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FIELD REPORT FOR 1997 ON GLACIAL DEPOSITS AT ALAN HILLS, ANTARCTICA

by

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in association with the

SCHOOL OF EARTH SCIENCES

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Te Whare Wananga o te Upoko o te Ika a Maui

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Frontispiece: Tents in Camp Valley with Manhaul glacier behind.

CONTENTS

INTRODUCTION

Location and Purpose

The Allan Hills form a wishbone-shaped nunatak situated high (1800-2300 metres above sea-level) in the Transantarctic Mountains in South Victoria Land near the edge of the present ice sheet (76° 45' S). The 50 square kilometres (km) of exposed rock is barely emergent with most of the area rising less than 100 metres (m) above the surrounding ice and the highest point approximately 340m above the ice. This low profile means that a small increase in the size of the ice sheet could override Allan Hills, and overriding events may be recorded there by glacial deposits and related features.

The purpose of the 1997 field programme, the first of 3 seasons planned was to carry out reconnaissance mapping and characterisation of glacial deposits known to be present in the central part of Allan Hills. The field programme was shared with Swiss geologists, Christian Schluchter and Silvio Tschudi, whose task was to collect samples from key locations for surface age dating using cosmogenic isotopes. This report documents only the glacial geological data.

BEDROCK GEOLOGY

The bedrock of Allan Hills (Figure 1) comprises near flat-lying Permian and Triassic sandstones, shales and coal measures of the Beacon Supergroup, intruded by extensive sills and occasionally thin dykes of Jurassic Ferrar Dolerite (Grapes et al., 1974; Ballance and Watters, 1971). An unusual feature of the bedrock geology is the Mawson Formation, an extremely poorly sorted volcanic breccia formed of a mixture of tholeiitic basalt and Beacon debris (Hall et al., 1982; Ballance and Watters, 1971). The Mawson Formation forms most of the bedrock in the southern and western part of the nunatak.

The sandstone units within the Beacon strata are generally fine to medium grained and moderately well cemented forming extensive platforms and bluffs. A few surfaces display well preserved glacial striae.

SIRIUS GROUP DEPOSITS

General description

The central part of Allan Hills has a patchy distribution of compact diamictite deposits. These range from tens of metres to almost 2000 m across. (Figure 1, Photo 1). The deposits are in most places is a thin (much of it 1m or less) veneer over the bedrock, particularly in the lowest central area. In a few places the diamictite is exposed in low bluffs to reveal thickness of up to seven metres and displaying vague stratification, possibly representing several different diamictite units.

In lithology the deposits are compact, extremely poorly sorted, clast-rich sandy diamictite. Colour varies from yellowish grey to greenish grey but is most commonly light grey. Clasts range in size from boulders over 1m in diameter to pebbles; average clast size is around 10

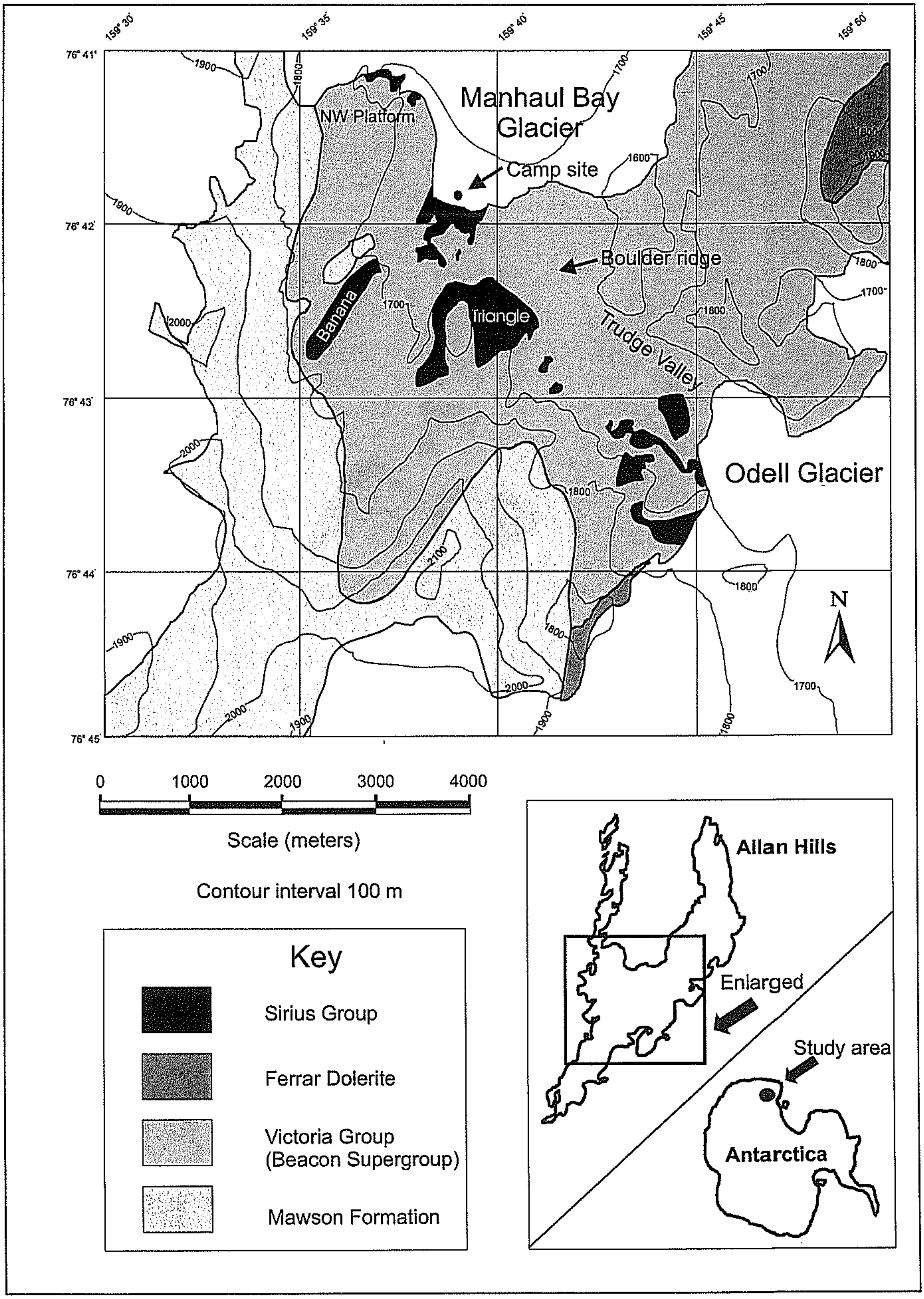


Figure 1. Location and distribution of main stratigraphic Units in central Allan Hills. Sirius Group deposits form a thin vaneer on a topography cut in flat lying Beacon strata and Mawson Formation.

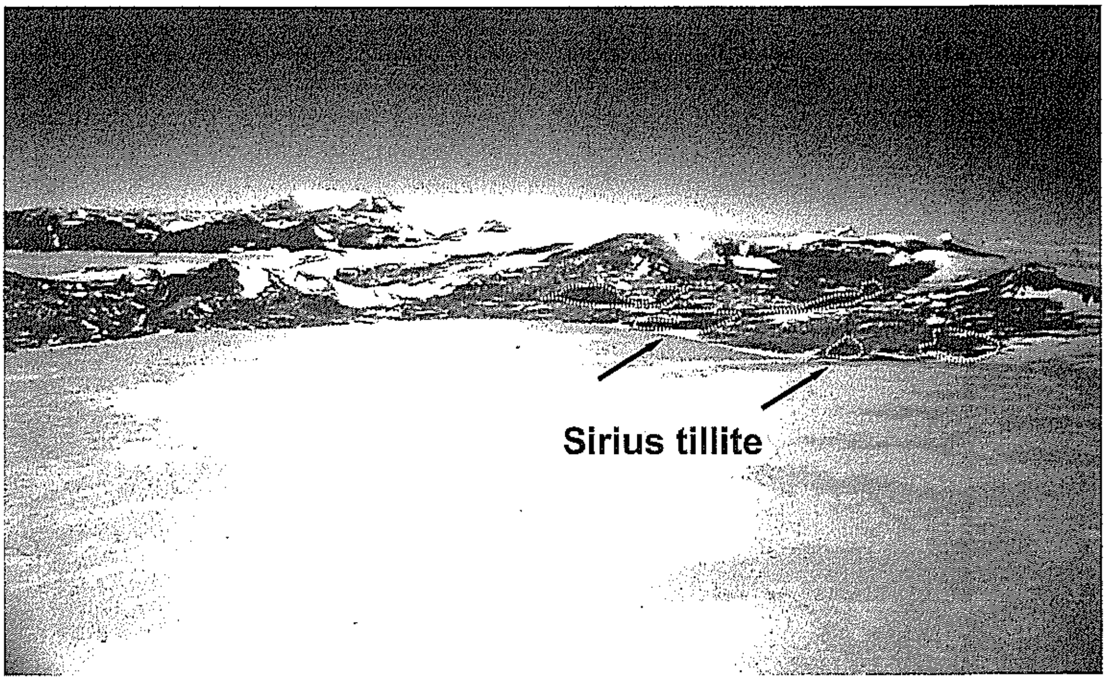


Photo 1. Aerial view of central Allan Hills, looking south. Manhaul bay ice lobe in center. Dark patches in central valley are areas of Sirius tillite. (Photo by Vanessa Thorn).

