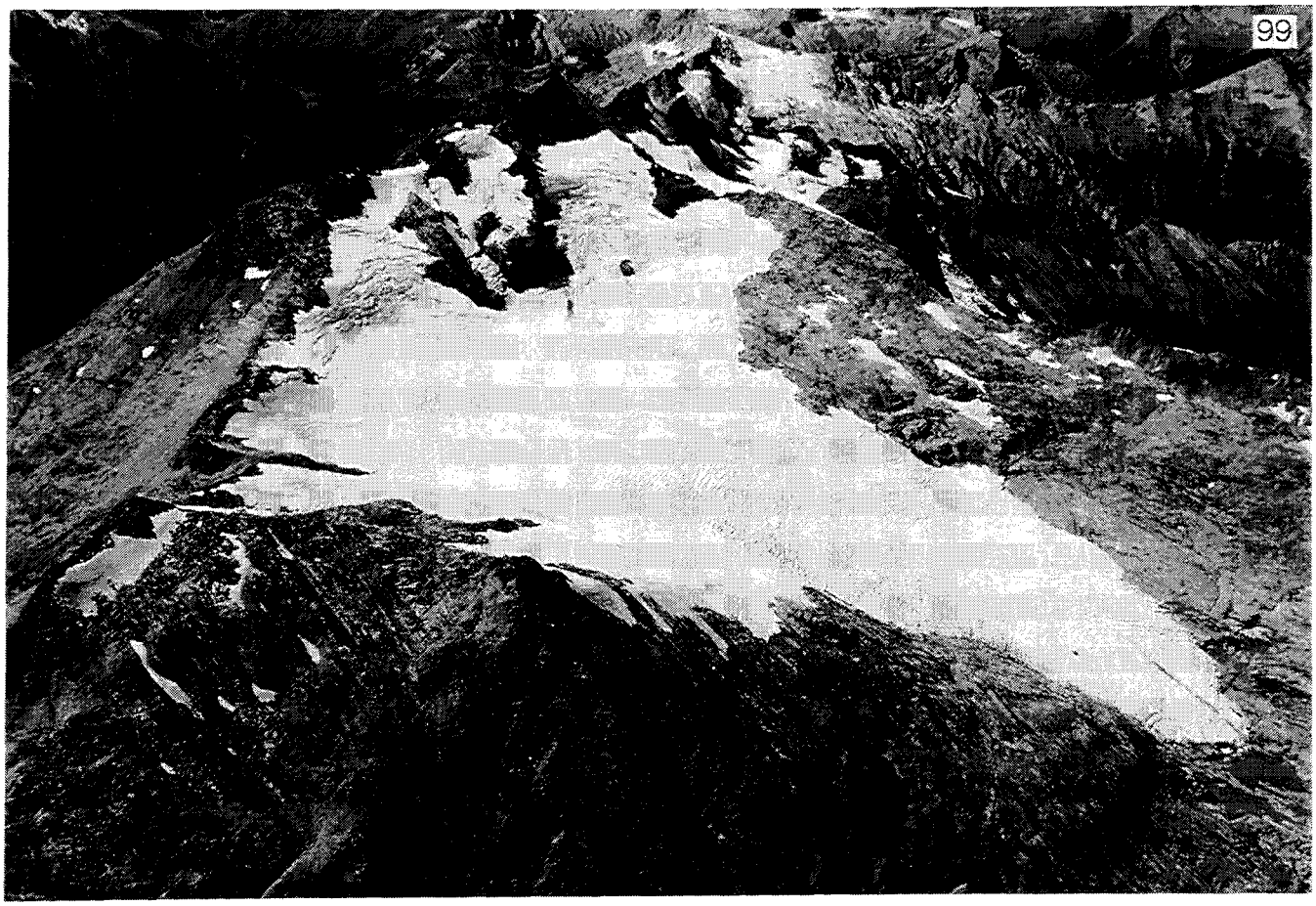
Left: Digitised map of Thurneyson Glacier for 1999 and oblique aerial photograph taken 1998.

Below: Plot of all available annual snowline departures from the ELA for Thurneyson Glacier. Down arrow indicates zero value.



BREWSTER GLACIER





Brewster Glacier

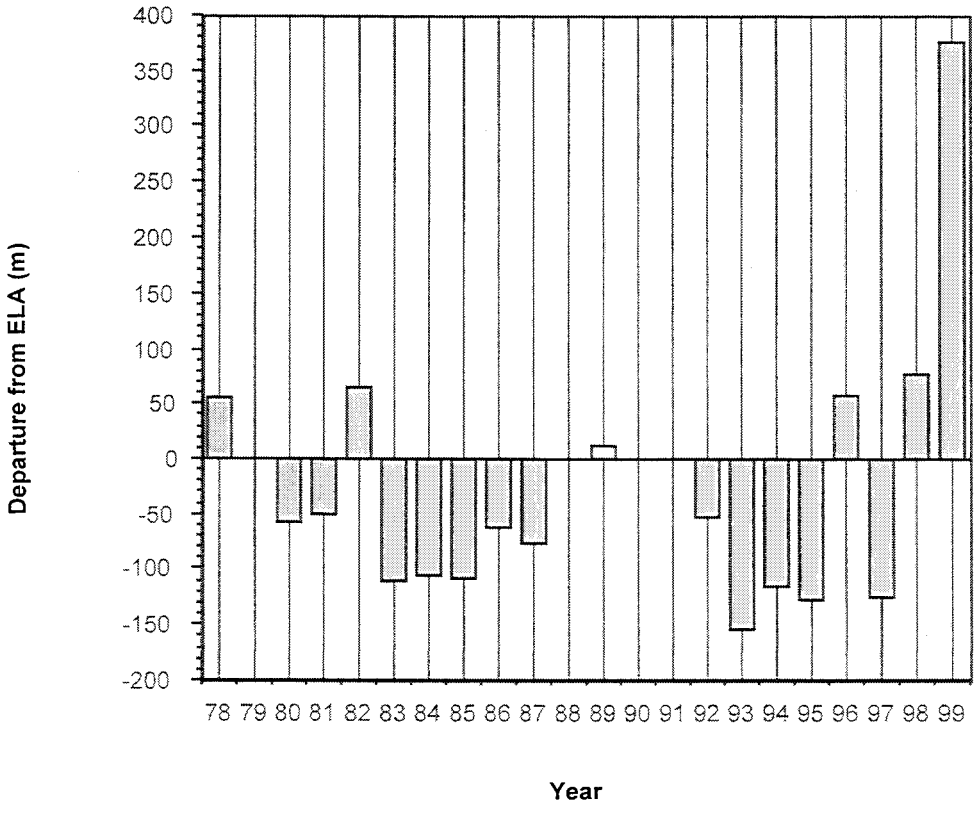
Inventory No. 868C/020
A valley glacier on Mt. Brewster, Haast R. catchment.

Glacier Data	
Glacier area (ha)	249.5
Equilibrium line altitude (ELA)	1905
Maximum elevation (m)	2390
Minimum elevation (m)	1650
Mean elevation (m)	2020
Elevation range (m)	740
Maximum length (km)	2.69
Gradient	0.296

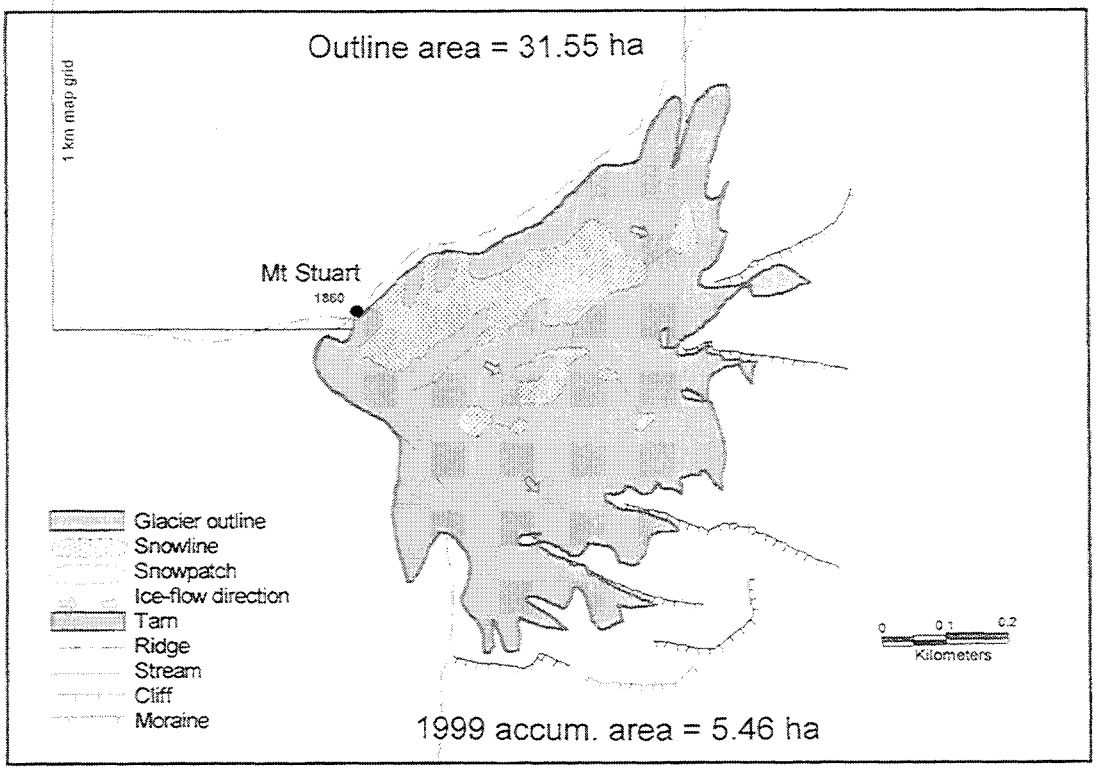
1999 Snowline Data	
1999 accumulation area (ha)	8.18
1999 snowline elevation (m)	2280
Snowline departure from ELA (m)	375
Accumulation area ratio (AAR)	0.03

Left: Digitised map of Brewster Glacier for 1999 and oblique aerial photograph taken 1999.

Below: Plot of all available annual snowline departures from the ELA for Brewster Glacier.



MOUNT STUART



Mt. Stuart

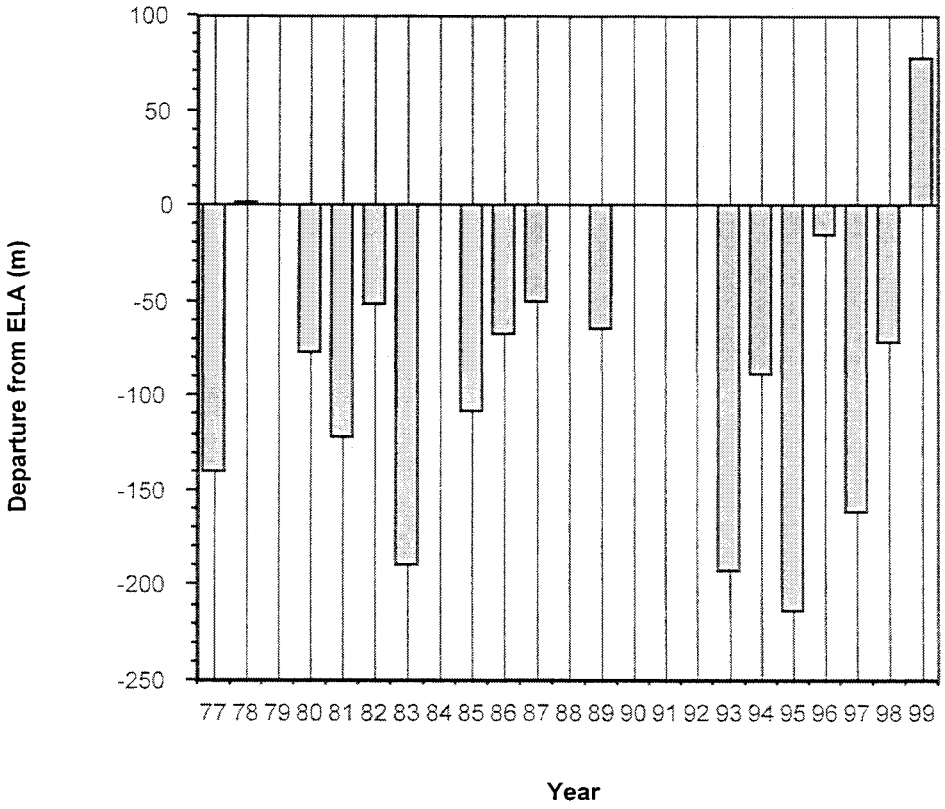
Inventory No. 752/104
A small mountain glacier on Mt. Stuart, Makarora R. catchment.

Glacier Data	
Glacier area (ha)	31.55
Equilibrium line altitude (ELA)	1728
Maximum elevation (m)	1860
Minimum elevation (m)	1570
Mean elevation (m)	1715
Elevation range (m)	290
Maximum length (km)	0.54
Gradient	0.5

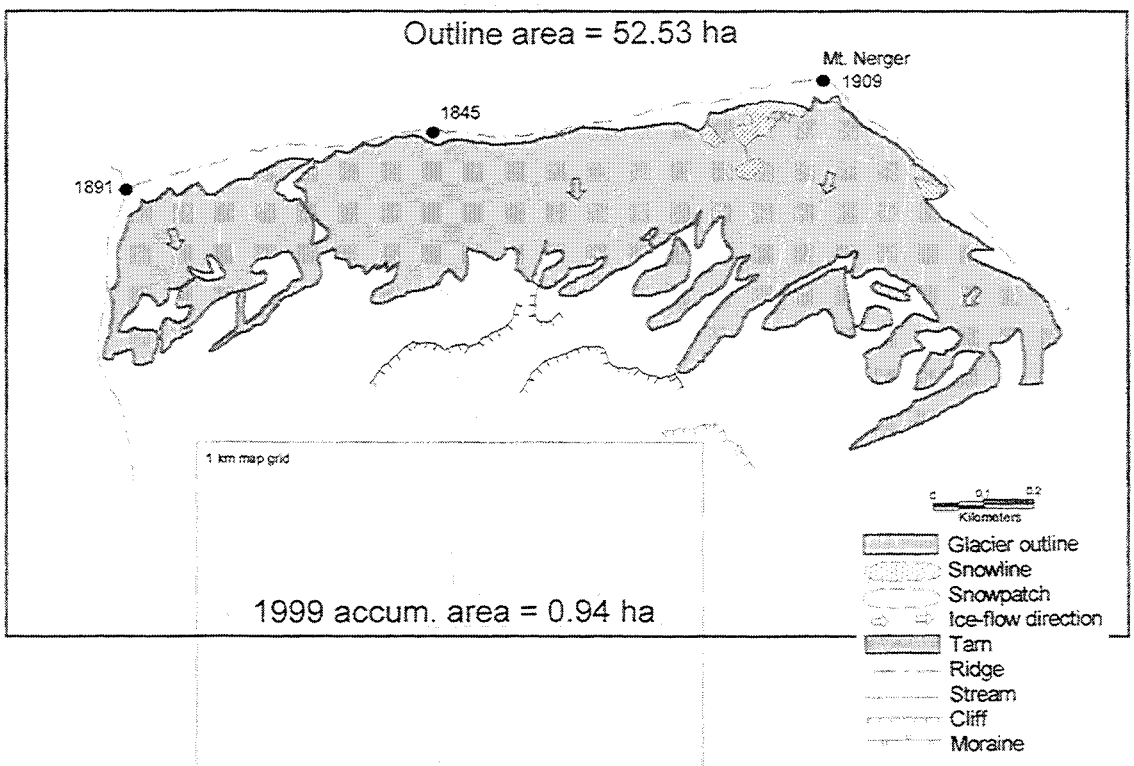
1999 Snowline Data	
1999 accumulation area (ha)	5.46
1999 snowline elevation (m)	1805
Snowline departure from ELA (m)	77
Accumulation area ratio (AAR)	0.17

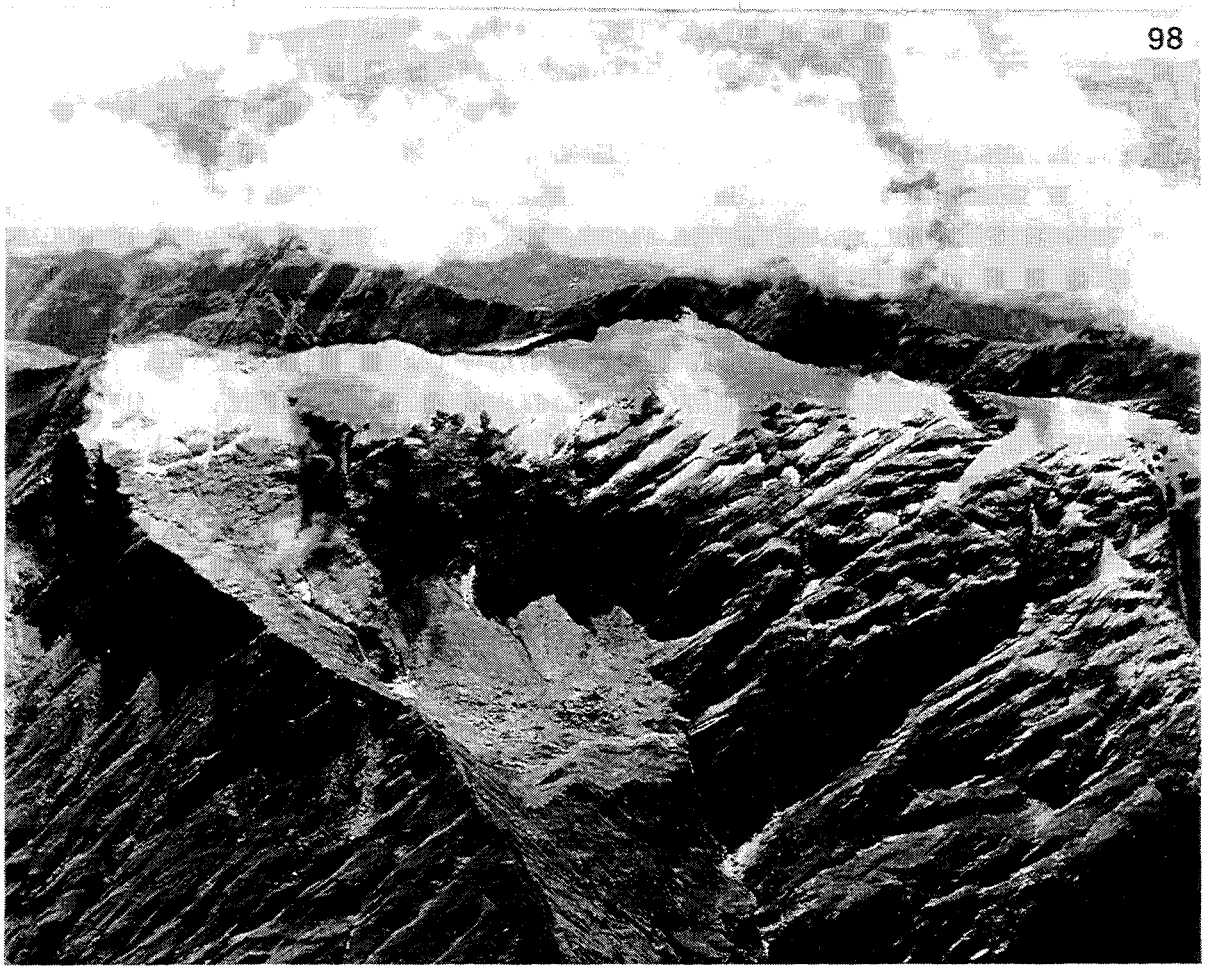
Left: Digitised map of Mt. Stuart for 1999 and oblique aerial photograph taken 1989.