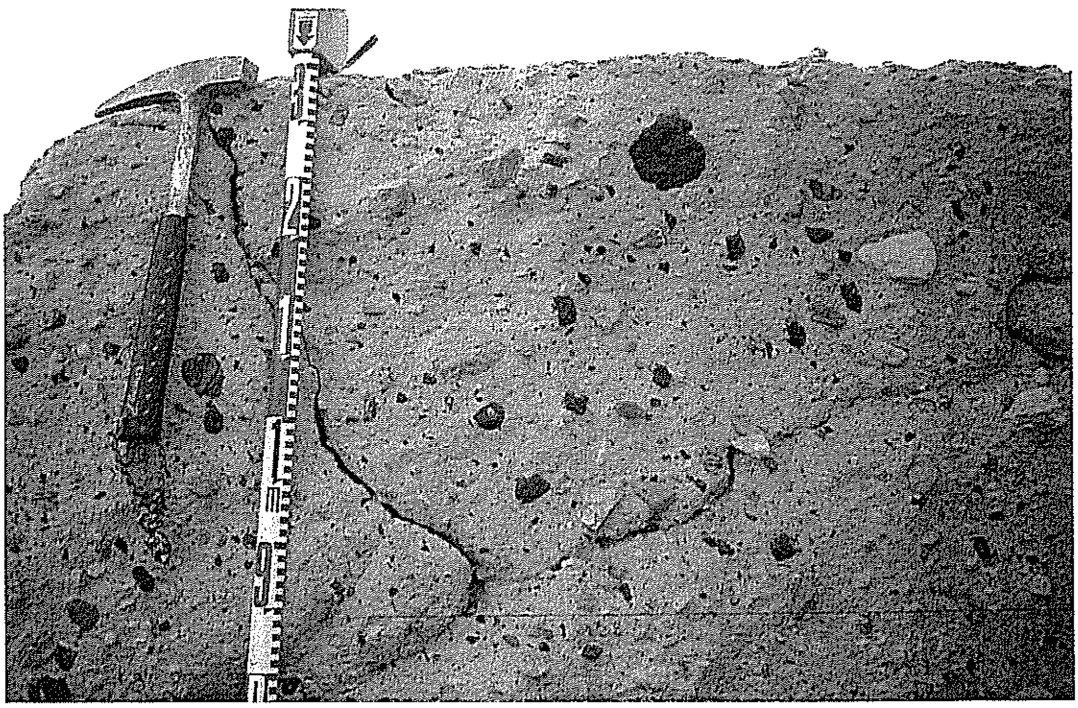


Photo 2. Typical outcrop of Sirius tillite in Camp Valley. Note the range of clast types derived from the underlying bedrock.

centimetres (cm). Clast types include sandstone, siltstone, coal, dolerite and breccia, all derived from the underlying bedrock, but also rare granite clasts (Photo 2). Many of the clasts, but particularly the dolerites display glacial shape such as bullets and facetts and surface features such as striae (Photo 3). These commonly form cross cutting sets and are regarded as clear evidence of being carried or over-ridden by moving basal glacial ice.

The bedrock beneath the diamictite commonly displays significant deformation that includes shearing, folding on a scale of cm to m and brecciation to cm-scale fragments to depths of several m, consistent with glacial over-riding.

In summary, the deposits has an abundance of features associated with the transport and deposition directly from sliding "wet-based" glacial ice, and is appropriately termed tillite.

Plots of changing elevation with distance of the base of the tillite (e.g. Figure 3 for Camp Valley) define a surface that is smoother and has lower relief than the present topography. The distribution pattern of these patches and their relation to the topography gives them the appearance of remnants of a much larger and more widespread "sheet" of till overlying glacially smoothed bedrock. The till is thought to represent the last time ice (wet based) overrode Allan Hills from the south, and is considered part of the Sirius Group tills, which are found at several locations within the Transantarctic mountains. The age of Sirius tills is still contentious issue.

The surface of the till at Allan Hills is characterised by a marked concentration of weathered, dark coloured and wind smoothed dolerite clasts ranging from pebble to boulder size. This is probably the result of wind deflation of the till surface concentrating the more resistant dolerite clasts on the surface. This feature of the till is useful for identifying the distribution from the air (Photo 1). Further possible evidence of significant wind influence are common ridges composed of gravel sized dolerite clasts. These have amplitude of up to 2 m and wavelength of about 5 m and interpreted by Ballance and Watters (1971) as being produced by wind influence.

Fieldwork focus.

Fieldwork focused on several deposits of Sirius till in central Allan Hills. These deposits were given field names according to location or shape of the deposit. Two deposits were identified on a Beacon Sandstone platform to the north-west of the campsite. These are "NW Platform 1 and NW Platform 2". Immediately adjacent to the campsite is a low relief valley with Sirius till and is labelled "Camp Valley" (CV). Other deposits identified are an elongate deposit termed the "Banana" and an extensive area of till south-east of the campsite termed the "Triangle". Data was collected from all of these deposits but particular focus was on the Camp valley (CV) and on the NW platform 1 deposits. This involved pace and compass mapping of the perimeter of these two deposits, recording the altitude above the camp elevation (1775 m asl) of each mapping site and performing shape and fabric analysis at selected sites. In addition, the orientation of striae on both bedrock and clasts lodged in the till were noted. Complementing the perimeter map of the Camp Valley deposit are two transects across the area. The transects are shown as cross-sections in Figure 5. These illustrate the "mantle" of till on the older or contemporaneously formed bedrock topography and the common eroded "windows" through the till to the underlying Beacon strata. The transects map only the surface extent of the till and therefore the thickness and base of the till shown on the cross sections is schematic only.

Shape and Fabric.

Shape and fabric measurements were made on clasts within the till at three sites, one on the NW platform (NW 1site 5) and two in the Camp Valley deposit (Sites CV 4 and CV 50). This was achieved by recording the lithology, length of the long (a) axis, Krumbein visual roundness of 100 clasts and the presence of surface features such as striae on the first 50 clasts at each site. In addition, the strike and dip of the a-b plane (the plane of intersection of the long and intermediate axis) was recorded for 50 clasts at each site. (Tables 1a, b, c). Figure 2 displays contoured, equal area, Schmidt lower hemisphere stereonet projections and clast roundness and lithology histograms of the three sites.

The clast roundness histograms all display similar broad distributions, with most clasts having Krumbein visual roundness value of between 0.2 (subangular) and 0.5 (rounded). No values greater than 0.6 were recorded. All sites are dominated by sandstone (at least 45%). Interestingly, dolerite is less than 10% at NW 1 site 5, slightly higher in CV site 4 and is highest at CV site 50 with 23%. Only 4 out of 50 clasts displayed striae at NW 1 site 5 (3 sandstone and 1 other). CV site 4 shows 11 striated clasts on all lithologies except coal. CV site 50 shows 8 striated clasts (1 siltstone and 7 dolerite). There does not appear to be any clear relationship between striae and lithology.

Initial analysis of the stereonet data indicates complex fabric in the till. No strong imbrication is shown, with S1 Eigen values less than 0.6 in all samples. However, the plots multimodal and require more comprehensive analysis. Measurement of the trend and plunge of the a-axis of prolate clasts is preferable for describing glacial fabrics and should be used in future work.

Overall, the clast shape data is consistent with the inferred glacial origin of the deposits and the occurrence of facetted and striated clasts is considered good evidence that the deposits were produced by wet based sliding ice. The fabrics at this stage do not yield any evidence of particular depositional process or paleo-ice flow direction. Additional clast shape and fabric data may provide more useful information about the processes that deposited the till.