Below: Plot of all available annual snowline departures from the ELA for Mt. Stuart.



LINDSAY GLACIER





Lindsay Glacier

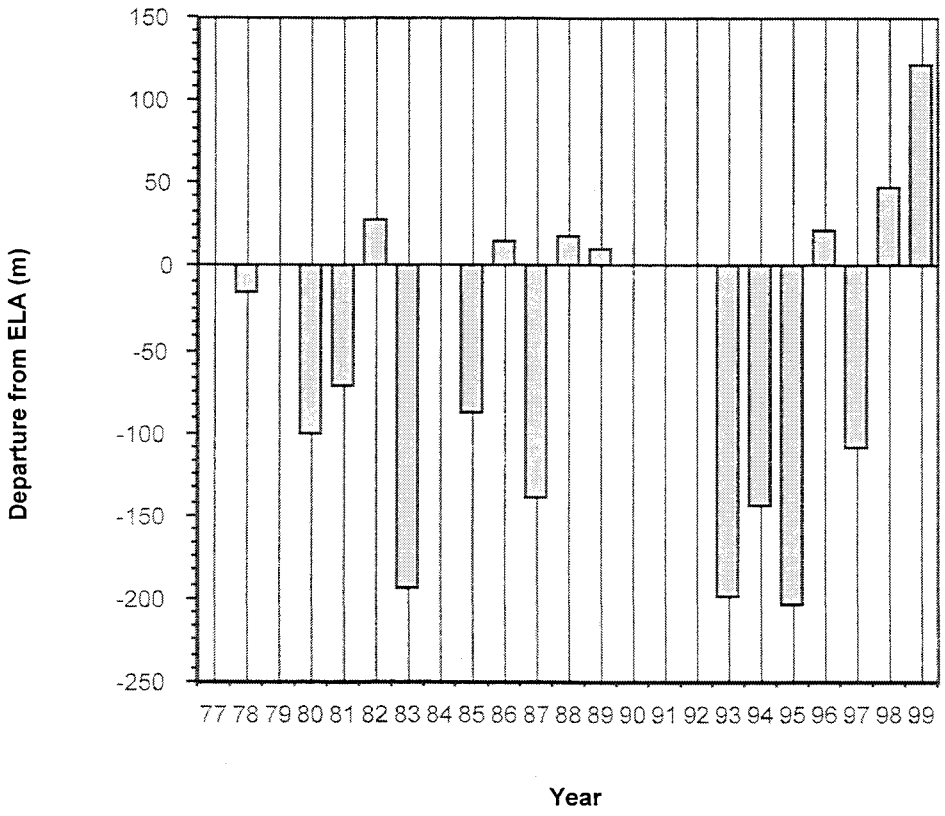
Inventory No. 867/002
A broad mountain glacier on Mt. Nerger, Okuru R. catchment.

Glacier Data	
Glacier area, (ha)	52.53
Equilibrium line altitude (ELA)	1754
Maximum elevation (m)	1880
Minimum elevation (m)	1610
Mean elevation (m)	1745
Elevation range (m)	270
Maximum length (km)	0.57
Gradient	0.535

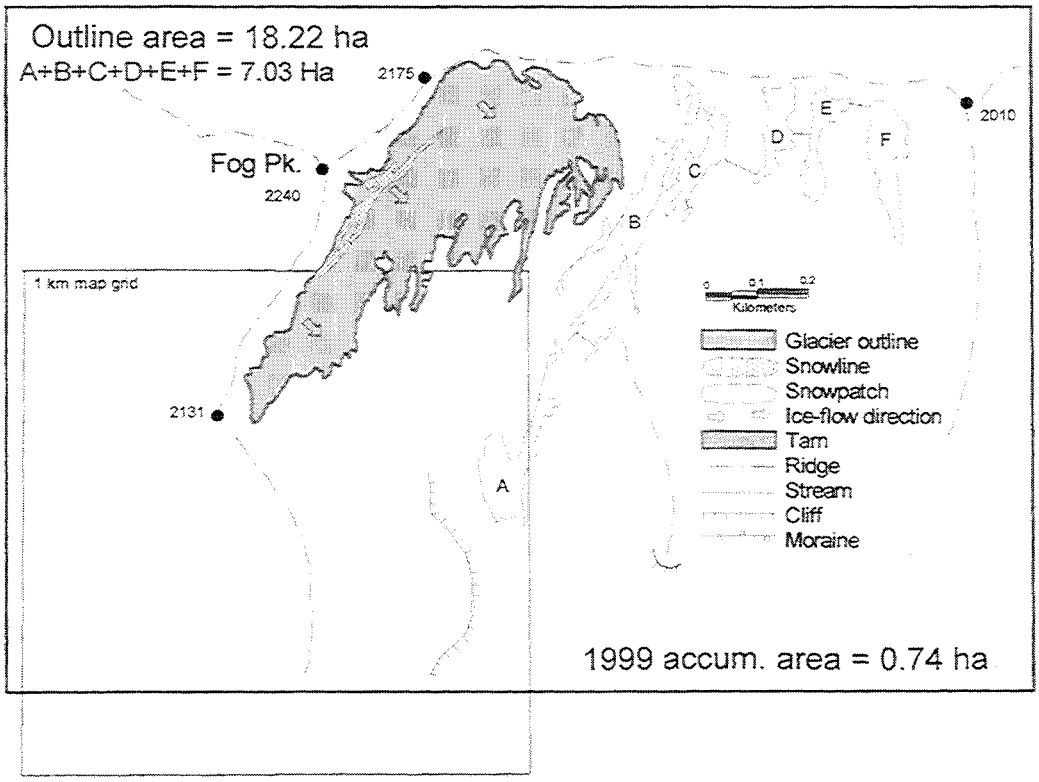
1999 Snowline Data	
1999 accumulation area (ha)	0.94
1999 snowline elevation (m)	1875
Snowline departure from ELA (m)	121
Accumulation area ratio (AAR)	0.02

Left: Digitised map of Lindsay Glacier for 1999 and oblique aerial photograph taken 1998.

Below: Plot of all available annual snowline departures from the ELA for Lindsay Gl.



FOG PEAK


Outline area = 18.22 ha
A+B+C+D+E+F = 7.03 Ha
2175
Fog Pk.
2240
2131
2010
A
B
C
D
E
F
1 km map grid
0 0.1 0.2
Kilometers
Glacier outline
Snowline
Snowpatch
Ice-flow direction
Tarn
Ridge
Stream
Cliff
Moraine
1999 accum. area = 0.74 ha

Fog Peak

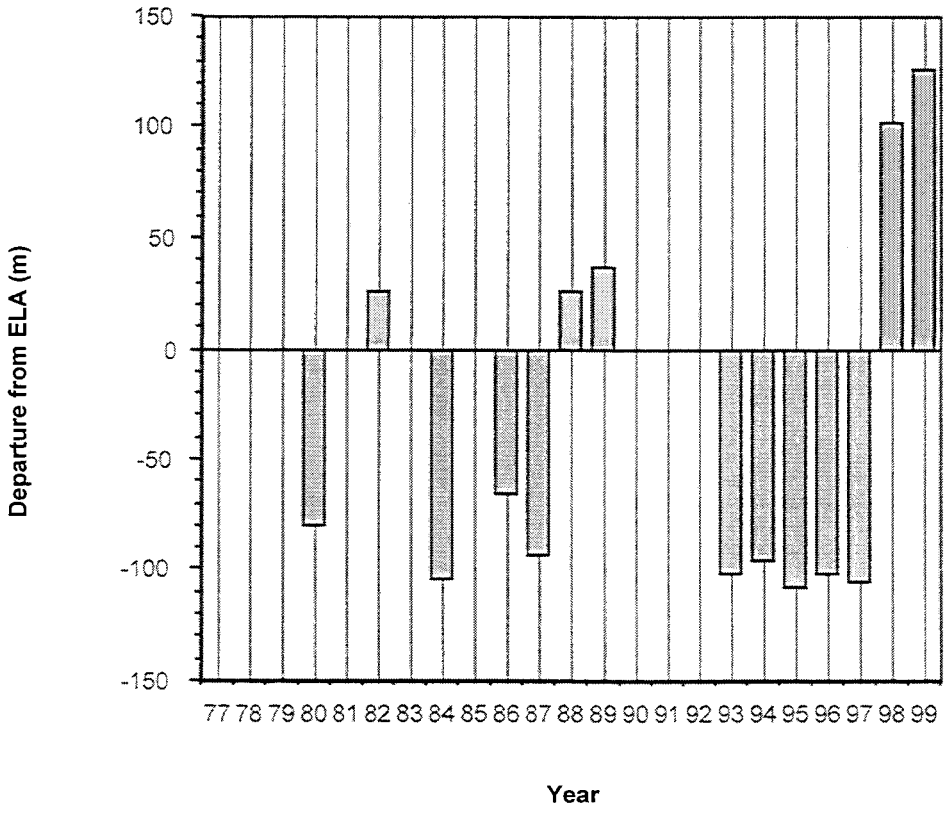
Inventory No. 752E/051
A small cirque mountain glacier on Fog Peak, Shotover R. catchment.

Glacier Data	
Glacier area (ha)	18.22
Equilibrium line altitude (ELA)	1995
Maximum elevation (m)	2150
Minimum elevation (m)	1840
Mean elevation (m)	1995
Elevation range (m)	310
Maximum length (km)	0.4
Gradient	0.625

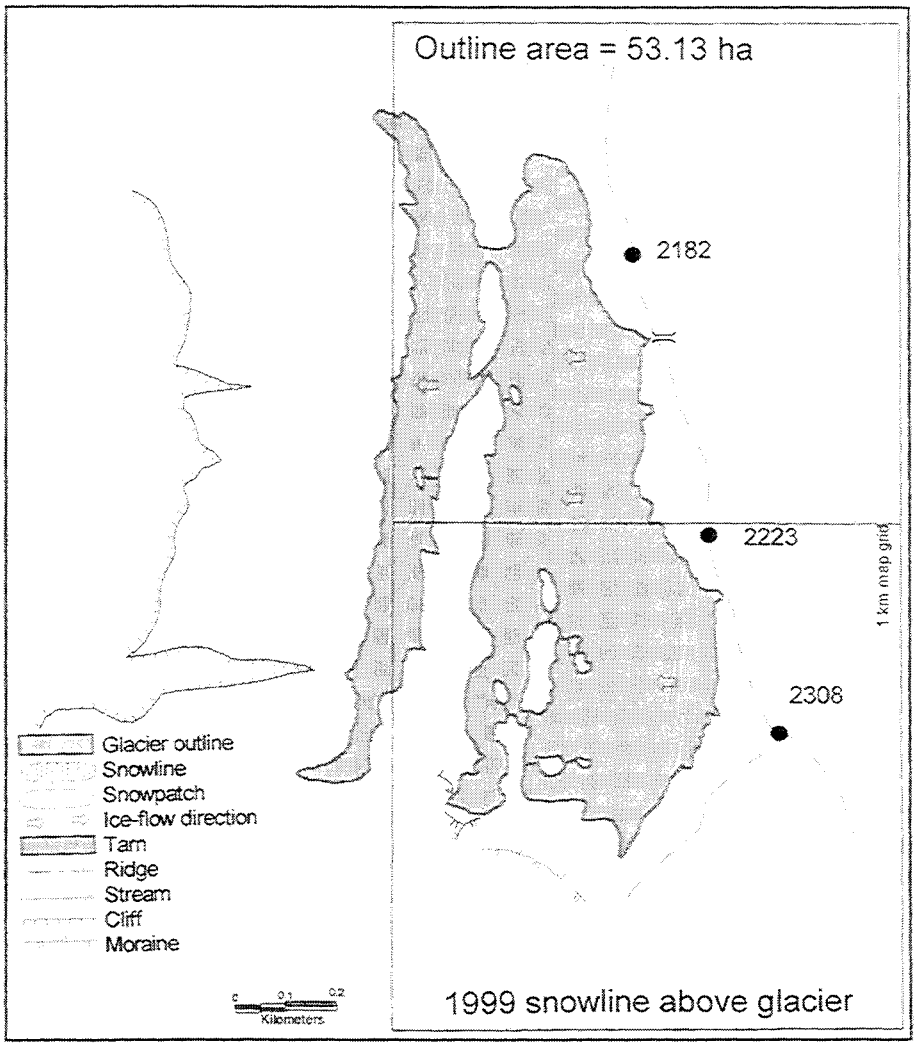
1999 Snowline Data	
1999 accumulation area (ha)	0.74
1999 snowline elevation (m)	2122
Snowline departure from ELA (m)	127
Accumulation area ratio (AAR)	0.03

Left: Digitised map of Fog Pk. and associated snow patches and oblique aerial photograph taken 1998.

Below: Plot of all available annual snowline departures from the ELA for Fog Pk.



SNOWY CREEK


Outline area = 53.13 ha
2182
2223
2308
1 km map grid
Glacier outline
Snowline
Snowpatch
Ice-flow direction
Tarn
Ridge
Stream
Cliff
Moraine
0
0.1
0.2
Kilometers
1999 snowline above glacier


98

Snowy Creek

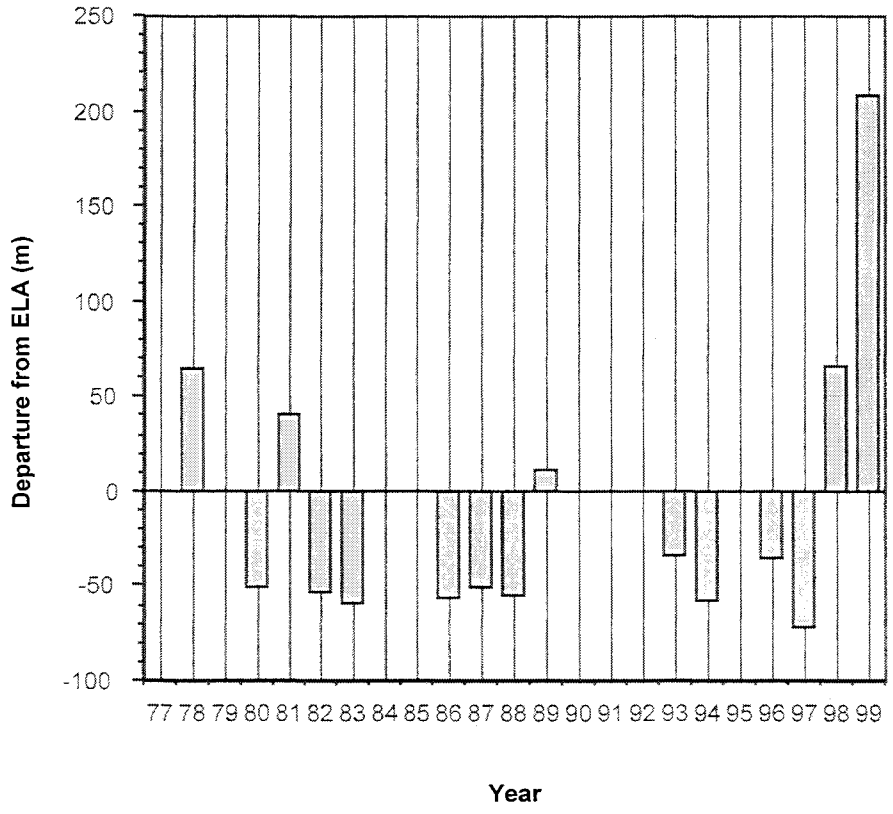
Inventory No. 752C/103
A small, thin mountain glacier at the head of Snowy Ck., Dart R. catchment.

Glacier Data	
Glacier area (ha)	53.13
Equilibrium line altitude (ELA)	2092
Maximum elevation (m)	2210
Minimum elevation (m)	2000
Mean elevation (m)	2105
Elevation range (m)	210
Maximum length (km)	0.73
Gradient	0.259

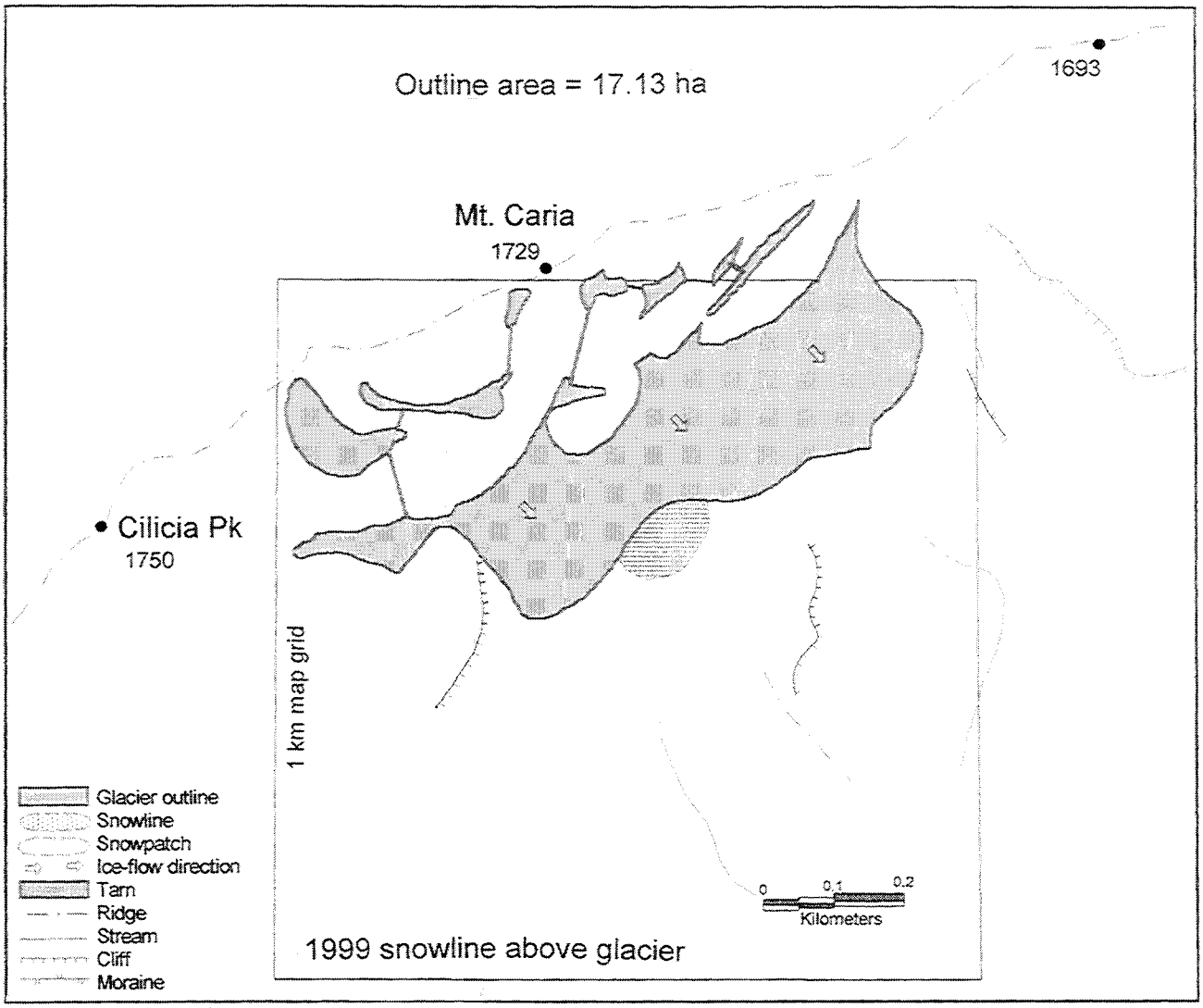
1999 Snowline Data	
1999 accumulation area (ha)	0, snowline at or above peak.
1999 snowline elevation (m)	2300
Snowline departure from ELA (m)	208
Accumulation area ratio (AAR)	0

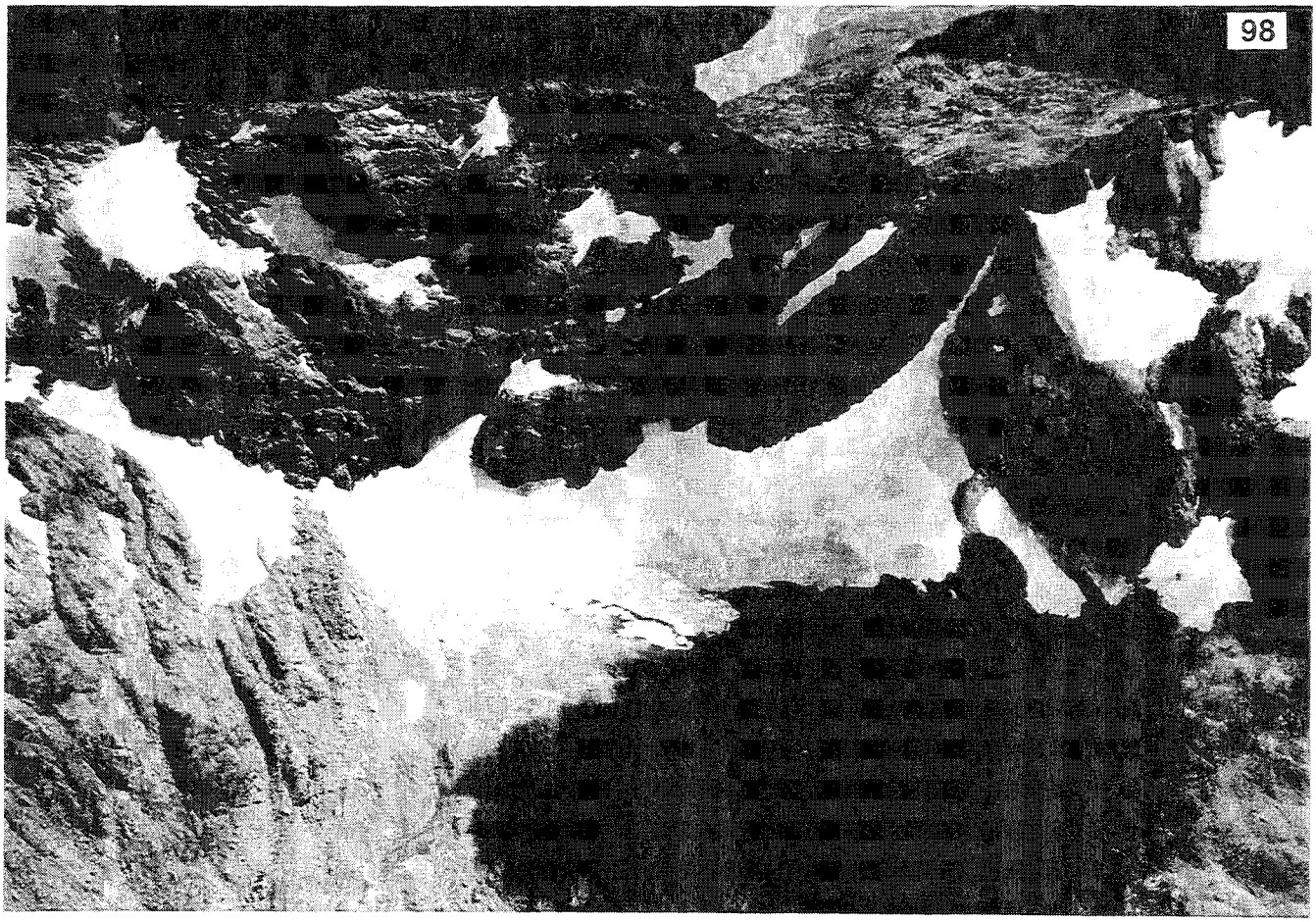
Left: Digitised map of Snowy Ck. and oblique aerial photograph taken 1998.

Below: Plot of all available annual snowline departures from the ELA for Snowy Ck.



MOUNT CARIA


Outline area = 17.13 ha
1693
Mt. Caria
1729
Cilicia Pk
1750
1 km map grid
Glacier outline
Snowline
Snowpatch
Ice-flow direction
Tarn
Ridge
Stream
Cliff
Moraine
0
0.1
0.2
Kilometers
1999 snowline above glacier


98

Mt. Caria

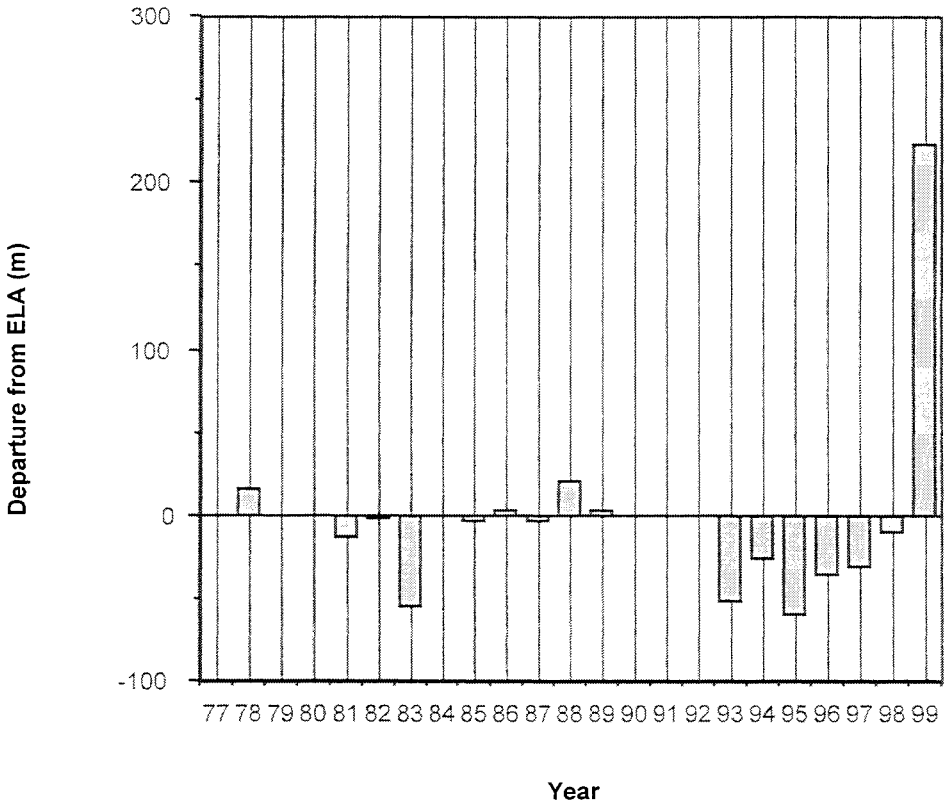
Inventory No. 863B/001
A small western cirque glacier in Arawata R. catchment.

Glacier Data	
Glacier area (ha)	17.13
Equilibrium line altitude (ELA)	1426
Maximum elevation (m)	1600
Minimum elevation (m)	1400
Mean elevation (m)	1500
Elevation range (m)	200
Maximum length (km)	0.3
Gradient	0.367

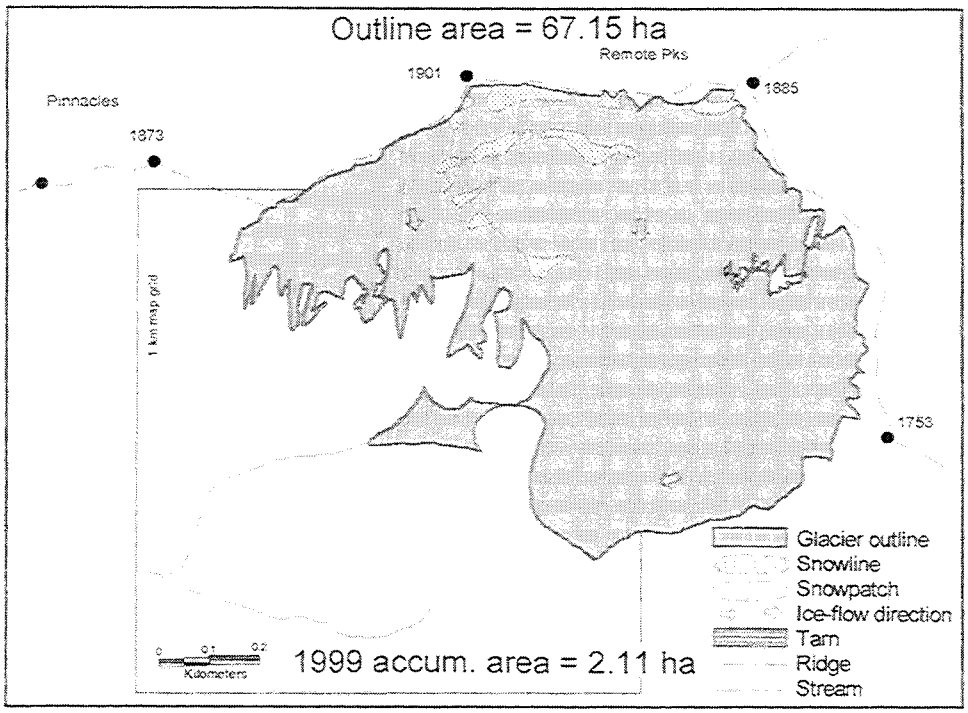
1999 Snowline Data	
1999 accumulation area (ha)	0, snowline at or above peak
1999 snowline elevation (m)	1650
Snowline departure from ELA (m)	224
Accumulation area ratio (AAR)	0

Left: Digitised map of Mt. Caria and oblique aerial photograph taken 1998.

Below: Plot of all available annual snowline departures from the ELA for Mt. Caria.



FINDLAY GLACIER



Findlay Glacier

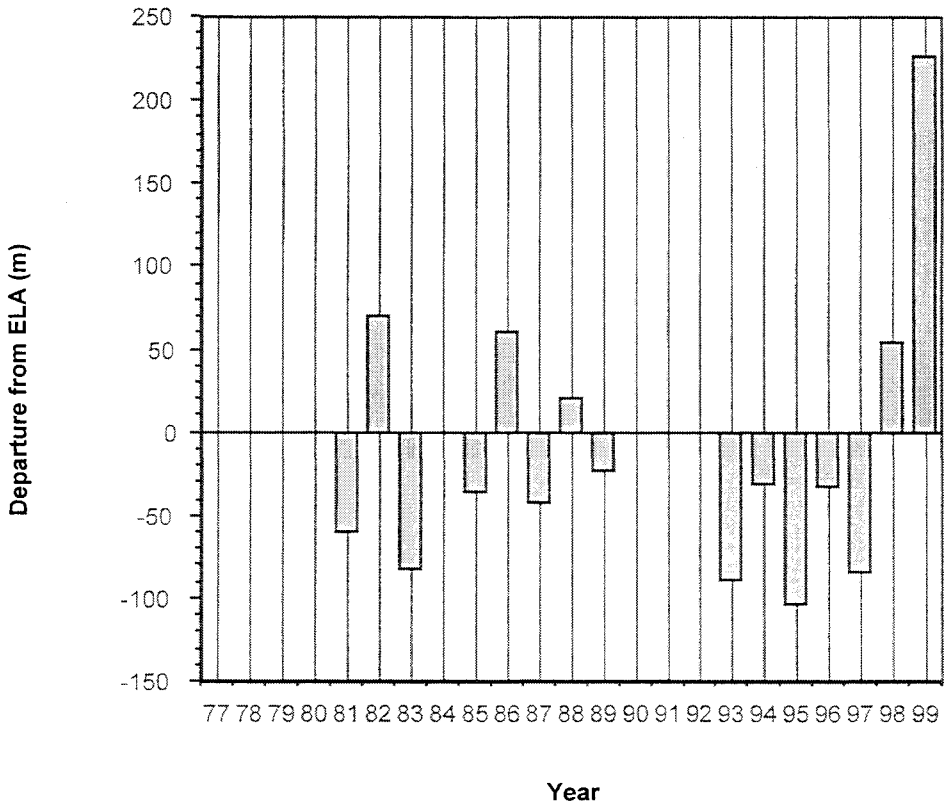
Inventory No. 859/009
A cirque glacier at the western end of Olivine Range, in Cascade R. catchment.

Glacier Data	
Glacier area (ha)	67.15
Equilibrium line altitude (ELA)	1664
Maximum elevation (m)	1550
Minimum elevation (m)	1400
Mean elevation (m)	1725
Elevation range (m)	350
Maximum length (km)	0.875
Gradient	0.4

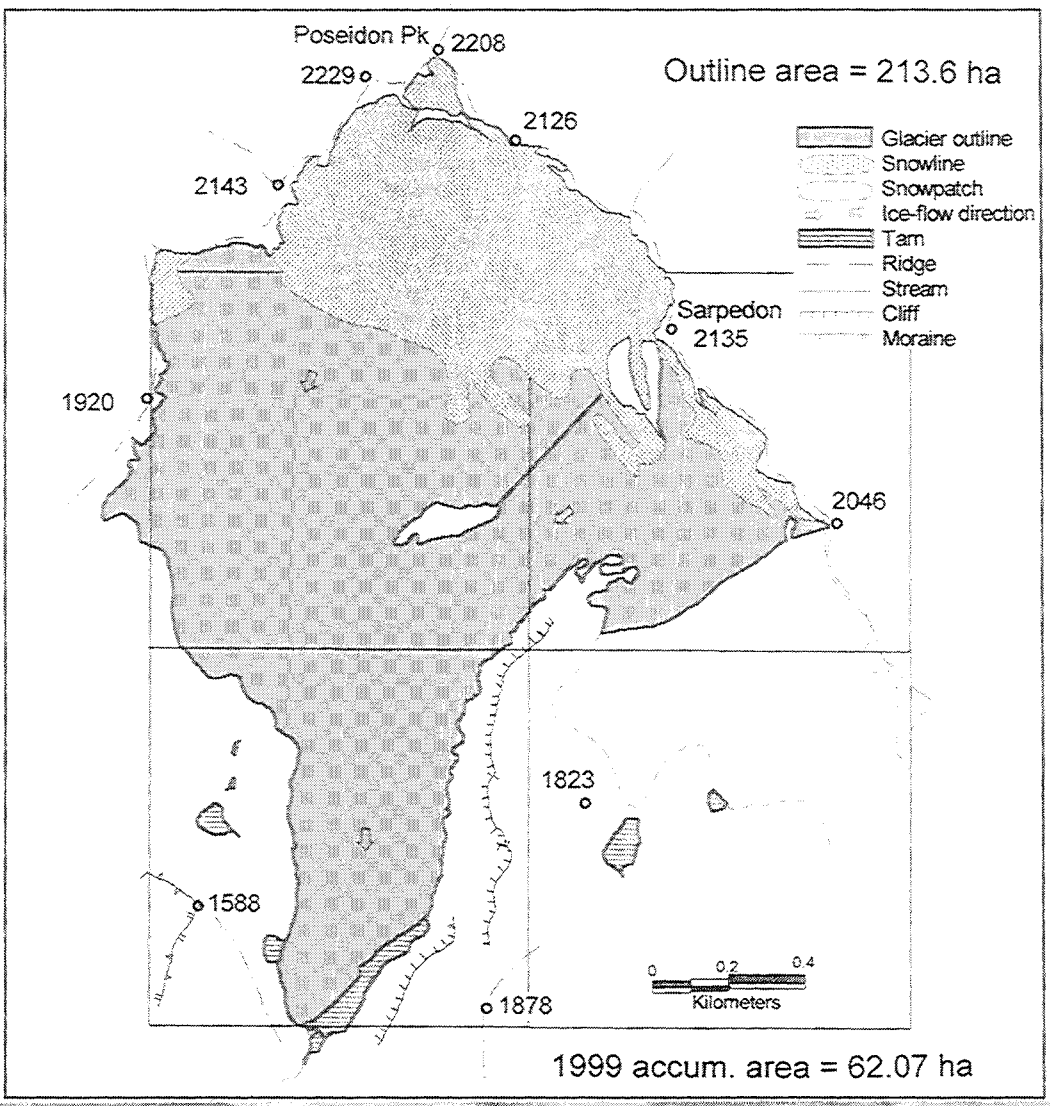
1999 Snowline Data	
1999 accumulation area (ha)	2.11
1999 snowline elevation (m)	1890
Snowline departure from ELA (m)	226
Accumulation area ratio (AAR)	0.03

Left: Digitised map of Findlay Glacier for 1999 and oblique aerial photograph taken 1999.