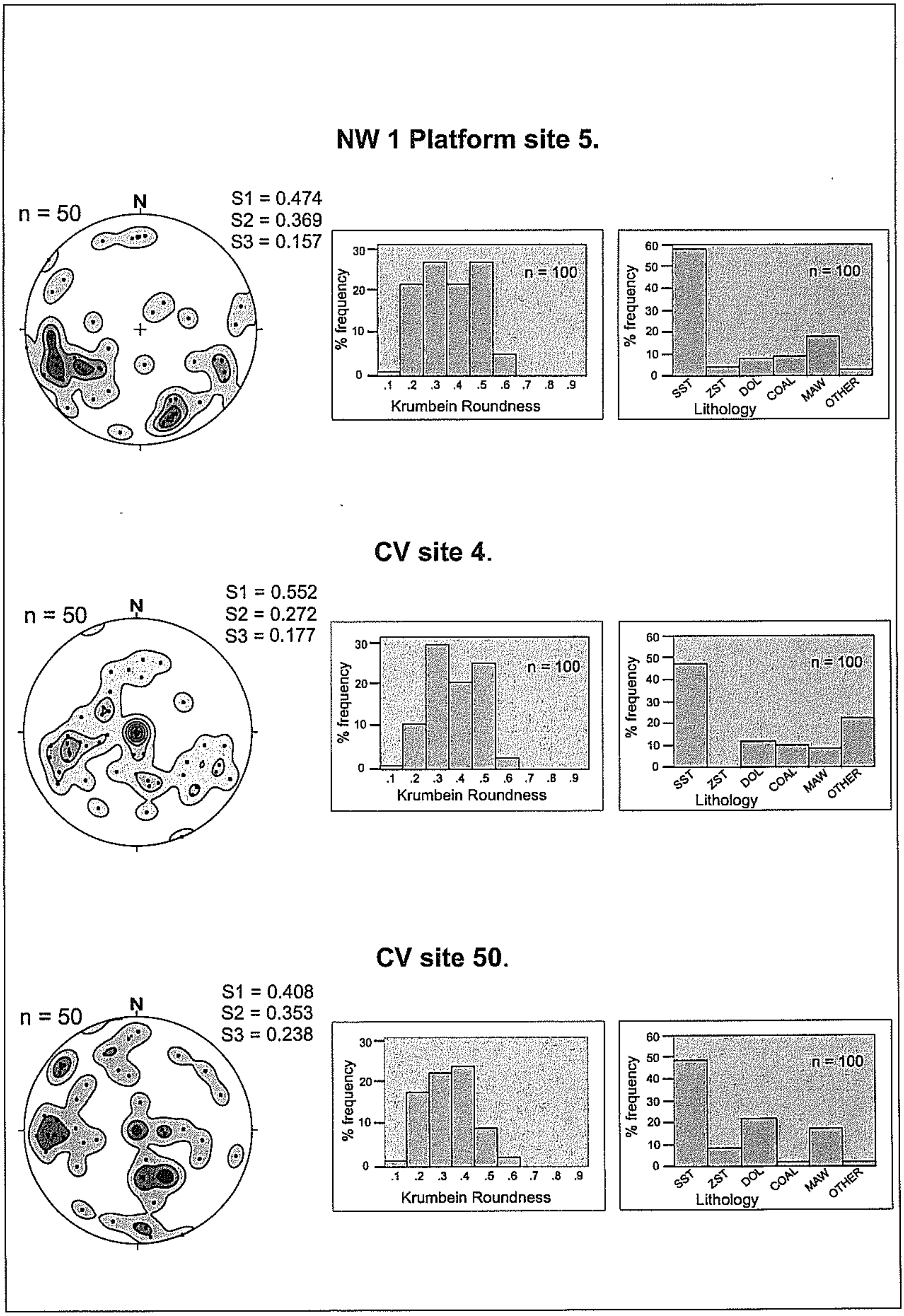


Figure 2, Summary clast data. Stereonets of contoured fabric data, principle Eigen values, clast roundness and lithology histograms for the three Sirius till fabric sites.

Table 1a
Fabric and summary clast data for NW1 site 5.

NO.	Lithol	Length	R'ness	Striae	Azmth	Dip		NO.	Lithol	Length	R'ness
1	SST	11	0.5		239	20		51	SST	7.3	0.5
2	MAWSON	3.6	0.3		225	50		52	SST	4.6	0.3
3	SST	6.7	0.5		191	10		53	SST	5.8	0.4
4	ZST	2	0.5		293	18		54	SST	6.4	0.6
5	SST	3	0.4		112	32		55	DOLERITE	3.5	0.2
6	?	6.4	0.3		303	22		56	SST	4.2	0.5
7	ZST	3.1	0.3		267	24		57	SST	3.9	0.4
8	?	3.1	0.4		266	22		58	SST	3.6	0.4
9	DOLERITE	4.8	0.4		161	18		59	SST	2.3	0.5
10	COAL	2.6	0.4		157	34		60	SST	3.1	0.4
11	ZST	2.3	0.6		261	0		61	SST	2.7	0.3
12	COAL	3.2	0.3		87	19		62	MAW	2.9	0.3
13	MAW	5.9	0.2		235	39		63	COAL	2	0.2
14	ZST	4.3	0.2		173	65		64	SST	4.9	0.4
15	COAL	3.7	0.2		37	75		65	MAW	2.7	0.2
16	SST	9.5	0.5		214	28		66	DOLERITE	6.7	0.5
17	COAL	3	0.2		141	20		67	SST	2	0.3
18	MAW	4.3	0.5		253	22		68	MAW	5.3	0.3
19	DOLERITE	3	0.4		337	18		69	SST	2.5	0.5
20	SST	2.9	0.3		207	40		70	SST	3.5	0.5
21	SST	3.2	0.4		157	22		71	COAL	2.5	0.2
22	SST	3.4	0.5		307	0		72	DOLERITE	3.4	0.3
23	MAW	3	0.2		153	33		73	MAW	2.4	0.3
24	COAL	5.2	0.3		121	16		74	SST	4	0.3
25	SST	3.9	0.3		227	50		75	SST	3.3	0.4
26	MAW	5.8	0.5		41	65		76	MAW	3.5	0.4
27	SST	8.4	0.2		251	25		77	SST	3.9	0.5
28	SST	6.5	0.3		77	12		78	SST	6.6	0.6
29	MAW	9.4	0.5		77	55		79	SST	4.8	0.2
30	SST	3.9	0.4		233	40		80	MAW	5.7	0.2
31	SST	3.4	0.6	*	117	20		81	MAW	10.5	0.3
32	SST	2.6	0.5	*	111	26		82	SST	3.3	0.3
33	?	3.4	0.5	*	0	0		83	SST	5.1	0.3
34	SST	4.7	0.4		237	21		84	SST	4.4	0.4
35	SST	3	0.5		167	15		85	SST	4	0.2
36	SST	3	0.3		166	18		86	SST	6.3	0.4
37	SST	5.8	0.5		121	45		87	SST	7.8	0.5
38	SST	4.2	0.3		247	38		88	SST	2.5	0.4
39	SST	4	0.5		355	22		89	SST	3.2	0.3
40	MAW	4.2	0.5		239	38		90	DOLERITE	5.2	0.2
41	SST	4.5	0.5		159	22		91	COAL	3.6	0.1
42	SST	4.3	0.6		223	8		92	SST	4.3	0.5
43	MAW	5.9	0.2		279	56		93	SST	5.5	0.2
44	SST	7.1	0.3		3	20		94	MAW	6.7	0.2
45	SST	2.7	0.4		247	22		95	SST	4	0.3
46	SST	9.9	0.4	*	265	24		96	SST	3.3	0.5
47	SST	4.1	0.5		248	14		97	SST	4.3	0.2
48	DOLERITE	6.2	0.4		245	8		98	MAW	3.2	0.2
49	MAW	3.3	0.3			0		99	DOLERITE	3.3	0.2
50	COAL	5.2	0.2		239	64		100	SST	3.5	0.3

Table 1b
Fabric and summary clast data for CV site 4.

NO.	Lithol	Length	R'ness	Striae	Azmth	Dip		NO.	Lithol	Length	R'ness
1	?	6.9	0.3		57	50		51	MAW	5.3	0.4
2	SST	2	0.5		101	40		52	COAL	2.6	0.3
3	SST	3.7	0.4		117	24		53	?	2.4	0.3
4	SST	3.7	0.3		157	50		54	MAW	9	0.5
5	?	3.9	0.2		237	18		55	COAL	3.4	0.2
6	SST	2.5	0.5		254	21		56	?	33	0.4
7	SST	3.5	0.5		173	30		57	MAW	3.9	0.3
8	SST	3.5	0.3		139	28		58	SST	2.7	0.3
9	SST	5.5	0.5		353	44		59	SST	5.2	0.5
10	?	2.4	0.6	*	255	52		60	COAL	2	0.4
11	MAW	4.3	0.3		261	24		61	MAW	5.3	0.5
12	?	6.5	0.2	*	261	38		62	SST	3.8	0.5
13	?	2.7	0.3		327	55		63	SST	4.7	0.5
14	SST	3.1	0.4		157	90		64	SST	9.6	0.4
15	SST	7.4	0.3		207	58		65	COAL	6	0.5
16	MAW	8.1	0.3	*	181	60		66	SST	4.9	0.4
17	MAW	7.5	0.4		253	38		67	DOLERITE	4	0.3
18	SST	3.1	0.5		5	50		68	?	6.5	0.3
19	SST	13.7	0.4	*POSS	157	90		69	COAL	5	0.3
20	COAL	2.4	0.1		267	39		70	MAW	5.8	0.6
21	MAW	7.4	0.5		19	36		71	DOLERITE	5.5	0.2
22	?	3	0.4	*	307	60		72	?	2.8	0.6
23	SST	2.2	0.4		5	36		73	?	4.2	0.3
24	?	2.6	0.3		157	90		74	SST	2.9	0.4
25	SST	4.5	0.5		157	90		75	DOLERITE	5.5	0.5
26	?	4.9	0.4		157	0		76	DOLERITE	3.5	0.3
27	SST	7	0.4		265	69		77	?	5.5	0.4
28	SST	2.7	0.3	*	252	38		78	COAL	2.3	0.2
29	SST	2.9	0.3		121	48		79	SST	4.7	0.5
30	DOLERITE	10.3	0.5		157	90		80	SST	4.1	0.2
31	?	9.8	0.2		187	74		81	SST	4.3	0.2
32	SST	2.9	0.5		255	62		82	DOLERITE	6.4	0.5
33	SST	6.1	0.3		307	65		83	?	4.4	0.5
34	DOLERITE	4.2	0.3	*	163	74		84	SST	2.4	0.3
35	SST	7.7	0.5		227	38		85	COAL	2.7	0.2
36	SST	6.2	0.3		248	34		86	?	4.7	0.2
37	SST	3.5	0.2		337	42		87	DOLERITE	2	0.4
38	SST	4.3	0.5	*	167	54		88	?	5.1	0.5
39	SST	3.9	0.5		99	24		89	SST	2.2	0.3
40	SST	6.9	0.3		243	24		90	COAL	4.3	0.3
41	SST	7	0.5	*	117	10		91	SST	5	0.4
42	SST	4.5	0.3		167	50		92	?	4.2	0.5
43	SST	11.7	0.5		112	24		93	DOLERITE	4.3	0.5
44	SST	6.4	0.4		157	90		94	SST	3.5	0.3
45	SST	3.3	0.4		207	26		95	?	4.7	0.4
46	SST	7	0.5		285	48		96	SST	3.3	0.4
47	SST	2.9	0.4		260	48		97	?	3.6	0.3
48	?	2.4	0.3	*		44		98	?	3.5	0.4
49	DOLERITE	3.5	0.3	*	133	30		99	DOLERITE	2.6	0.3
50	SST	4.7	0.2		297	62		100	COAL	3	0.3

Table 1c
Fabric and summary clast data for CV site 50.