Below: Plot of all available annual snowline departures from the ELA for Findlay Glacier.



PARK PASS GLACIER



Park Pass Glacier

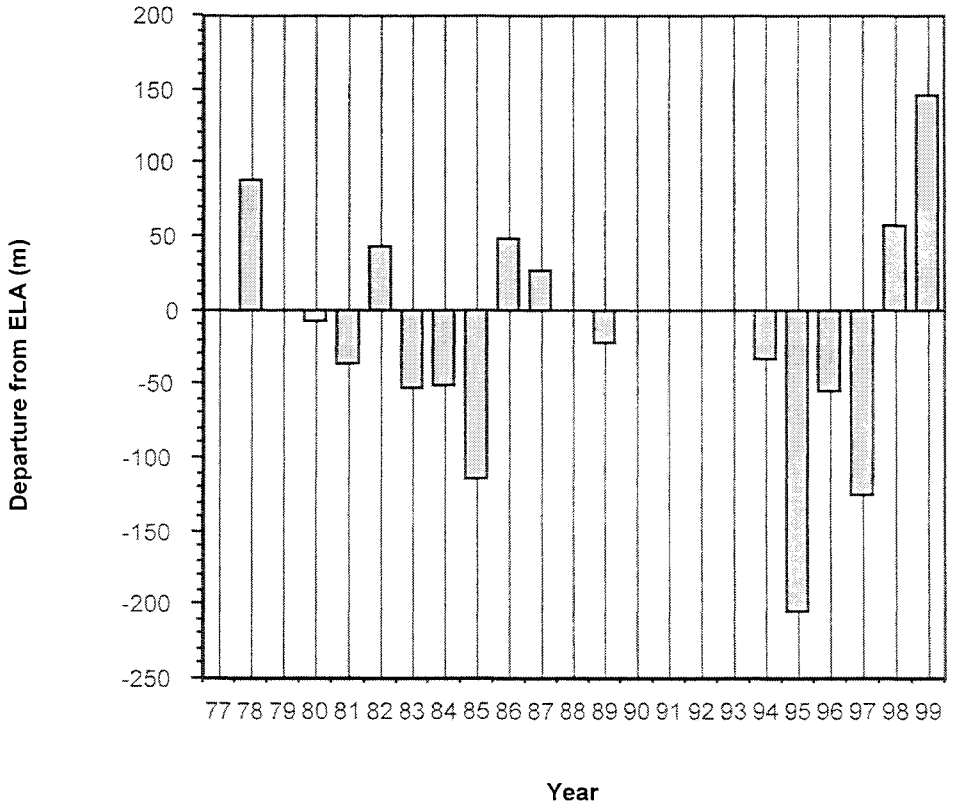
Inventory No. 752B/048
A valley glacier draining into Rockburn R., Clutha R. catchment.

Glacier Data	
Glacier area (ha)	213.6
Equilibrium line altitude (ELA)	1815
Maximum elevation (m)	2200
Minimum elevation (m)	1500
Mean elevation (m)	1850
Elevation range (m)	700
Maximum length (km)	2.63
Gradient	0.267

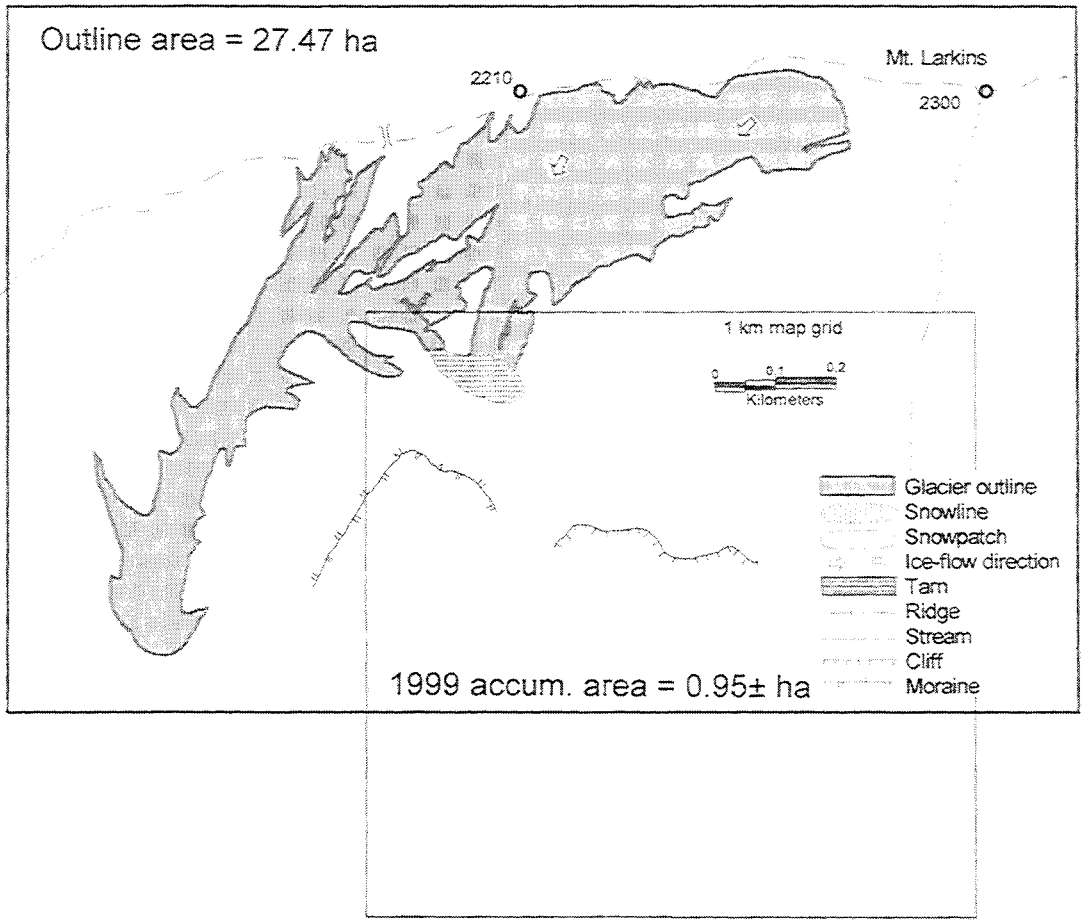
1999 Snowline Data	
1999 accumulation area (ha)	62.07
1999 snowline elevation (m)	1962
Snowline departure from ELA (m)	147
Accumulation area ratio (AAR)	0.29

Left: Digitised map of Park Pass Glacier for 1999 and oblique aerial photograph taken 1998.

Below: Plot of all available annual snowline departures from the ELA for Park Pass Glacier.



MOUNT LARKINS



Mt. Larkins

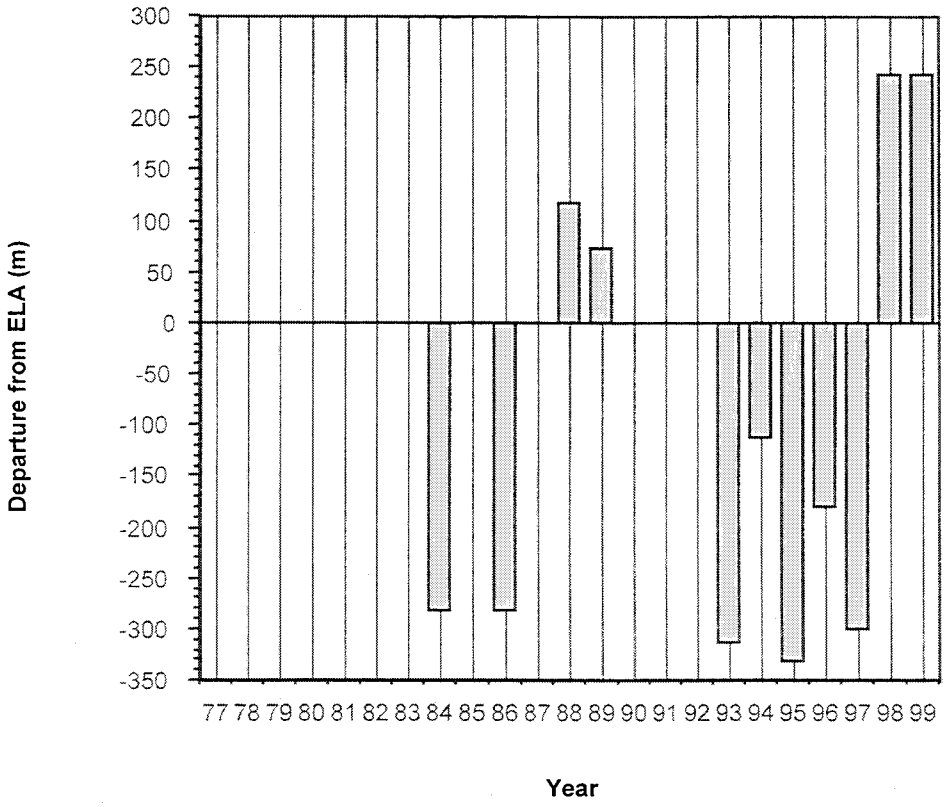
Inventory No. 752E/002
A small mountain glacier on Mt. Larkins, Shotover R. catchment.

Glacier Data	
Glacier area (ha)	27.47
Equilibrium line altitude (ELA)	1962
Maximum elevation (m)	2220
Minimum elevation (m)	1700
Mean elevation (m)	1960
Elevation range (m)	520
Maximum length (km)	0.5
Gradient	0.46

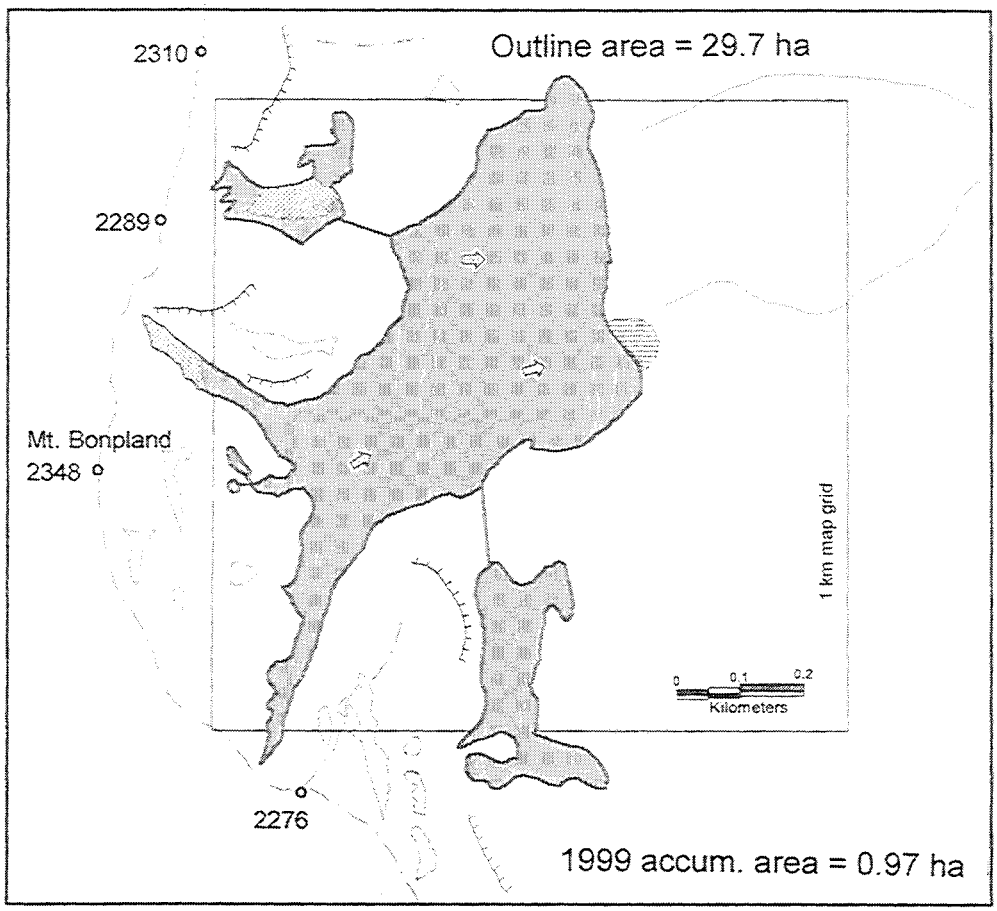
1999 Snowline Data	
1999 accumulation area (ha)	0.95
1999 snowline elevation (m)	2205
Snowline departure from ELA (m)	243
Accumulation area ratio (AAR)	0.03

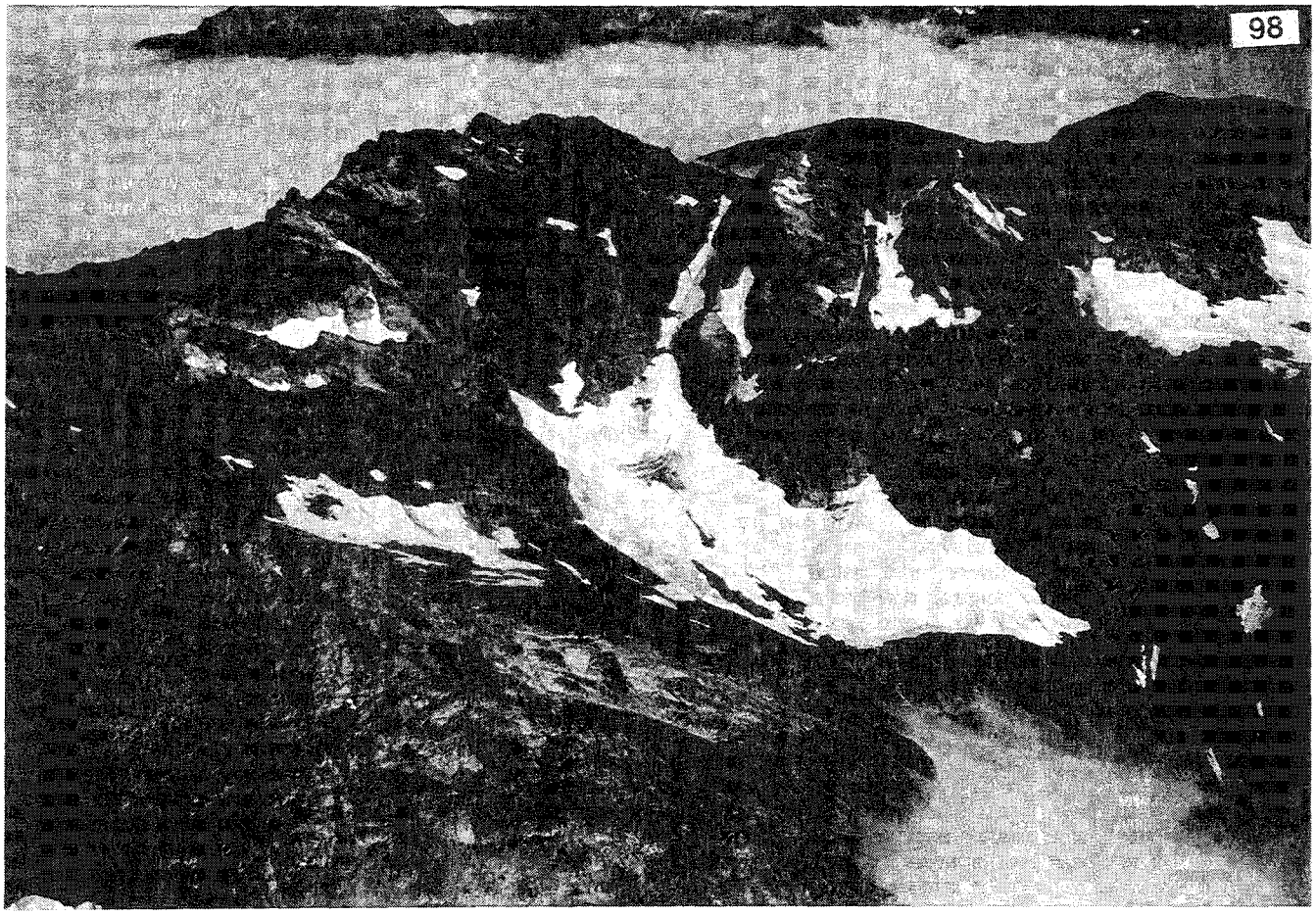
Left: Digitised map of Mt. Larkins for 1999 and oblique aerial photograph taken 1996.

Below: Plot of all available annual snowline departures from the ELA for Mt. Larkins.



BRYANT GLACIER





Bryant Glacier

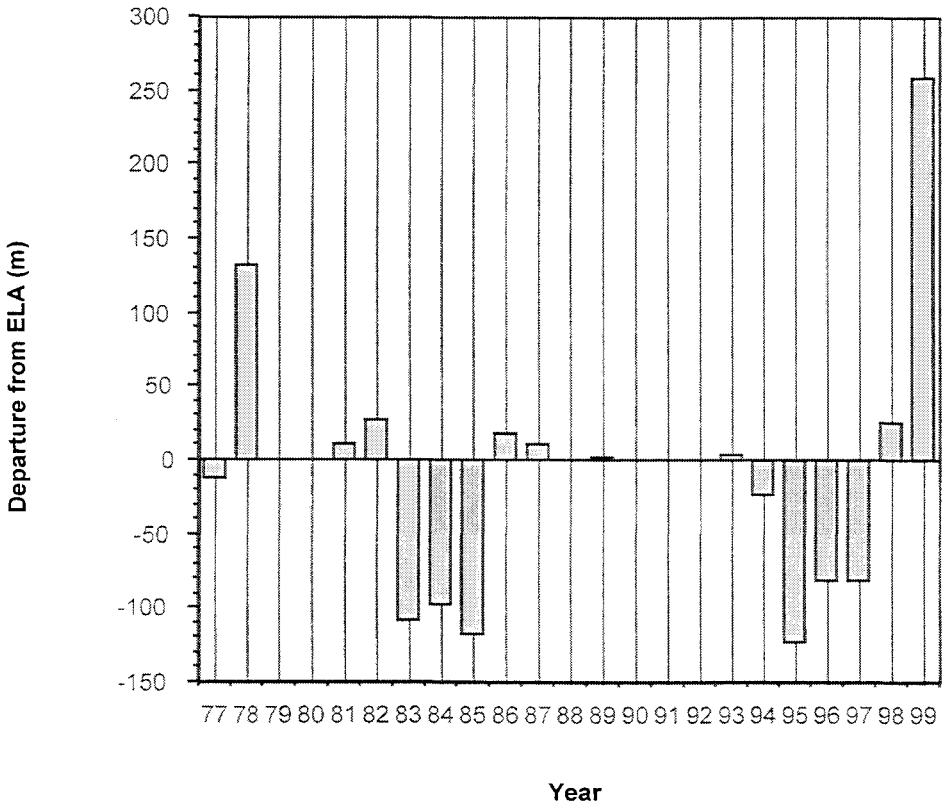
Inventory No. 752B/025
A cirque glacier on Mt. Bonpland, W side of L. Wakatipu, Clutha R. catchment.

Glacier Data	
Glacier area (ha)	29.7
Equilibrium line altitude (ELA)	1752
Maximum elevation (m)	2180
Minimum elevation (m)	1660
Mean elevation (m)	1920
Elevation range (m)	520
Maximum length (km)	0.94
Gradient	0.62

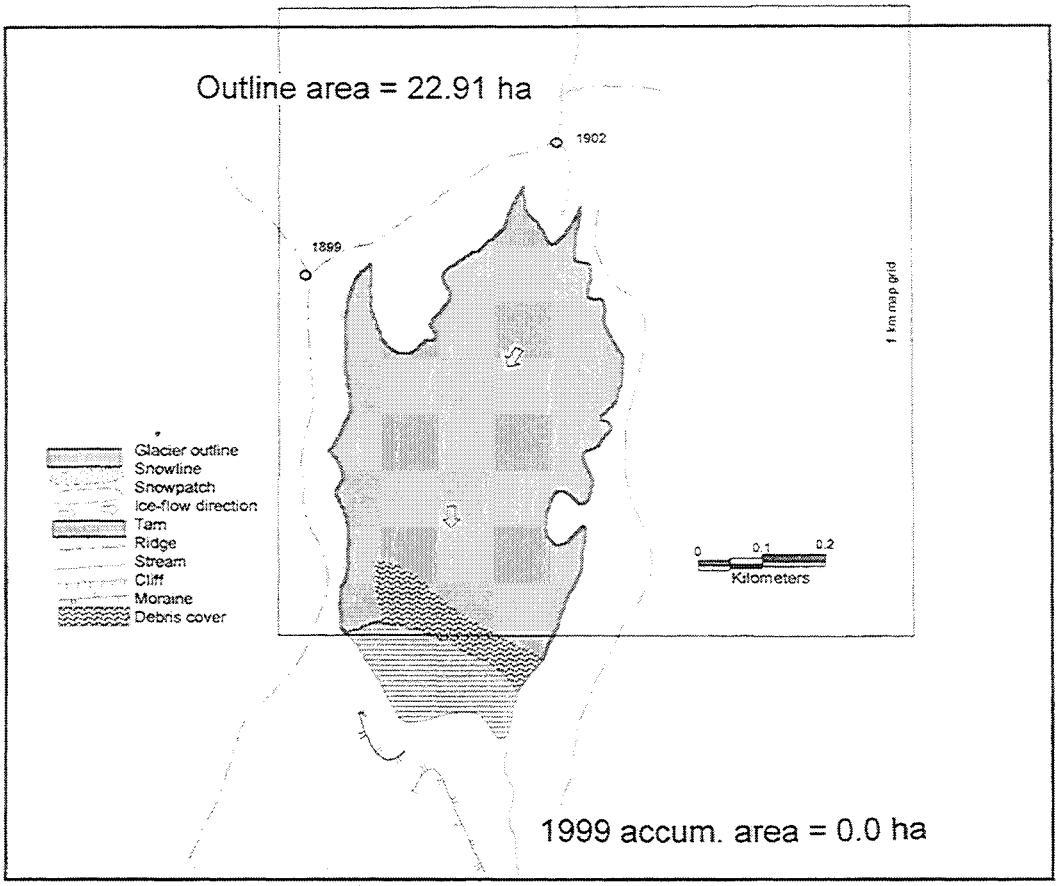
1999 Snowline Data	
1999 accumulation area (ha)	0.97
1999 snowline elevation (m)	2010
Snowline departure from ELA (m)	258
Accumulation area ratio (AAR)	0.03

Left: Digitised map of Bryant Glacier for 1999 and oblique aerial photograph taken 1998.

Below: Plot of all available annual snowline departures from the ELA for Bryant Glacier.



AILSA RANGE


Outline area = 22.91 ha
1902
1899
1 km map grid
Glacier outline
Snowline
Snowpatch
Ice-flow direction
Tarn
Ridge
Stream
Cliff
Moraine
Debris cover
0
0.1
0.2
Kilometers
1999 accum. area = 0.0 ha


89

Ailsa Range

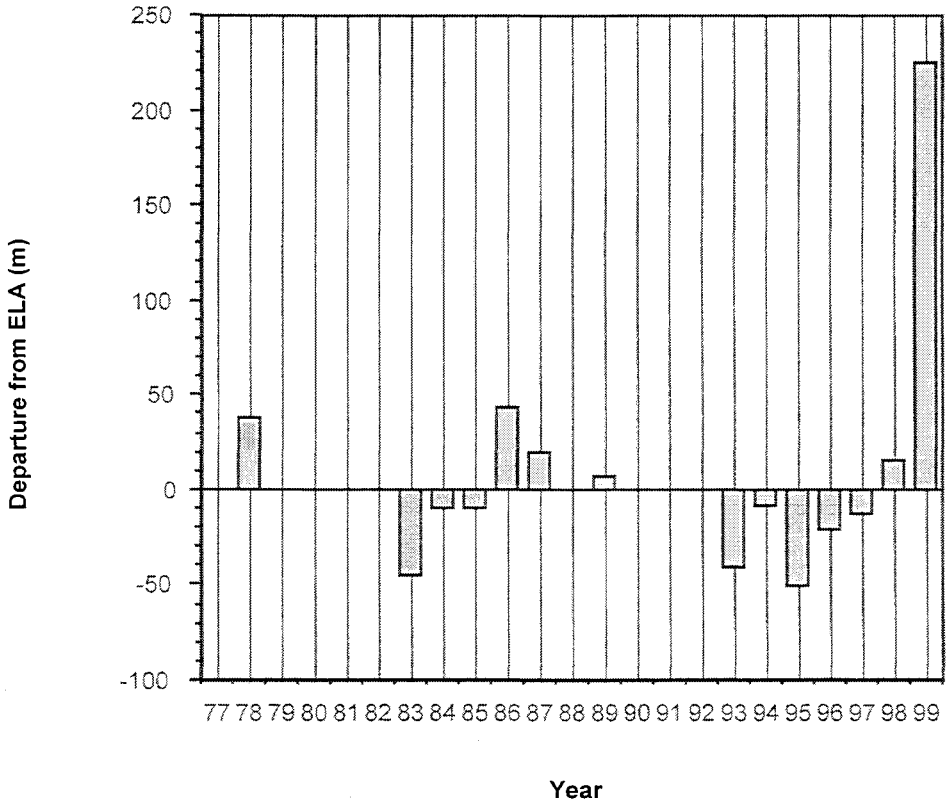
Inventory No. 752B/013
A cirque glacier with lake, on Ailsa Range, Clutha R. catchment.

Glacier Data	
Glacier area (ha)	22.91
Equilibrium line altitude (ELA)	1605
Maximum elevation (m)	1830
Minimum elevation (m)	1530
Mean elevation (m)	1680
Elevation range (m)	300
Maximum length (km)	0.75
Gradient	0.36

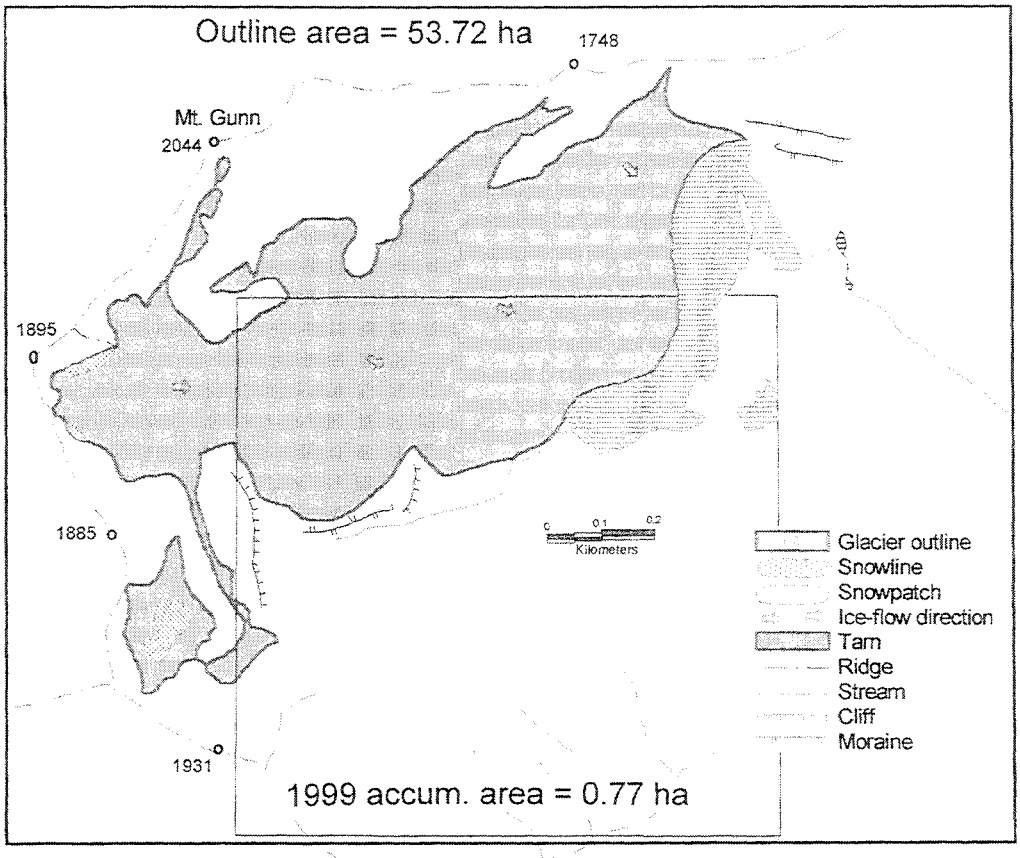
1999 Snowline Data	
1999 accumulation area (ha)	0
1999 snowline elevation (m)	1830
Snowline departure from ELA (m)	225
Accumulation area ratio (AAR)	0

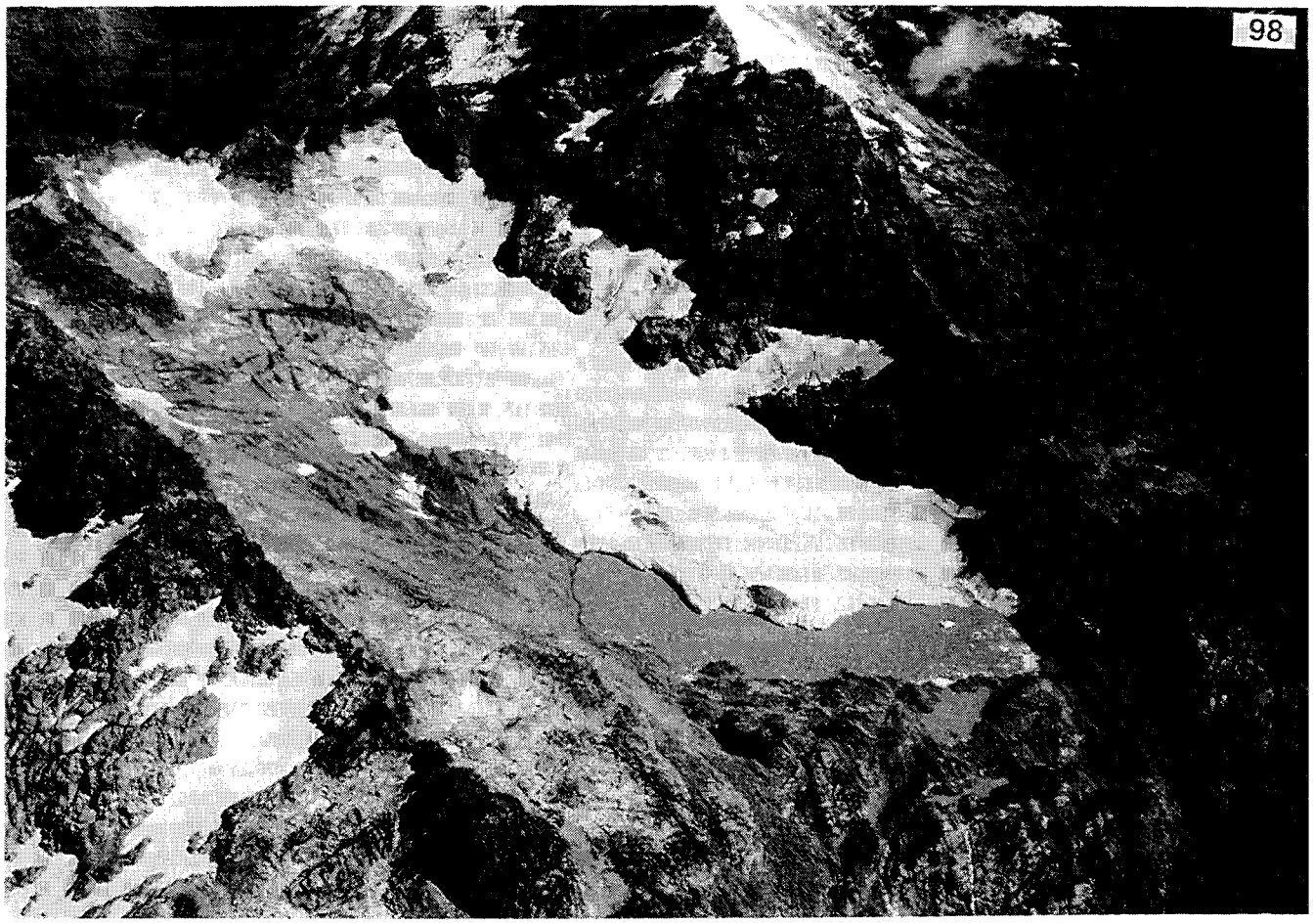
Left: Digitised map of Ailsa Range for 1999 and oblique aerial photograph taken 1989.

Below: Plot of all available annual snowline departures from the ELA for Ailsa Ra.



MOUNT GUNN


Outline area = 53.72 ha
1748
Mt. Gunn
2044
1895
1885
1931
0
0.1
0.2
Kilometers
Glacier outline
Snowline
Snowpatch
Ice-flow direction
Tarn
Ridge
Stream
Cliff
Moraine
1999 accum. area = 0.77 ha


98

Mt. Gunn

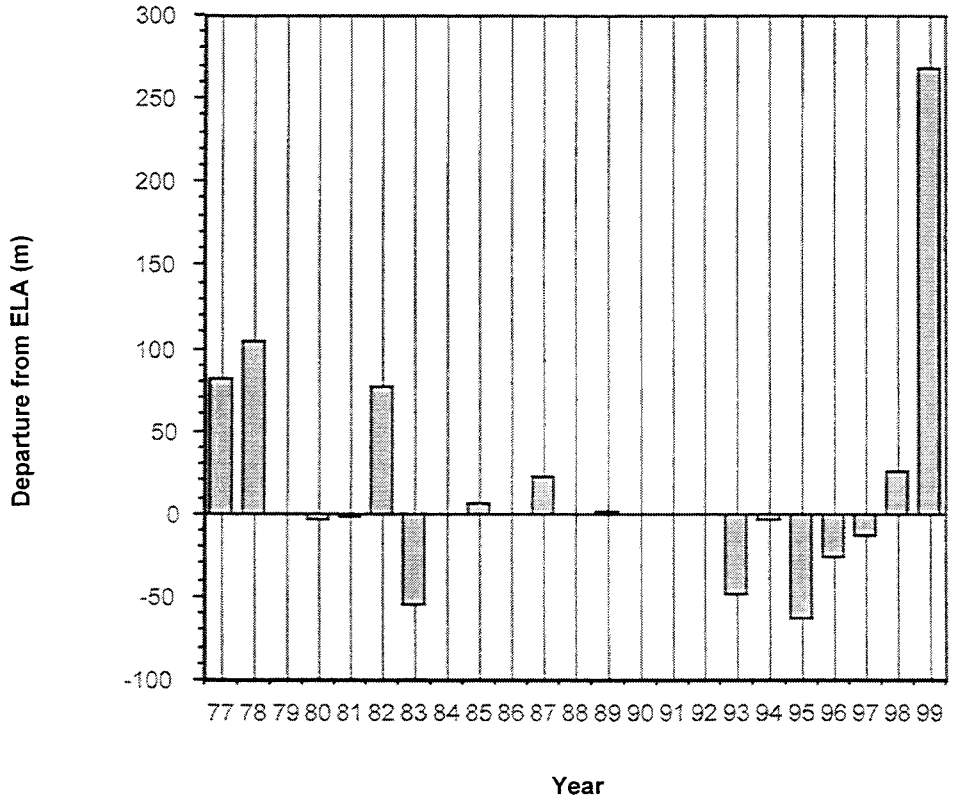
Inventory No. 851B/057
A cirque glacier with developing lake on Mt Gunn, Hollyford R. catchment.