NO.	Lithol	Length	R'ness	Striae	Azmth	Dip		NO.	Lithol	Length	R'ness
1	SST	3.1	0.5		307	16		51	SST	3.9	0.3
2	SST	2.4	0.5		172	56		52	SST	4.5	0.5
3	SST	5.3	0.4		272	45		53	MAW	4.5	0.4
4	SST	2.8	0.4		312	40		54	MAW	2.3	0.3
5	DOLERITE	9.5	0.3		89	72		55	DOLERITE	3.2	0.3
6	DOLERITE	4.1	0.2	*	0	90		56	MAW	3.6	0.4
7	BASALT	6.4	0.2		167	35		57	MAW	2.4	0.2
8	SST	7.9	0.3		361	14		58	SST	2	0.4
9	SST	3.9	0.3		181	18		59	COAL	2	0.2
10	DOLERITE	2.2	0.1		265	35		60	DOLERITE	4.4	0.4
11	SST	3.5	0.2		343	44		61	SST	2.9	0.2
12	DOLERITE	2.3	0.3		279	18		62	SST	2	0.4
13	SST	2.6	0.4		149	48		63	ZST	4.7	0.5
14	DOLERITE	3	0.3		352	50		64	DOLERITE	3.9	0.3
15	SST	5.3	0.6		277	29		65	SST	4.6	0.3
16	DOLERITE	6.7	0.2	*	267	12		66	SST	5	0.5
17	DOLERITE	5.7	0.4	*	147	55		67	SST	2.3	0.5
18	DOLERITE	2.5	0.2		67	22		68	SST	2.5	0.2
19	ZST	3	0.5		0	90		69	SST	2.7	0.4
20	SST	3.5	0.5		297	40		70	SST	5.5	0.4
21	ZST	3.4	0.4		89	57		71	ZST	4.2	0.3
22	SST	3.7	0.3		99	42		72	MAW	2.9	0.3
23	MAW	3.6	0.2		157	0		73	COAL	5.4	0.2
24	SST	4.1	0.3		7	70		74	DOLERITE	2.5	0.4
25	DOLERITE	3.7	0.2		157	90		75	SST	2.7	0.3
26	MAW	3.3	0.3		257	60		76	MAW	3.7	0.3
27	SST	3.2	0.4		105	12		77	MAW	2.4	0.4
28	DOLERITE	2	0.5		97	70		78	SST	3.4	0.3
29	SST	2.7	0.5		29	26		79	MAW	2.4	0.4
30	MAW	5.2	0.6		345	28		80	SST	2.2	0.4
31	SST	2.6	0.4		195	18		81	MAW	3.6	0.3
32	MAW	2	0.4		175	15		82	SST	2.2	0.2
33	ZST	2.6	0.3	*	115	40		83	SST	3.4	0.3
34	ZST	3.1	0.4		145	46		84	SST	5.6	0.3
35	DOLERITE	2.4	0.3	*	267	28		85	DOLERITE	2.6	0.2
36	MAW	4.6	0.2		163	68		86	SST	2	0.2
37	DOLERITE	7.4	0.2	*	267	22		87	DOLERITE	2.6	0.2
38	SST	7.3	0.4		257	18		88	MAW	4.9	0.3
39	SST	10	0.6		149	52		89	MAW	2.4	0.2
40	BASALT	3.6	0.4		175	56		90	SST	4.8	0.4
41	DOLERITE	3	0.2	*	355	20		91	SST	3.4	0.4
42	ZST	4.6	0.4		215	16		92	SST	3.6	0.2
43	SST	2	0.1		337	28		93	SST	2.5	0.3
44	DOLERITE	5.3	0.4		173	6		94	SST	2.4	0.4
45	SST	6.4	0.4		311	12		95	MAW	6.1	0.4
46	DOLERITE	4.2	0.5	*	257	50		96	SST	3.5	0.5
47	DOLERITE	2.9	0.4		49	22		97	SST	2.4	0.2
48	ZST	3.6	0.3		239	38		98	SST	3.6	0.3
49	ZST	2.8	0.2		173	48		99	SST	6.9	0.3
50	SST	2	0.3		312	15		100	SST	3.6	0.4

Striae

The orientation of striae on clasts lodged in the till and on bedrock surfaces in the mapped areas was measured primarily to establish the direction of ice flow across each site. The orientations of the striae are given as an azimuth to the south for consistency but does not indicate ice flow direction, as it was not possible to distinguish this in the field. All field measurements have been corrected for magnetic declination of 157 degrees. Data are shown in Tables 2, 3 and 4 and Figure 6. On clasts with more than one set of striae, relative age determination of each set from cross cutting relationships was sometimes possible. However, there are no obvious orientation trends defined by different generations. Some striae will have formed during basal transport, prior to lodgement and have no ice flow directional value and confuse the averaged azimuths.

Striae were recorded on 7 lodged clasts on the "Banana" deposit and yield an averaged azimuth of 196 degrees and a range of 81 degrees. Striae from 15 lodged clasts on the "Triangle" give an averaged azimuth of 205 and wide range of 146 degrees.
Striae from the Camp Valley deposit show an average azimuth of 188 degrees and a range of 106 degrees. While there is significant variation in the ranges, the average azimuths are broadly consistent (Table 2, Figure 3). No striated bedrock was observed at these deposits.

The striae from the NW platform deposits are more complicated as both weathered and presumably recent unweathered striae are present on clasts and bedrock. Weathered striae orientations were recorded from lodged clasts at 9 sites on both NW Platforms 1 and 2. NW Platform 1 shows a range of 82 degrees and an average azimuth of 218 degrees (Table 2, Figure 4). NW Platform 2 deposit shows a wider range of 166 degrees but a remarkably similar averaged azimuth of 214 degrees. This is slightly more west/east than the striae for other sites. A few clasts (including abraded ventifacts) on the surface of the till show fresh, unweathered striae or abrasion, but were not recorded in the striae dataset.

The bedrock striae consist of both weathered and recent unweathered examples. The striae are mostly on the Beacon sandstone surfaces, often directly underlying the till, but a few fresh abrasion marks appear on the till surface. The weathered striae show an average orientation of 196 degrees and a range of 61 degrees. These examples are typically arranged in sub parallel sets, less than 5mm deep, variable length and width and with a clear but weathered appearance. In sharp contrast to these are fresh unweathered and presumably recent striae. These are found on the same sandstone surfaces as the weathered striae but are less common and appear less uniform in shape. Only five examples were measured on the NW platform Sirius deposit but show a range of 28 degrees and an average azimuth of 189 degrees, at a distinct angle to the weathered striae on the same surface (Figure 4, Photo 4).

Table 2
Striae orientations on clasts lodged in Sirius till.

No.	Site name	Lithology	Sets	Dirc'n Set 1	Dirc'n Set 2
1	CV site 6	Dolerite	2	199 dominant	209
2	"	Sandstone	1	202	
3	CV site 16	Dolerite	1	207	
4	CV site 22	Dolerite	2	195 dominant	152 youngest
5	"	Dolerite	1	195	
6	CV site 26	Dolerite	2	192	161
7	"	Dolerite	2	183,youngest	164 dom, older
8	"	Dolerite	1	191	
9	"	Dolerite	1	197	
10	CV site 28	Dolerite	2	229	147
11	"	Dolerite	1	245	
12	"	Dolerite	1	197	
13	CV site 33	Dolerite	1	187	
14	CV site 37	Dolerite	2	198, dominant	170, youngest
15	CV site 44	Dolerite	1	157	
14	CV site 47	Dolerite	2	189, dom, older	141 youngest
15	CV site 48	Dolerite	1	204	
16	"	Dolerite	1	199	
17	"	Dolerite	1	202	
18	CV site 53	Dolerite	1	197	
19	CV site 54	Dolerite	2	139, older	177, youngest
20	CV site 56	Dolerite	1	185	
21	"	Dolerite	2	186	201
22	CV site 57	Dolerite	1	167	
23	"	Dolerite	1	181	
24	"	Dolerite	1	195	
25	Transect	Dolerite	1	197	
26	Transect	Dolerite	1	187	
27	Transect	Dolerite	1	175	
28	Transect	Dolerite	1	219	
				average = 188 range = 106	
29	NW1 site 1	Dolerite	3	245,young, dom	163, older
30	NW1 site 1	Sandstone	2	189, youngest	263, older
31	NW1 site10	Dolerite	1	237	
32	NW1 site A	Dolerite	1	221	
33	NW1 site B	Dolerite	1	195	
34	NW1 site D	Dolerite	1	229	
35	NW1 site F	Sandstone	1	184	
36	NW1 site H	Sandstone	1	233	
37	NW1 site H	Dolerite	1	239	
				average = 218 range = 82	

Table 2 (Continued)
Striae orientations on clasts lodged in Sirius till.