Glacier Data	
Glacier area (ha)	53.72
Equilibrium line altitude (ELA)	1533
Maximum elevation (m)	1820
Minimum elevation (m)	1470
Mean elevation (m)	1645
Elevation range (m)	350
Maximum length (km)	0.75
Gradient	0.44

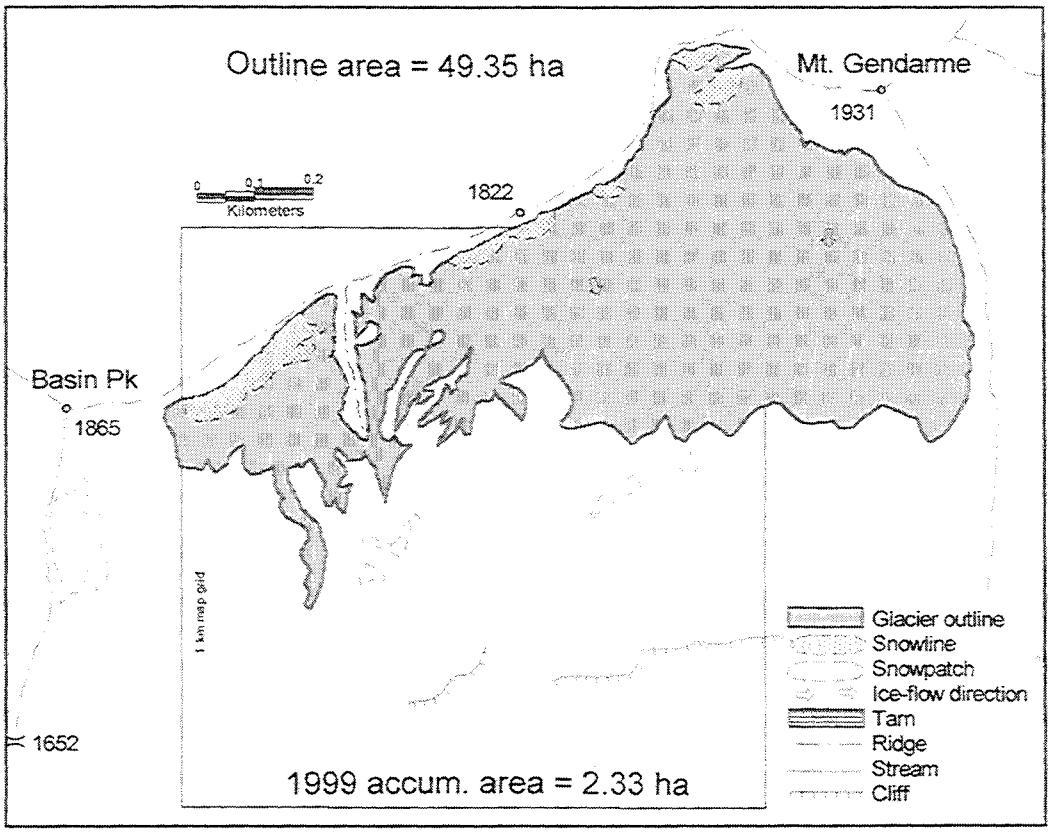
1999 Snowline Data	
1999 accumulation area (ha)	0.77
1999 snowline elevation (m)	1802
Snowline departure from ELA (m)	269
Accumulation area ratio (AAR)	0.01

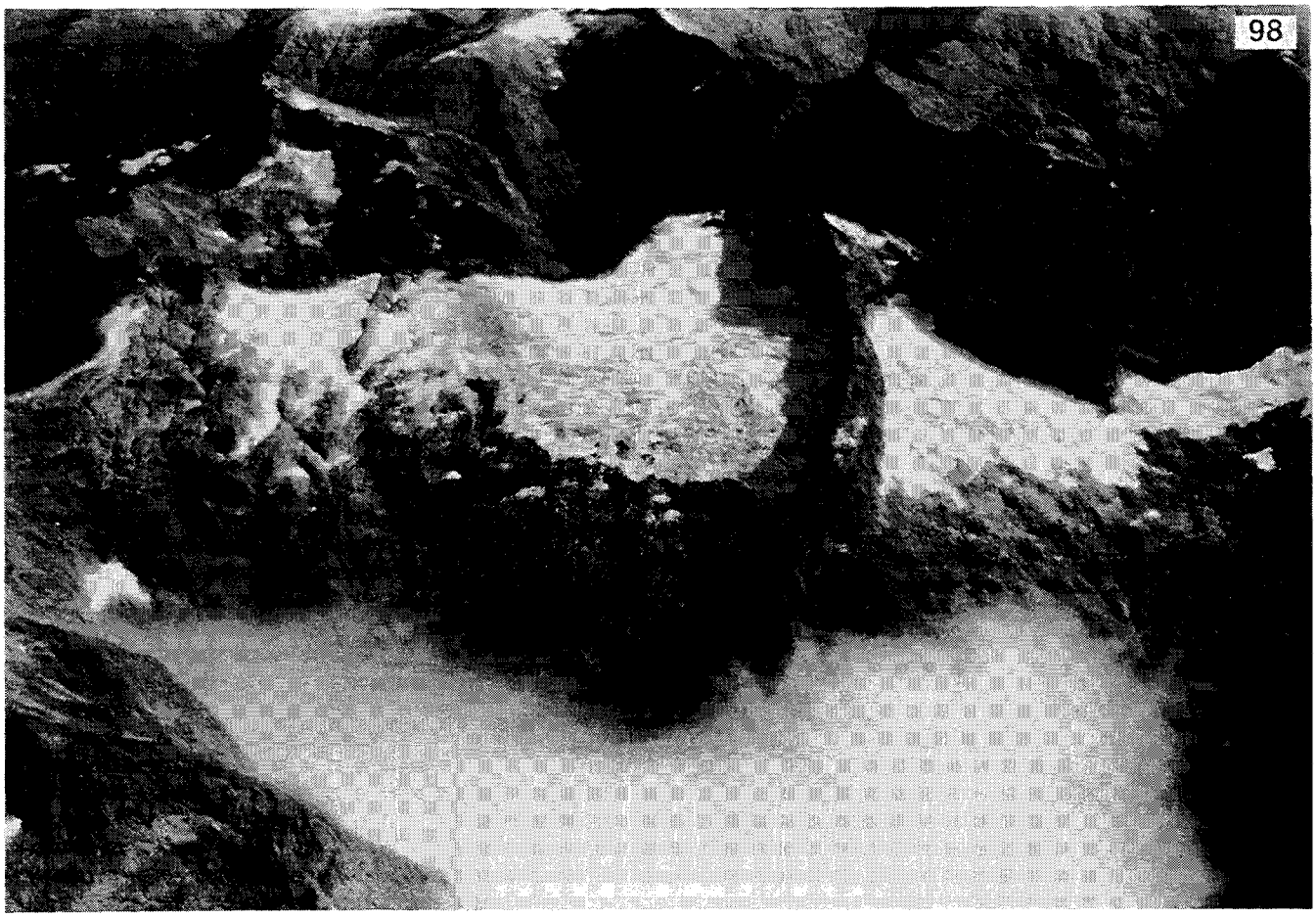
Left: Digitised map of Mt. Gunn for 1999 and oblique aerial photograph taken 1998.

Below: Plot of all available annual snowline departures from the ELA for Mt. Gunn.



MOUNT GENDARME





Mt. Gendarme

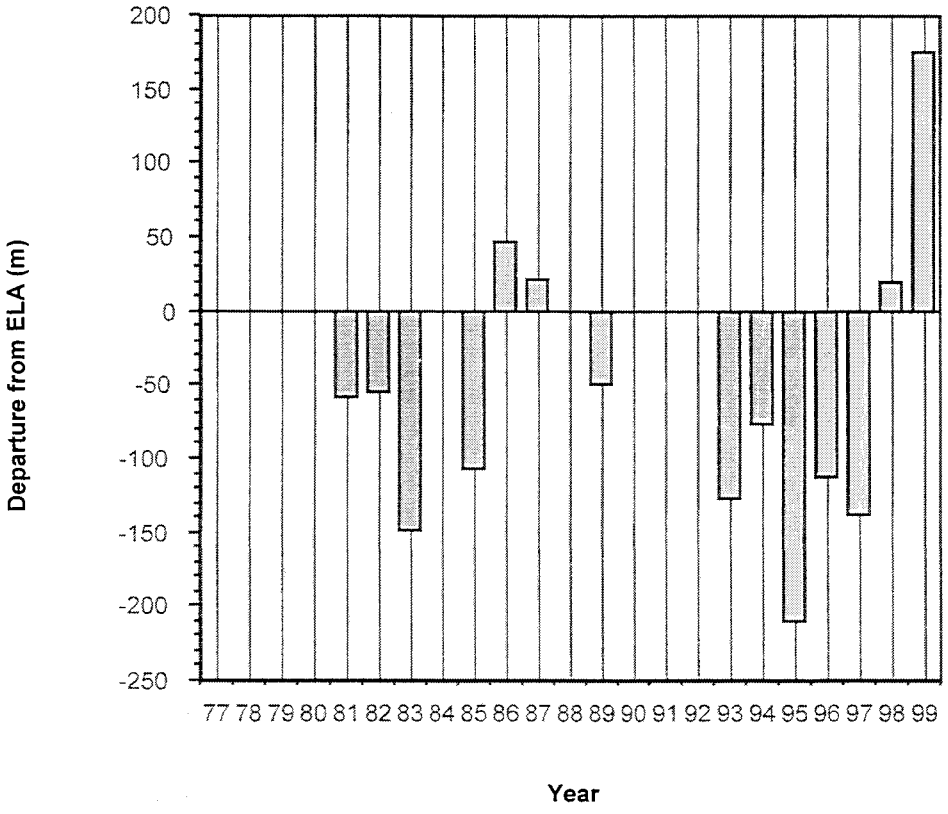
Inventory No. 797G/033
A steep cirque glacier on Mt Gendarme, Clinton R. catchment.

Glacier Data	
Glacier area (ha)	49.35
Equilibrium line altitude (ELA)	1628
Maximum elevation (m)	1900
Minimum elevation (m)	1440
Mean elevation (m)	1670
Elevation range (m)	460
Maximum length (km)	0.525
Gradient	0.876

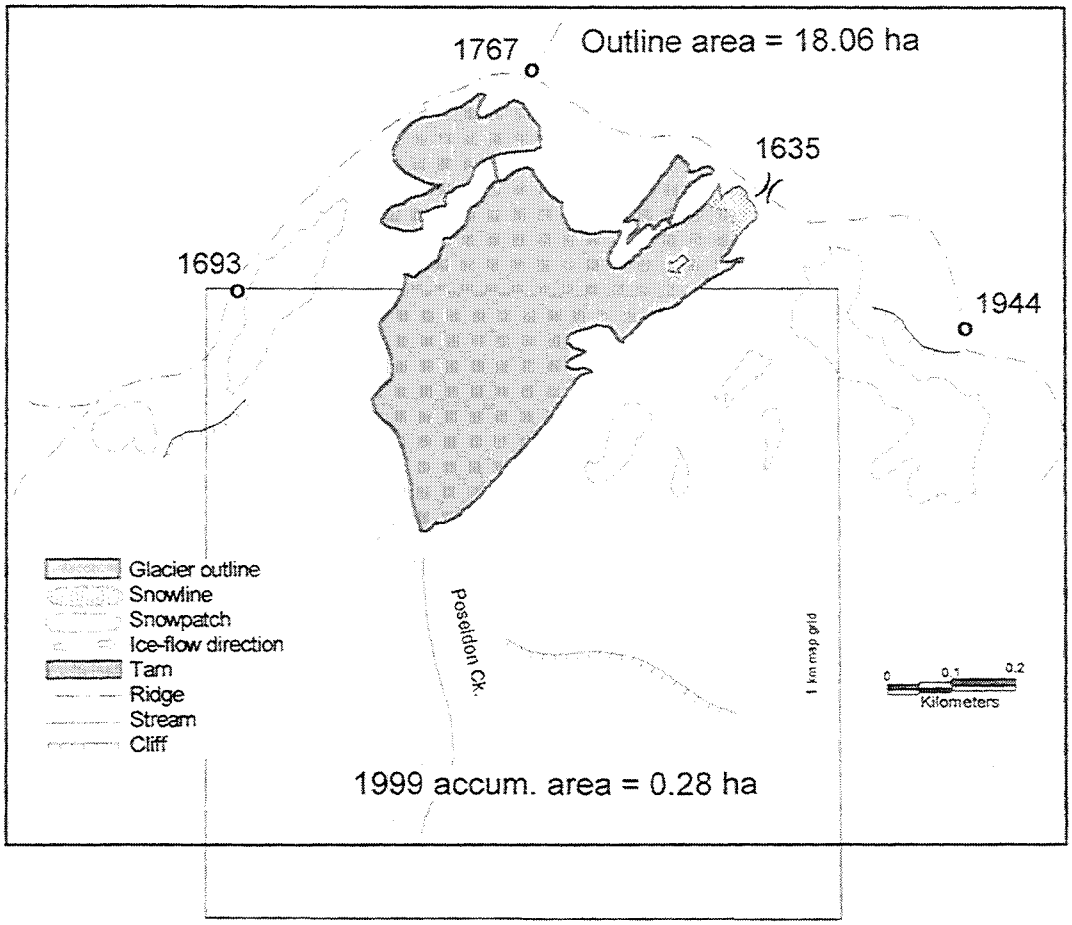
1999 Snowline Data	
1999 accumulation area (ha)	2.33
1999 snowline elevation (m)	1804
Snowline departure from ELA (m)	176
Accumulation area ratio (AAR)	0.05

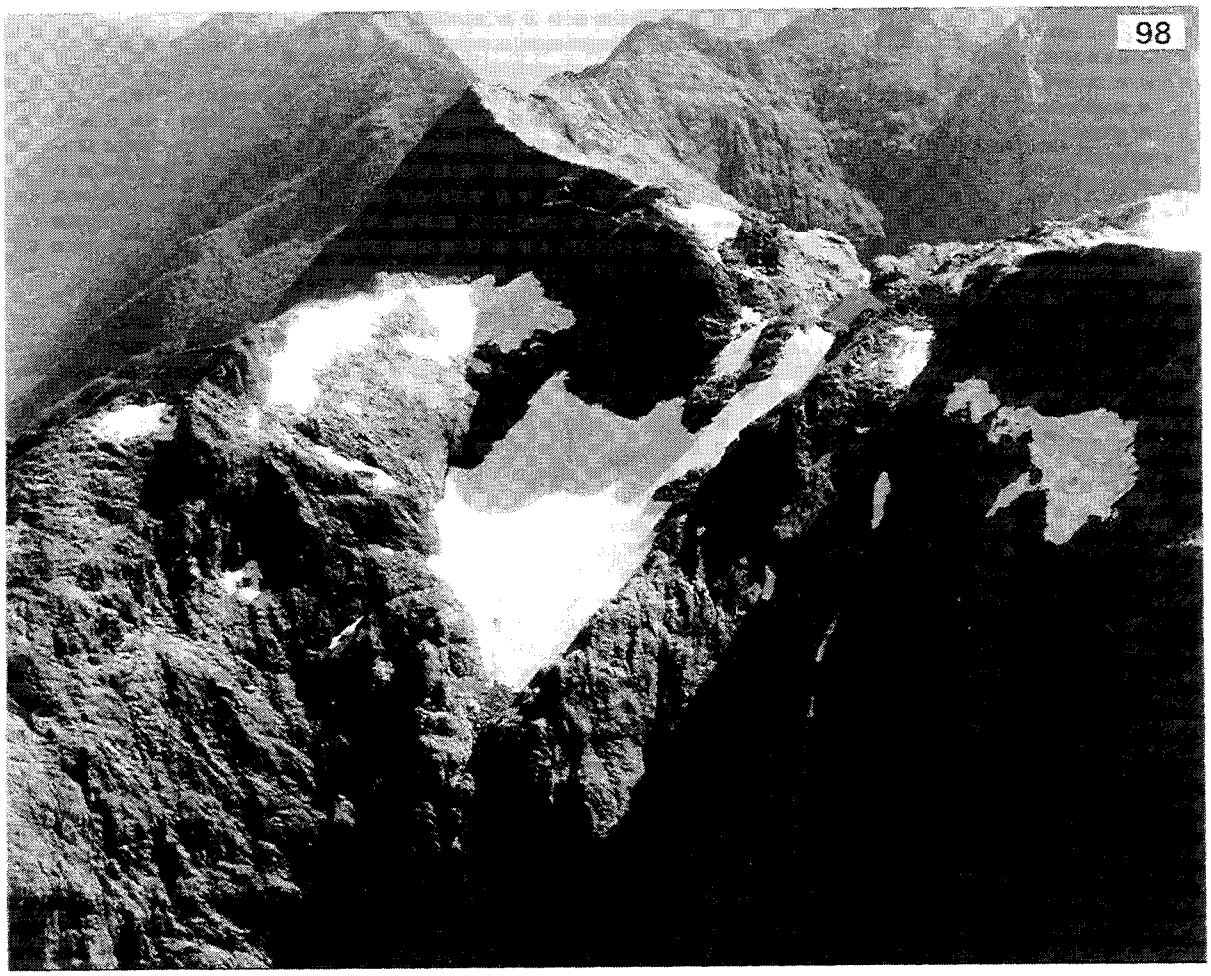
Left: Digitised map of Mt. Gendarme for 1999 and oblique aerial photograph taken 1998.

Below: Plot of all available annual snowline departures from the ELA for Mt. Gendarme.



LLAWRENNY PEAKS





Llawrenny Peaks

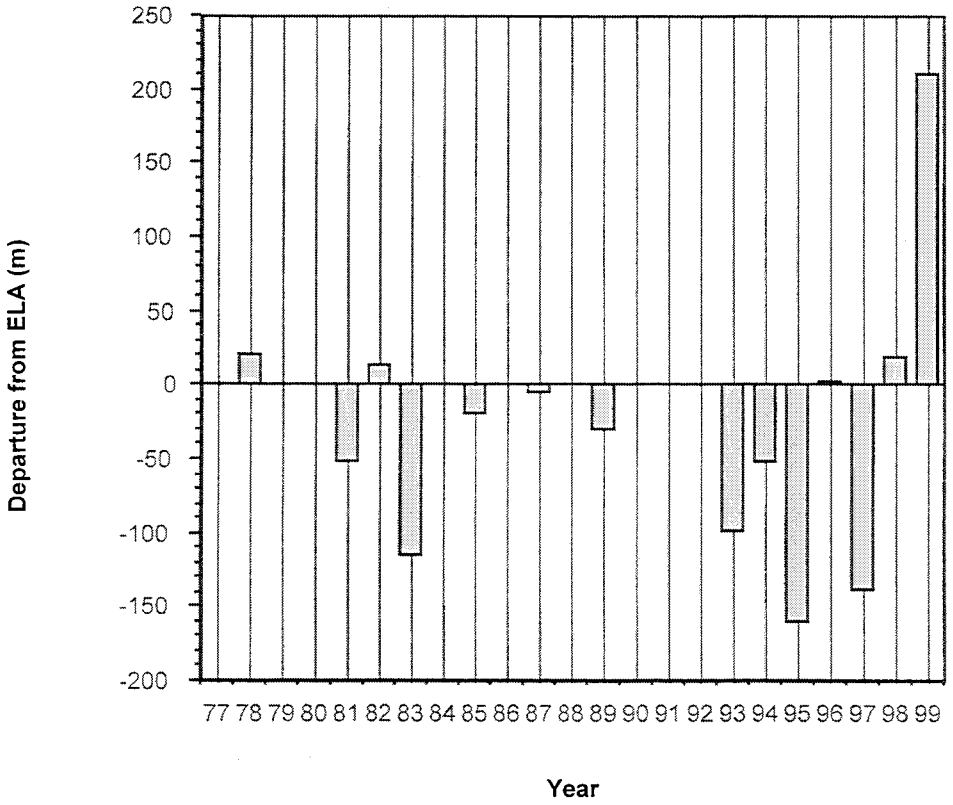
Inventory No. 846/035
A small cirque glacier on Llawrenny Peaks massif, Arthur R. catchment.

Glacier Data	
Glacier area (ha)	18.06
Equilibrium line altitude (ELA)	1460
Maximum elevation (m)	1680
Minimum elevation (m)	1310
Mean elevation (m)	1495
Elevation range (m)	370
Maximum length (km)	0.75
Gradient	0.426

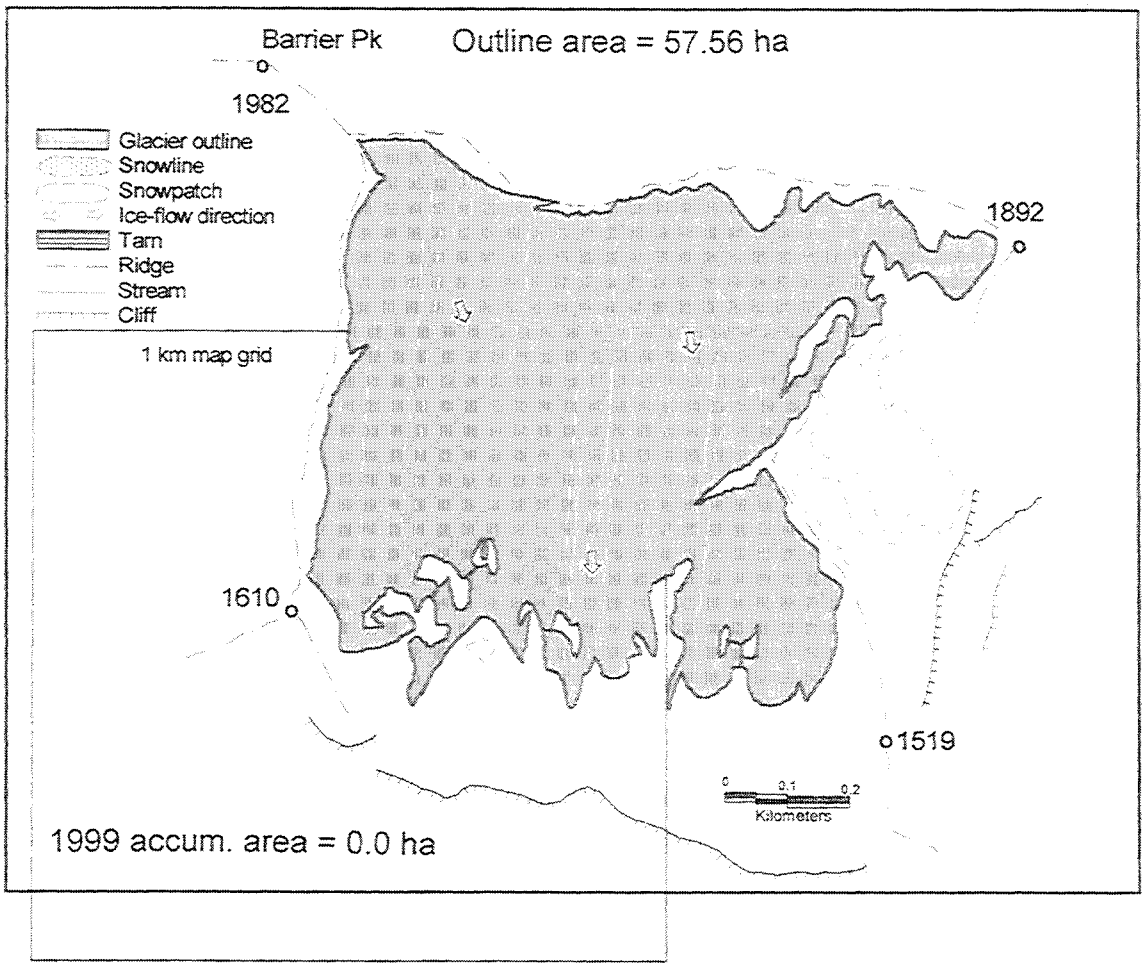
1999 Snowline Data	
1999 accumulation area (ha)	0.28
1999 snowline elevation (m)	1670
Snowline departure from ELA (m)	210
Accumulation area ratio (AAR)	0.02

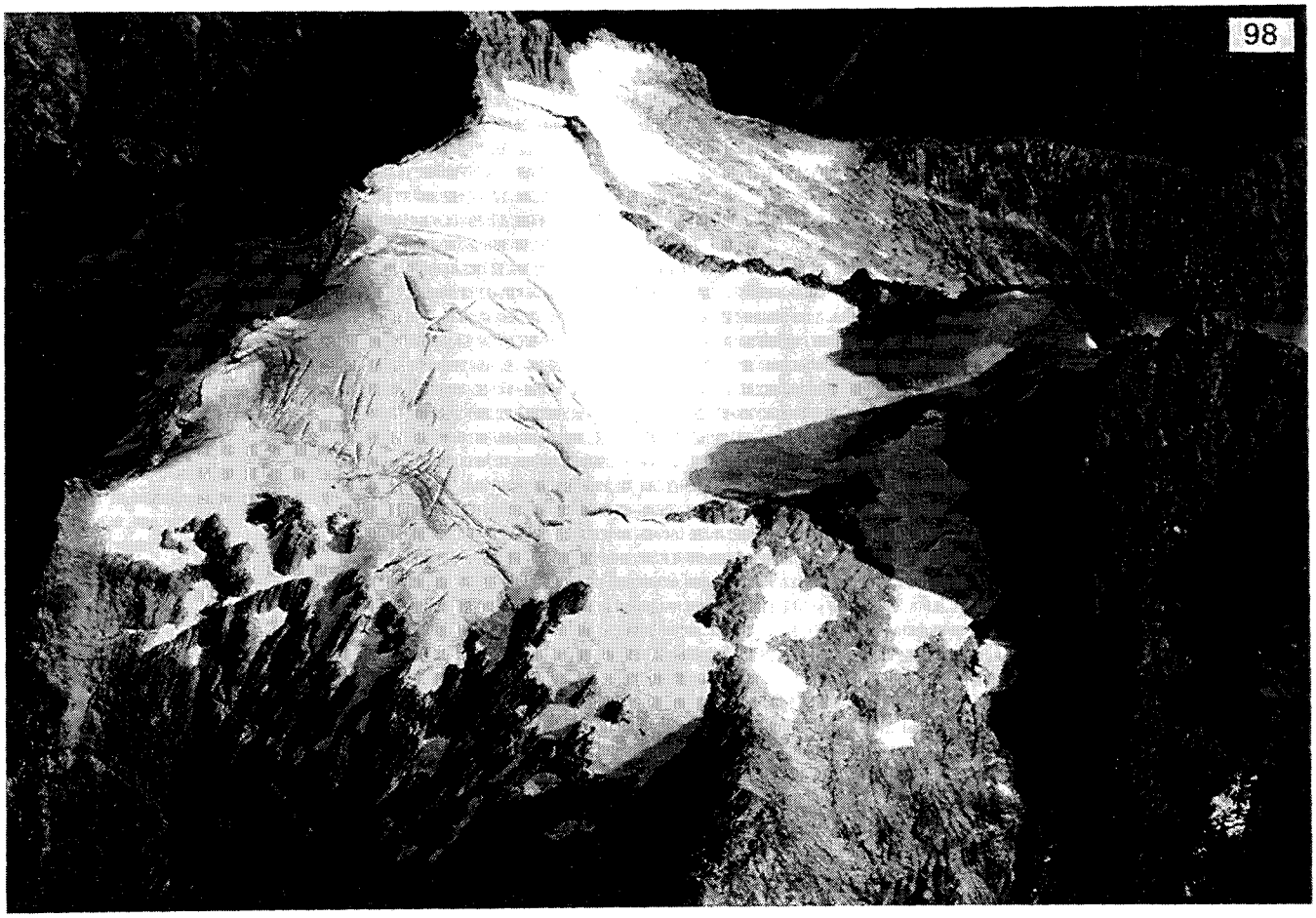
Left: Digitised map of Llawrenny Peaks for 1999 and oblique aerial photograph taken 1998.

Below: Plot of all available annual snowline departures from the ELA for Llawrenny Peaks.



BARRIER PEAK





Barrier Peak

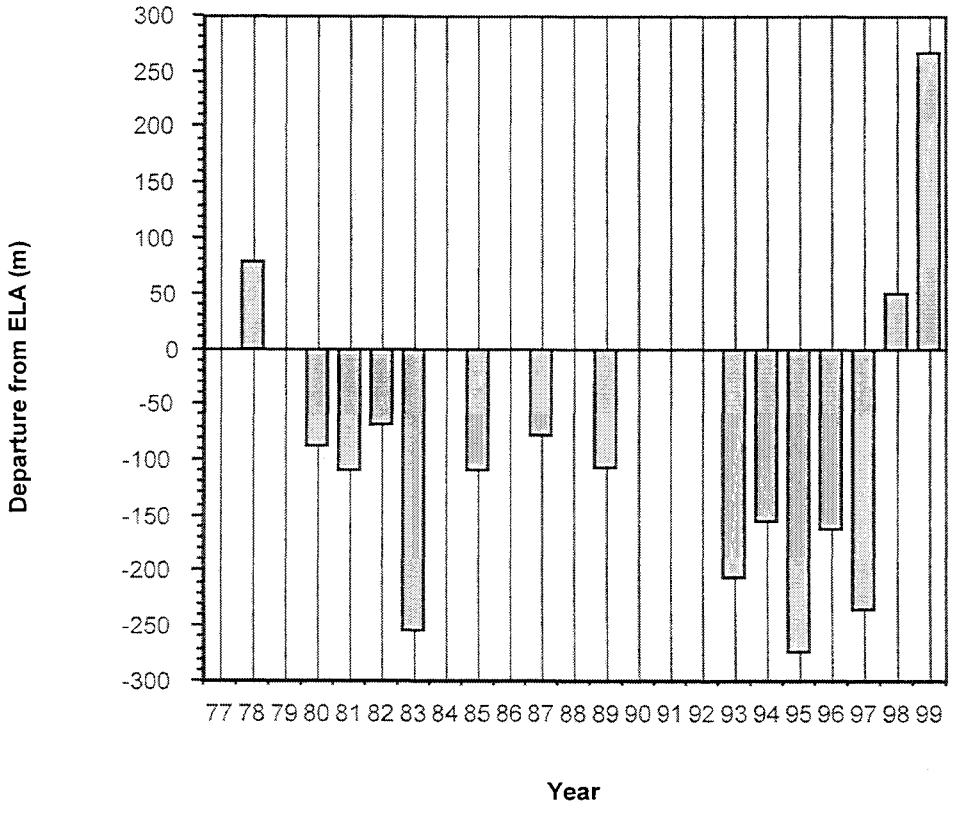
Inventory No. 797F/004
A cirque glacier on Barrier Peak, Clinton R. catchment.

Glacier Data	
Glacier area (ha)	57.56
Equilibrium line altitude (ELA)	1632
Maximum elevation (m)	1900
Minimum elevation (m)	1420
Mean elevation (m)	1660
Elevation range (m)	480
Maximum length (km)	0.55
Gradient	0.872

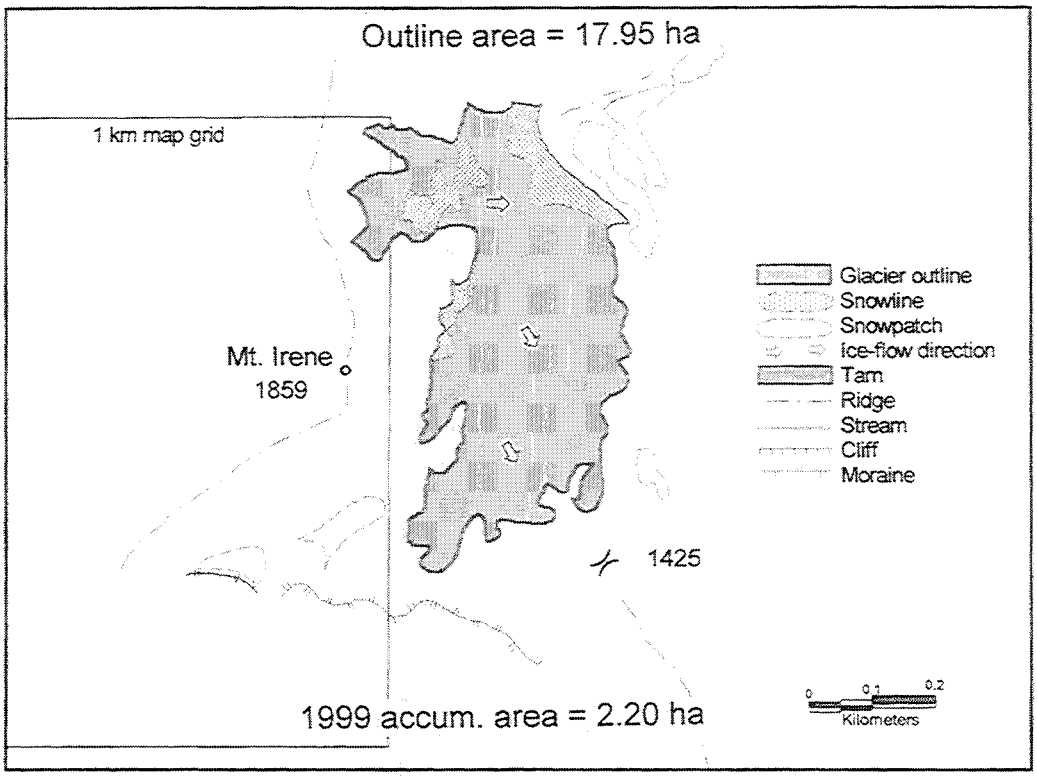
1999 Snowline Data	
1999 accumulation area (ha)	0, snowline at glacier top
1999 snowline elevation (m)	1900
Snowline departure from ELA (m)	268
Accumulation area ratio (AAR)	0

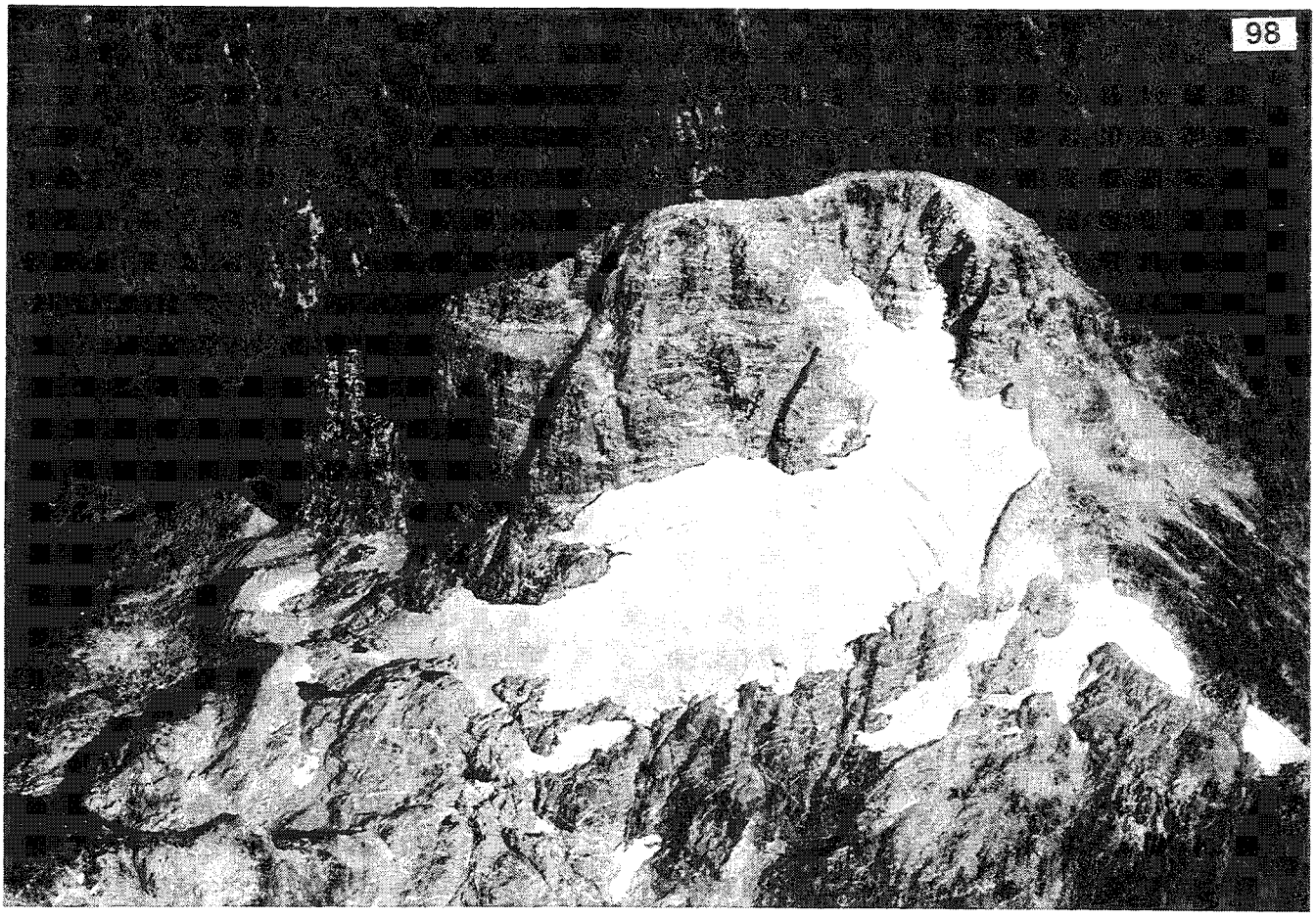
Left: Digitised map of Barrier Peak for 1999 and oblique aerial photograph taken 1998.