No.	Site name	Lithology	Sets	Dirc'n Set 1	Dirc'n Set 2
38	NW1 site 10a	Sandstone	1	184	Recent, unweath'd
39	NW2 site A	Dolerite	1	219	
40	NW2 site B	Dolerite	1	211	
41	NW2 site C	Dolerite	1	225	
42	NW2 site D	Dolerite	1	242	
43	NW2 site E	Dolerite	1	219	
44	NW2 site F	Dolerite	1	215	
45	NW2 site G	Dolerite	1	211	
46	NW2 site H	Dolerite	1	263 youngest	217 older
		Dolerite	2	247 youngest	199 older
47	NW2 site I	Dolerite	2	252	172
			2	219	97
				average = 214 range = 166	
48	Banana	Dolerite	2	224	
49	Banana	Dolerite	1	212	
50	Banana	Dolerite	1	209	
51	Banana	Dolerite	2	205	143
52	Banana	Dolerite	2	206	161
53	Banana	Dolerite	1	215	
54	Banana	Dolerite	1	194	
				average =196 range = 81	
55	Triangle 1	Dolerite	1	259	
56		Dolerite	1	147	
57		Dolerite	1	246	
58		Dolerite	1	217	
59	Triangle 2	Dolerite	1	218	
60		Dolerite	1	214	
61		Dolerite	1	212	
62		Dolerite	1	215	
63		Dolerite	1	113	
64	Triangle 3	Dolerite	2	225	247
65		Dolerite	1	215	
66		Dolerite	1	148	
67		Dolerite	1	224	
68		Dolerite	1	215	
69		Dolerite	1	167	
				average = 205 range = 146	

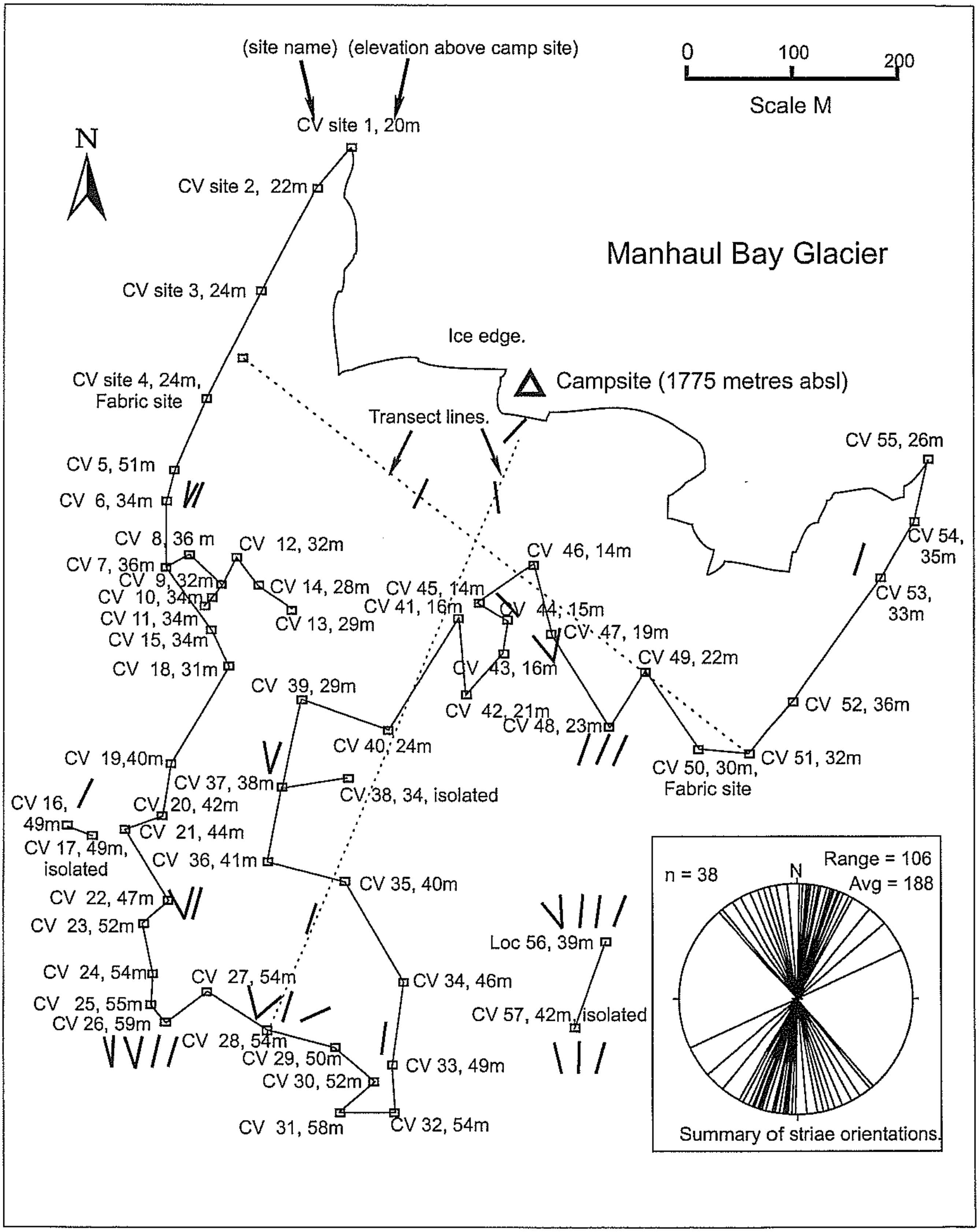


Figure 3, Pace and compass map of Camp Valley Sirius till deposit and orientation of lodged clast striae.

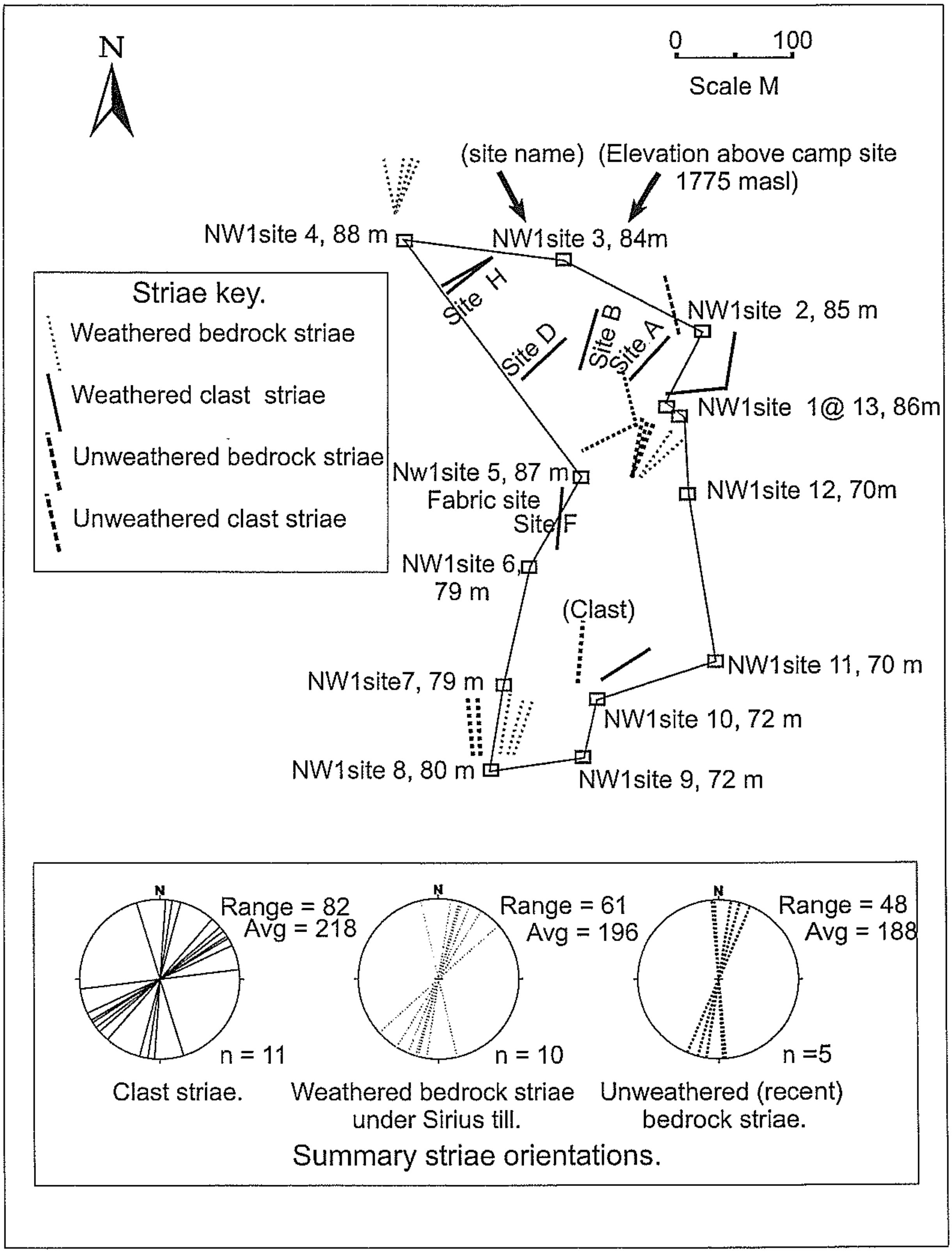


Figure 4, Pace and compass map of Northwest 1 platform Sirius till and orientation of bedrock and clast striae.

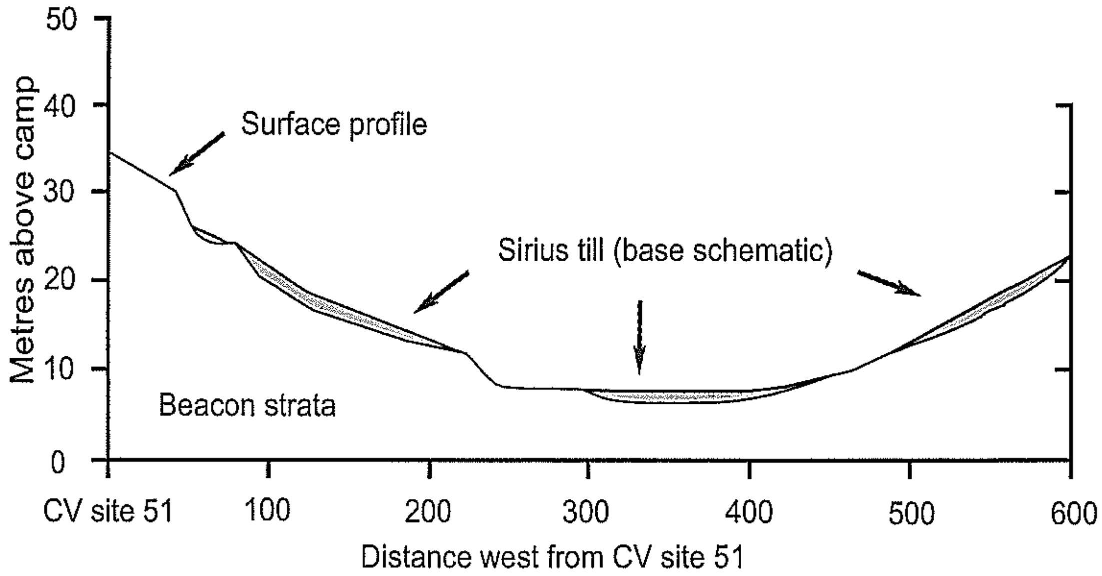


Figure 5a, Cross section of Camp valley Sirius Till deposit from CV site 51
(See trancetct lines on Fig 2)

NB. Sirius till surface only observed in transects. Base of the till and depth in these profiles is schematic.