Below: Plot of all available annual snowline departures from the ELA for Barrier Peak.



MOUNT IRENE


Outline area = 17.95 ha
1 km map grid
Mt. Irene
1859
1425
Glacier outline
Snowline
Snowpatch
ice-flow direction
Tarn
Ridge
Stream
Cliff
Moraine
0
0.1
0.2
Kilometers
1999 accum. area = 2.20 ha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Mt. Irene

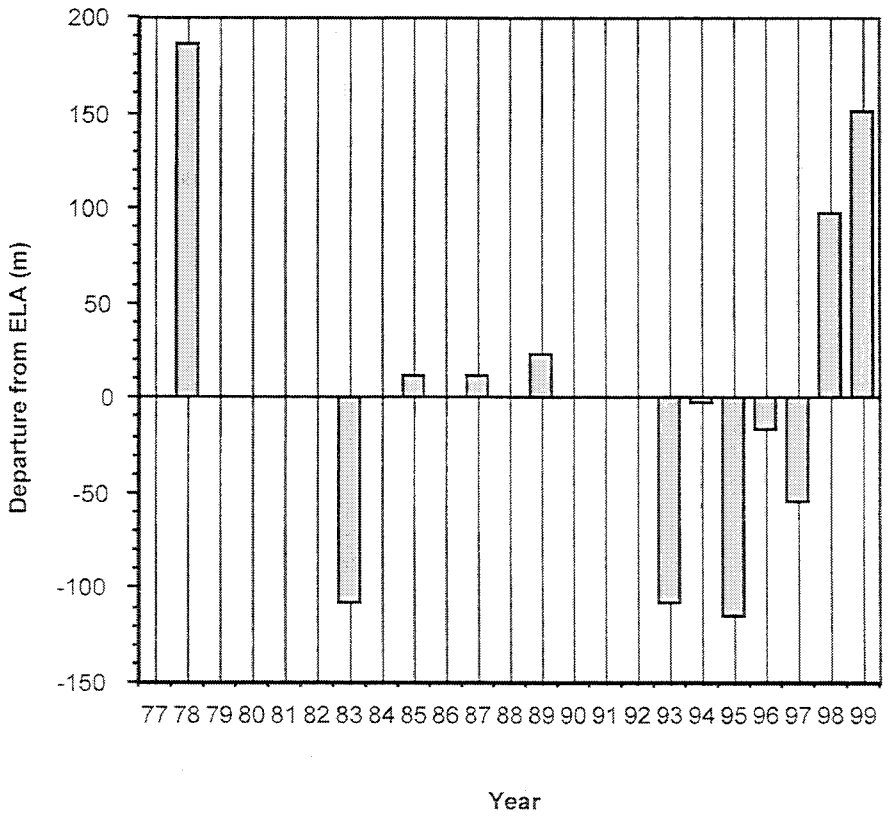
Inventory No. 797D/001
A cirque glacier on Mt. Irene, Waiau R. catchment.

Glacier Data	
Glacier area (ha)	17.95
Equilibrium line altitude (ELA)	1515
Maximum elevation (m)	1800
Minimum elevation (m)	1435
Mean elevation (m)	1618
Elevation range (m)	365
Maximum length (km)	0.5
Gradient	0.64

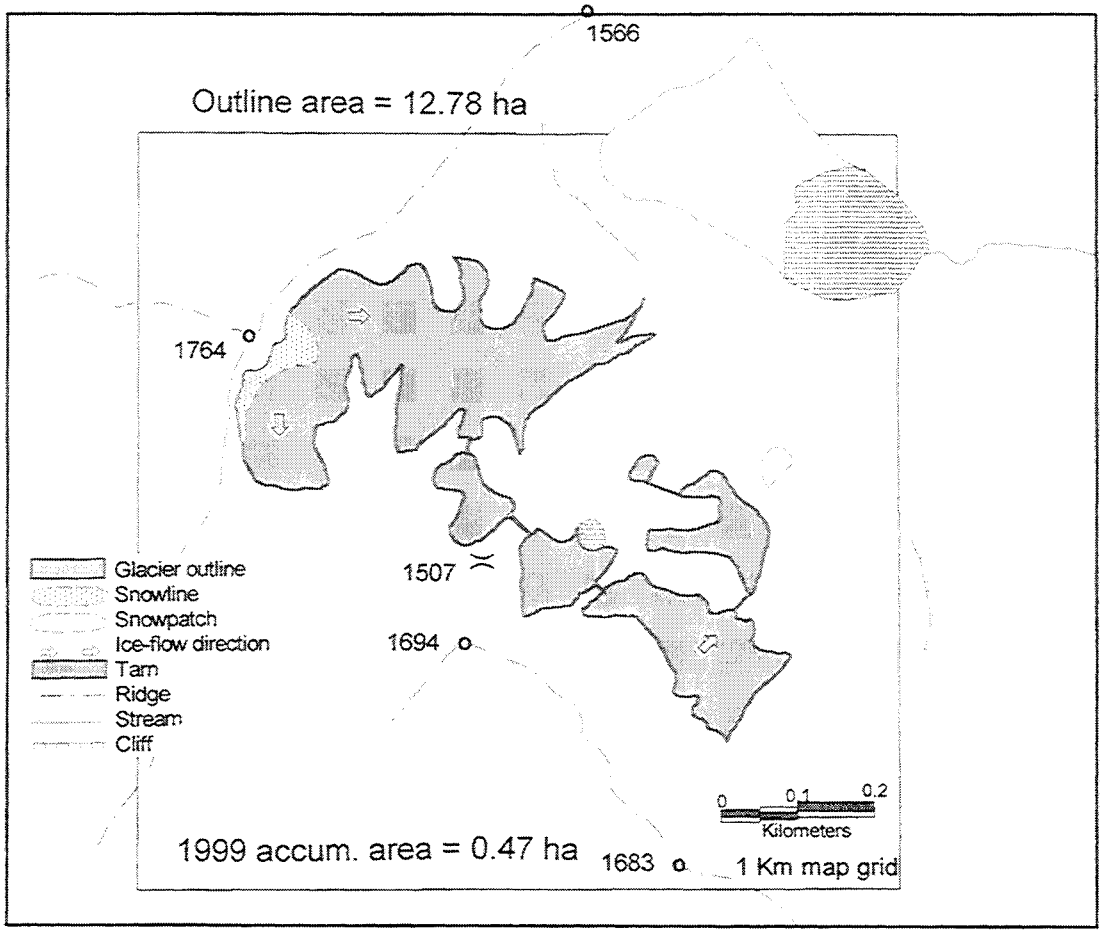
1999 Snowline Data	
1999 accumulation area (ha)	2.20
1999 snowline elevation (m)	1665
Snowline departure from ELA (m)	150
Accumulation area ratio (AAR)	0.12

Left: Digitised map of Mt. Irene for 1999 and oblique aerial photograph taken 1996.

Below: Plot of all available annual snowline departures from the ELA for Mt. Irene.



MERRIE RANGE



Merrie Range

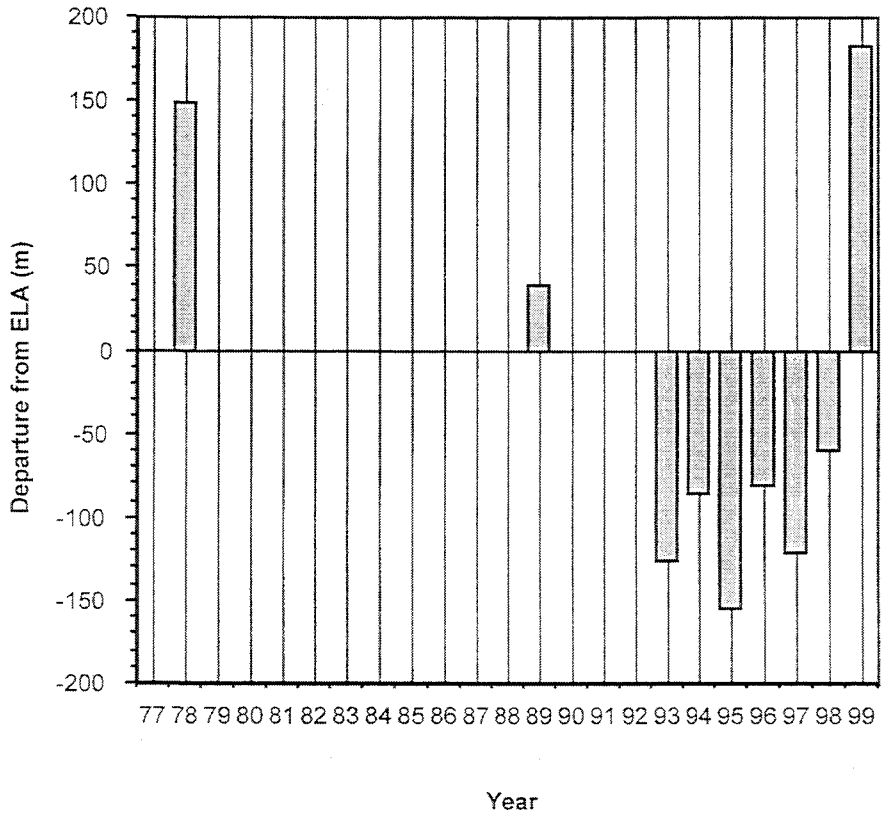
Inventory No. 797B/010
A small glacierette glacier on Merrie Range, Waiau R. catchment.

Glacier Data	
Glacier area (ha)	12.78
Equilibrium line altitude (ELA)	1505
Maximum elevation (m)	1707
Minimum elevation (m)	1370
Mean elevation (m)	1538
Elevation range (m)	337
Maximum length (km)	0.5
Gradient	0.244

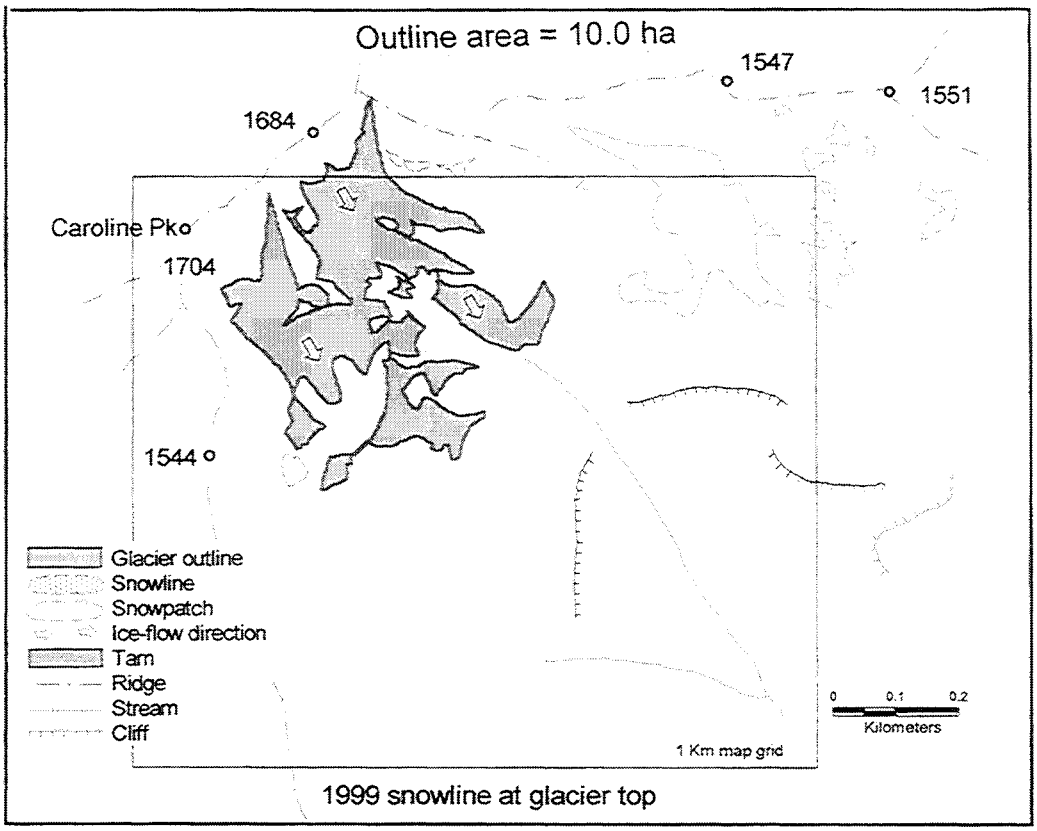
1999 Snowline Data	
1999 accumulation area (ha)	0.47
1999 snowline elevation (m)	1688
Snowline departure from ELA (m)	183
Accumulation area ratio (AAR)	0.04

Left: Digitised map of Merrie Range for 1999 and oblique aerial photograph taken 1996.

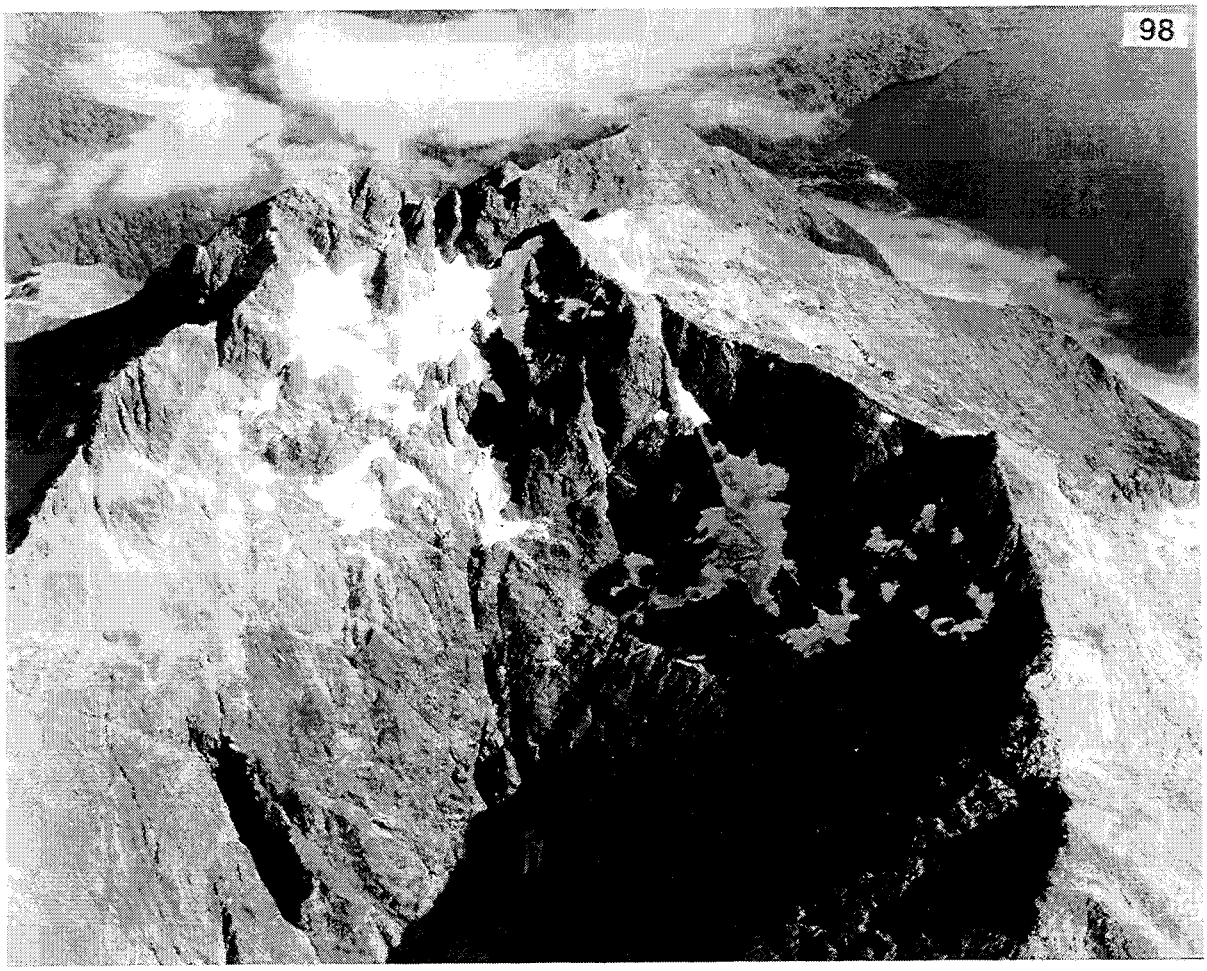
Below: Plot of all available annual snowline departures from the ELA for Merrie Range.



CAROLINE PEAK



1999 snowline at glacier top



Caroline Peak

Inventory No. 803/001
A group of small glacierettes on Caroline Peak, Lake Hauroko catchment.

Glacier Data	
Glacier area (ha)	10.0
Equilibrium line altitude (ELA)	1425
Maximum elevation (m)	1676
Minimum elevation (m)	1463
Mean elevation (m)	1570
Elevation range (m)	213
Maximum length (km)	0.5
Gradient	0.42

1999 Snowline Data	
1999 accumulation area (ha)	0, snowline at glacier top
1999 snowline elevation (m)	1600
Snowline departure from ELA (m)	175
Accumulation area ratio (AAR)	0

Left: Digitised map of Caroline Peak for 1999 and oblique aerial photograph taken 1998.

Below: Plot of all available annual snowline departures from the ELA for Caroline Peak.