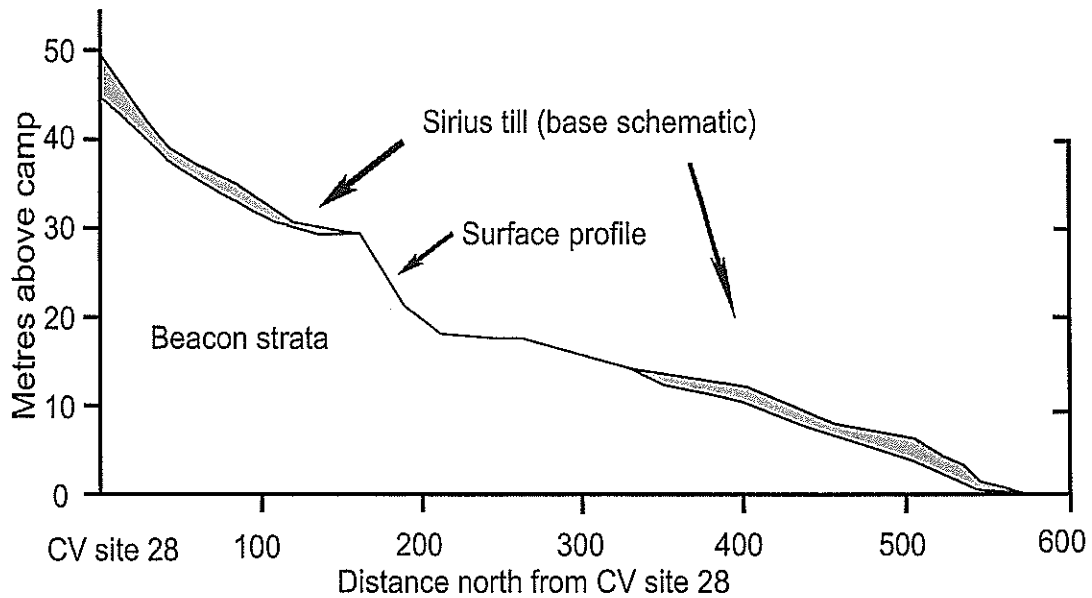


Figure 5b, Cross section of Camp valley Sirius Till deposit from CV site 28
(See trancetct lines on Fig 2)

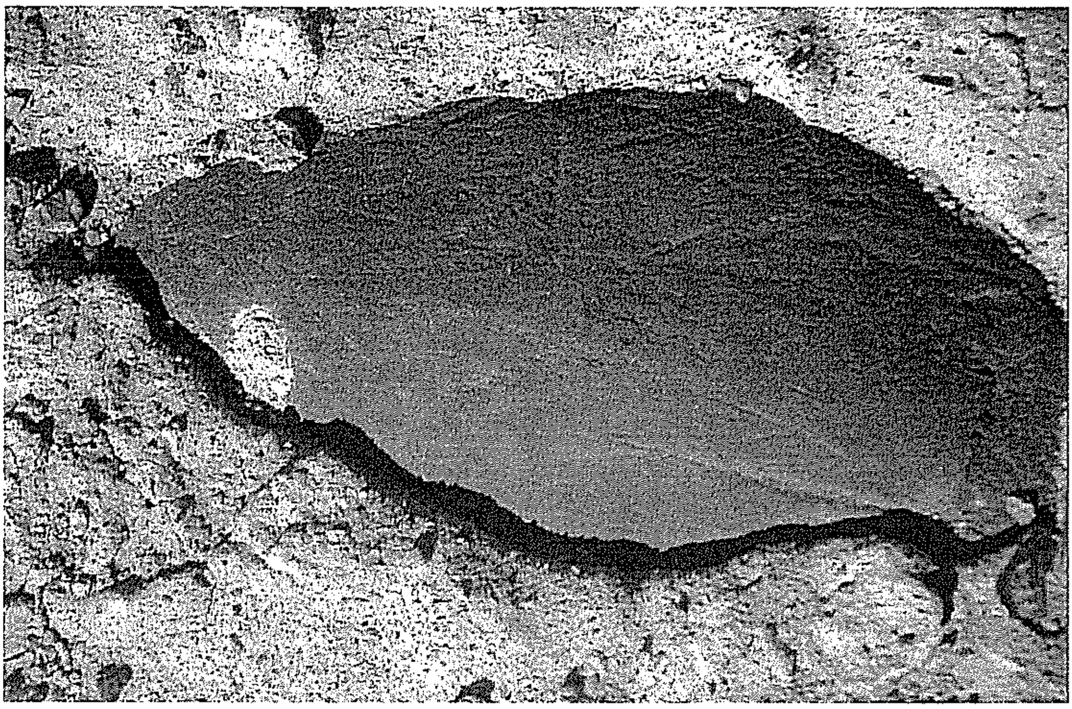


Photo 3. Striated clast lodged in Sirius till, Camp Valley. Clast is approx. 30cm long.
Photo by Cliff Atkins.

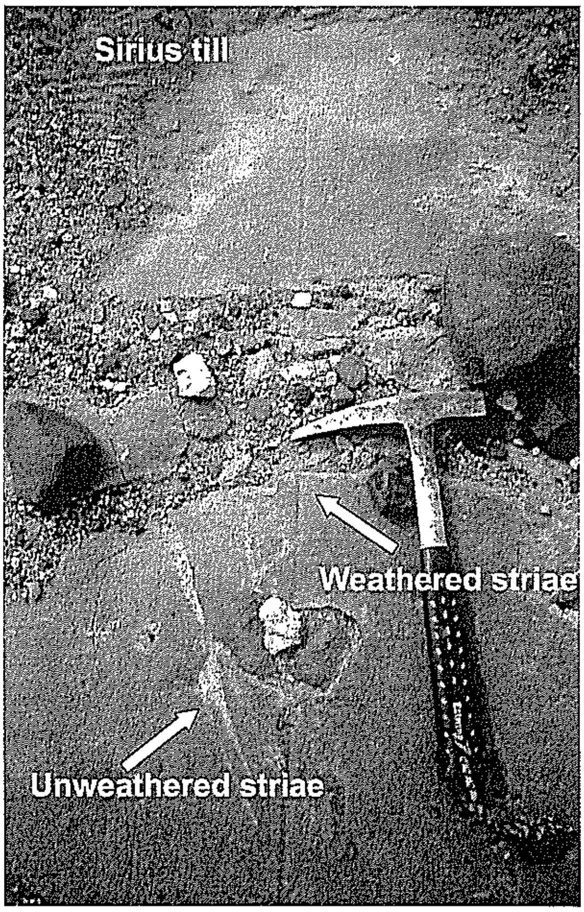


Photo 4. Two distinct sets of striae on a Beacon sandstone surface. NW1 platform.
Photo by Cliff Atkins.

BEDROCK STRIAE

Introduction.

Bedrock abrasion features are found widespread throughout Allan Hills. In addition to measuring the orientation of striae to indicate ice flow direction, other features were recorded in an attempt to characterise and distinguish different sets of striae. This included recording basic dimensions such as length, width and depth, consistency of shape on individual surfaces and comment on the general appearance such as weathering. As indicated by striae found at the NW Platform deposits (see above), the bedrock striae can be grouped into two distinct sets on the basis of shape and weathering appearance. Therefore, striae are recorded on separate tables (Table 3 is weathered striae and Table 4 is unweathered striae). Locations are shown on Figure 6.

Weathered Striae (Boulder ridge and dolerite dyke pavements).

Weathered striae are found on Beacon sandstone surfaces (pavements), on dolerite dykes and on concreted paleosol surfaces. The sandstone surfaces often shows an orange-brown coloration typical of weathered Beacon Sandstone and on some surfaces, individual striae have been widened by wind erosion. The dolerite surfaces display characteristic red-brown wind-smoothed and varnished surfaces.

Striae appear in uniform, sub parallel and parallel sets. On sandstone surfaces, areas up to 3 meters in diameter show cm scale depth and width striae, sometimes with a cover of delicate fine (mm scale depth and width) striae superimposed exactly parallel to the larger striae.

Many of the measured striae are located on a flat-topped ridge of Beacon Sandstone east of the central Camp Valley. This ridge has a prominent 2m high sandstone boulder on top and is referred to as the "Boulder ridge". Five separate striated pavements were recorded on the ridge (Bldrge, pv 1-5, Table 3, Figure 6). Boulder ridge pavements 1 and 3 are on hard dark coloured concreted sandstone paleosols on the top of the ridge. The main striae are of variable length, less than 22mm wide and less than 5mm deep. These striae are covered with parallel fine striae, which are approximately 2mm wide and 1mm deep. Pavement 1 has an azimuth range of only 9 degrees and an average azimuth of 186 degrees. Pavement 3 is of only 3 measurements but shows an average azimuth of 179 degrees. Boulder ridge pavement 2 is on Beacon sandstone and displays striae similar to those above. This pavement is also covered by fine mm scale striae. The azimuth range is again 8 degrees and an average azimuth of 185 degrees compares very closely with that of pavements 1 and 3.

Pavement 4 is exposed on a sloping sandstone surface on the extreme south-eastern edge of the boulder ridge. This pavement again has large striae of similar dimensions to those above and is covered by fine, 3mm wide and 2mm deep striae (Photo 5). The azimuth range for this pavement is 3 degrees and average azimuth is 192 degrees. Pavement 5 consists of well-defined rat tails and one striae. This site shows an average azimuth of 189 degrees and a range of 9 degrees. Pavement 5 indicates ice flow from the north to the south. All of these pavements show a remarkable consistency in orientation with less than 10 degrees variation at each site and 12 degrees between all sites.

Striae were observed on 4 sandstone pavements directly on the southern side of a dolerite dyke that tends north-west/south-east (Dyke pv 1-4, Table 3, Figure 6). Pavement 1 lies near the southern end of the Boulder ridge and consists of clear but weathered striae, up to 860mm in length, up to 27mm wide (usually less than 6mm) and less than 6mm deep. Some have a coating of very fine-grained mud smeared on the striae surface displaying mm scale lineations parallel to the larger striae. The striae extend under a loose, thin (less than 10cm) surface debris layer. The striae give an average azimuth of 185 degrees with a range of 7 degrees. Pavement 2 is similar with clear weathered striae less than 5mm in width and only 1 or 2 mm depth. Average azimuth is 186 degrees with a range of 3 degrees. Pavements 3 and 4 are also similar, with average azimuths of 187 and ranges of 3 and 7 respectively. Striae were also recorded on the dyke itself at 3 locations. These were mostly hairline striae with width and depth less than 1mm. For these striae, orientation only was recorded (Dyke ori 1-3, Table 3, Figure 6). Sites 1 and 2 give azimuths of 187 and 186 close to the average pavement azimuths and site 3 gives an average azimuth of 178 degrees and a range of 9 degrees.

Overall, measurements of weathered striae from the boulder ridge and Dyke area give remarkably consistent striae orientation. The rat-tails on boulder ridge pavement 5 give the only convincing ice flow direction, indicating ice flow from the north to the south.

Unweathered Striae (Ice edge sites).

Contrasting strongly with the weathered, uniform striae are rare, fresh, unweathered abrasion features on Beacon sandstone surfaces (Table 4). These striae are much cruder in shape and orientation. These features range from broad scrape marks up to 160mm wide to narrow deep grooves and gouges up to 20mm deep (Photo 6). Some have crushed sandstone smeared onto the surface, which show fine mm scale lineations. The other notable feature of these abrasion marks is the distribution. They are found around the perimeter of the present "dry" based ice lobe of Manhaul Bay, sometimes on the southern side of hard concretions within the sandstone. Most are within several meters of the ice edge and abundance decreases rapidly away from the ice, with very few more than 20 meters inland. Striae were recorded at 13 sites (Ice edge sites) around the Manhaul Bay ice lobe. The average striae azimuth at each site shows that they tend to fan out from the ice lobe. In addition, the range of azimuths at each site decreases from the central part of the lobe. On the north-western side, range in striae azimuths decreases from 55 degrees at Ice edge sites 1, 2, 3 to 40 degrees at site 4, 39 degrees at site 5, 35 degrees at site 6 and finally 25 degrees at Site 7. Similarly on the south-western side of the lobe, the range at the central Ice edge sites 8, 9, 10 is 41 degrees, decreases to 17 degrees at site 11 and finally 14 degrees at Ice edge sites 11 and 12 (Table 4, Figure 6).

Striae dimension comparison.

Initial analysis of striae dimensions indicate that width and depth of abrasion features can be useful for discriminating striae sets. Overall, weathered striae have less variability than unweathered striae. Weathered striae give width ranges from 1.0 mm to 30 mm with an average of 10 mm. Unweathered striae show a greater range from 3 mm to 160 mm and an average of 27 mm. Also, weathered striae depth ranges from 0.5 mm to 7 mm with an average of 2.6 mm whereas unweathered striae have a range from 0.2 mm to 18 mm with an average depth of 3.5 mm (Figure 7).

In summary, the striae in the central part of Allan Hills can be grouped on the basis of shape, appearance and distribution and orientation into two types:

1. Weathered striae on clasts and bedrock associated with the patches of Sirius till and widespread bedrock surfaces.

2. Fresh, unweathered striae and abrasion on bedrock and till found near the edge of the Manhaul Glacier.

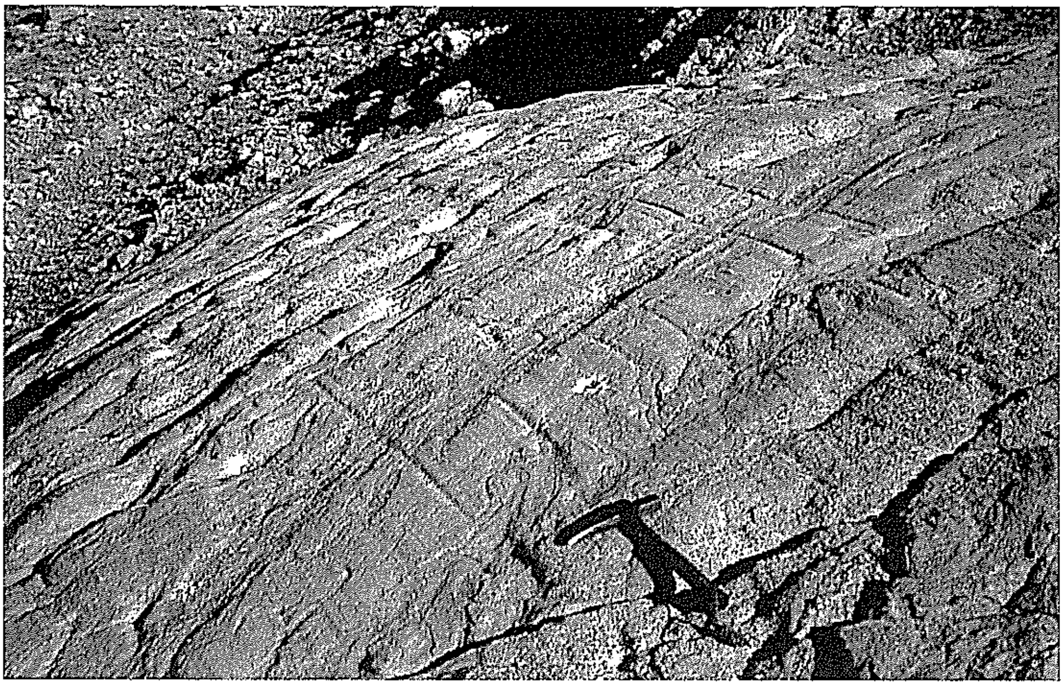


Photo 5. Fine, uniform, parallel, weathered striae on Beacon sandstone
(Boulder Ridge, pavement 4).

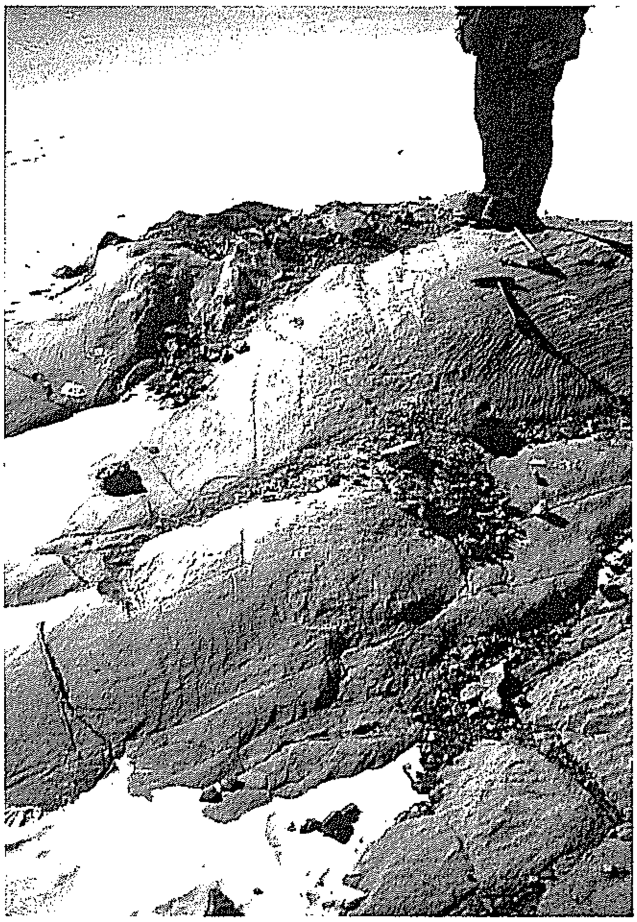


Photo 6. Crude, unweathered striae near the Manhaul bay ice edge.
Photos by Cliff Atkins.

Table 3
Weathered striae on Beacon sst surfaces and dolerite dykes.

Measurements in mm.

No.	Site	Lith'y	Length	Width	Depth	Azmth	Sets	Condition
1	NW1 site, 2	sst	50	NR	NR	167	1	Nailhead, tapers to north
2.1	NW1 site, 4	sst	100	10	3	167	3	NR
2.2	"	sst	385	20	5	203		NR
2.3	"	sst	270	13	3	203		NR
2.4	"	sst	235	7	2	196		NR
3.1	NW1 site, 8	sst	280	9	4	195		Sirius till overlies sst surface
3.2	"	sst	420	30	4	189		Sirius till overlies sst surface
3.3	"	sst	240	6	2	197		Sirius till overlies sst surface
4.1	NW1 site1,13	sst	180	6	1	212		old/weathered
4.2	"	sst	80	8	2	228	2	old/weath'd tapers to south
		Av'ge	224	12.1	2.9	196		
		stddev	124.0	8.0	1.27	18.6		
5.1	BldRge, pv1	sst,p'sol	470	22	3	187	2	clear/weathered. Pavement has
5.2	"	sst,p'sol	470	20	3	181		a cover of fine striae,
5.3	"	sst,p'sol	190	13	3	185		2mm wide & 1 mm deep
5.4	"	sst,p'sol	130	6	2	189		"
5.5	"	sst,p'sol	190	7	5	187		"
5.6	"	sst,p'sol	230	12	2	187		"
		Av'ge	280	13.3	3	186		
		stddev	150.6	6.6	1.10	2.8		
6.1	BldRge, pv2	sst	350	21	3	187	2	clear/weathered. Pavement has
6.2	"	sst	400	20	3	188		a cover of fine striae,
6.3	"	sst	120	6	1	187		1mm wide & 1 mm deep
6.4	"	sst	90	5	1	184		"
6.5	"	sst	140	19	3	188		"
6.6	"	sst	130	17	4	180		"
6.7	"	sst	330	10	3	183		"
6.8	"	sst	130	21	3	181		"
		Av'ge	211	14.9	2.6	185		
		stddev	125.5	6.8	1.1	3.2		
7.1	BldRge, pv3	sst	60	8	2	182		clear/weathered.
7.2	"	sst	60	5	2	177		"
7.3	"	sst	50	4	1	177		"
		Av'ge	57	5.7	1.7	179		
		stddev	5.8	2.1	0.6	2.9		
8.1	BldRge, pv4	sst	1600	18	6	191		clear/weathered. Pavement has
8.2	"	sst	330	20	7	191		a cover of fine striae,
8.3	"	sst	900	16	3	191		3mm wide & 2 mm deep
8.4	"	sst	1300	18	6	193		"
8.5	"	sst	680	17	5	193		"
		Av'ge	962	17.8	5.4	191.8		
		stddev	501.02	1.5	1.5	1.1		
9.1	BldRge, pv5	sst	105	7	3	191	2	clear, delicate rat-tails.
9.2	"	sst	120	7	2	191		NB. Depth measure is height.
9.3	"	sst	160	14	3	195		"
9.4	"	sst	270	11	2	193		"
9.5	"	sst	210	5	1	191		"
9.6	"	sst	270	9	2	191		Striae on rat-tails surface
9.7	"	sst	750	7	3	181		"
9.8	"	sst	120	8	2	187		"
9.9	"	sst	280	11	1	187		"
9.10	"	sst	140	9	1	187		"
		Av'ge	242.5	8.8	2	189.4		
		stddev	190.84	2.62	0.82	3.98		

Table 3 (Continued)

Weathered striae on Beacon sst surfaces and dolerite dykes.

No.	Site	Lith'y	Length	Width	Depth	Azmth	Sets	Condition
10.1	Dyke, pv1	sst	420	6	3	187		clear, sharp on sst near dyke
10.2	"	sst	360	27	5	189		some have grn,gry mud lining &
10.3	"	sst	550	5	6	183		fine striae parallel to large
10.4	"	sst	860	5	5	183		striae
10.5	"	sst	300	5	3	181		"
		Av'ge	498	9.6	4.4	184.6		
		stddev	222.53	9.74	1.34	3.29		
11.1	Dyke, ori 1	dol	NA	NA	NA	7		fine striae, direction only
12.1	Dyke, pv2	sst	290	5	1	186	1	Clear, sharp
12.2	"	sst	340	4	2	185		"
12.3	"	sst	200	4	2	185		"
12.4	"	sst	120	3	1	187		"
12.5	"	sst	140	4	2	187		"
		Av'ge	218	4	1.6	186		
		stddev	94.97	0.71	0.55	1		
13.1	Dyke, pv3	sst	300	4	1	188	1	Clear, sharp
13.2	"	sst	320	6	1	187		"
13.3	"	sst	500	10	2	187		"
13.4	"	sst	360	4	2	187		"
13.5	"	sst	430	13	3	186		"
13.6	"	sst	480	4	2	186		"
13.7	"	sst	200	10	3	187		"
13.8	"	sst	200	10	3	188		"
		Av'ge	348.8	7.6	2.1	187		
		stddev	116.06	3.54	0.83	0.8		
14.1	Dyke, ori 2	dol	NR	1	NR	186	1	fine striae, direction only
15.1	Dyke, pv4	dol	40	1	0.5	192	1	fine, clear
15.2	"	dol	70	3	1	189		"
15.3	"	dol	80	3	1	185		"
15.4	"	dol	80	3	2	185		"
15.5	"	dol	95	2	1	185		"
		Av'ge	73	2.4	1.1	187		
		stddev	20.49	0.89	0.55	3.2		
16.1	Dyke, ori 3	dol	NA	NA	NA	181	1	fine striae, direction only
16.2	"	dol	NA	NA	NA	181		"
16.3	"	dol	NA	NA	NA	173		"
16.4	"	dol	NA	NA	NA	175		"
		Av'ge				177.5		
		stddev				4.1		
No.	Site	Lith'y	Length	Width	Depth	Azmth	Sets	Condition
17.1	Dyke, ori 4	dol	NA	NA	NA	214	1	fine striae, direction only
17.2	"	dol	NA	NA	NA	216		"
17.3	"	dol	NA	NA	NA	210		"
17.4	"	dol	NA	NA	NA	210		"
17.5	"	dol	NA	NA	NA	212		"
17.6	"	dol	NA	NA	NA	209		"
		Av'ge				211.8		
		stddev				2.7		
18.1	Dyke, ori 5	dol	NA	NA	NA	189	1	fine striae, direction only
18.2	"	dol	NA	NA	NA	187		"
18.3	"	dol	NA	NA	NA	189		"
18.4	"	dol	NA	NA	NA	195		"
18.5	"	dol	NA	NA	NA	187		"
18.6	"	dol	NA	NA	NA	192		"
18.7	"	dol	NA	NA	NA	197		"
		Av'ge				190.9		
		stddev				3.9		

Table 4
Unweathered, (Cold?) ice abrasion near Manhaul bay ice lobe.

Measurement in mm.

No.	Site	Lith'y	Length	Width	Depth	Azmth	Sets	Condition
19.1	Ice edge, 1	sst	370	25	4	221	1	Broad scrape
19.2	"	sst	430	8	1	200		Sharp grooves.
19.3	"	sst	430	66	5	205		plough mark with mud coating
19.4	"	sst	200	26	3	212		
19.520.1	Ice edge, 2	sst	230	23	3	201	1	
20.2	"	sst	800	25	2	212		Broad scrape mark
20.3	"	sst	120	50	3	220		short, wide with mud coating
20.4	"	sst	100	30	1	206		clear grooves with mud coating
20.5	"	sst	90	17	3	202		
21.1	Ice edge, 3	sst	1250	160	7	218	2	Broad track, mud smear on surface
21.2	"	sst	60	4	1	200		Clear groove
21.3	"	sst	640	11	2	222		Clear groove
21.4	"	sst	430	20	1	167		Broad mark
21.5	"	sst	230	17	0.5	196		Clear, discrete
21.6	"	sst	150	16	2	213		Clear,discrete
		Avge	368.7	33.2	2.6	206.3		
		S.D	324.0	38.5	1.8	13.8		
No.	**Site**	**Lith'y**	**Length**	**Width**	**Depth**	**Azmth**	**Sets**	**Condition**
22.1	Ice edge, 4	sst	250	20	5	184	2	Deep V shaped groove.
22.2	"	sst	280	35	8	209		Deep groove with mud coating
22.3	"	sst	220	55	6	211		Broad plough mark.
22.4	"	sst	420	15	1	171		Striae skewed off sst butte
22.5	"	sst	160	8	0.2	196		v.shallow scratch
		Avge	266	26.6	4.0	194.2		
		S.D	96.9	18.7	3.3	16.9		
No.	**Site**	**Lith'y**	**Length**	**Width**	**Depth**	**Azmth**	**Sets**	**Condition**
23.1	Ice edge, 5	sst,cn	100	26	9	223		sharp V shape
23.2	"	sst	40	11	0.5	204		short, wide scrape
23.3	"	sst	80	30	1	211		wide, mud lining
23.4	"	sst	420	20	2	195		clear
23.5	"	sst	50	8	3	192		short, sharp, clear
23.6	"	sst	50	15	1	184		mud lining
		Avge	123.3	18.3	2.8	201.5		
		S.D	147.1	8.6	3.2	14.1		
No.	**Site**	**Lith'y**	**Length**	**Width**	**Depth**	**Azmth**	**Sets**	**Condition**
24.1	Ice edge, 6	sst	90	12	1	200		weak but clear
24.2	"	sst	40	10	10	178		deep gouge
24.3	"	sst	530	70	5	197		wide with mud lining
24.4	"	sst	70	26	3	184		
24.5	"	sst	240	40	5	213		Broad plough mark
		Avge	194	31.6	4.8	194.4		
		S.D	203.1	24.6	3.3	13.8		
No.	**Site**	**Lith'y**	**Length**	**Width**	**Depth**	**Azmth**	**Sets**	**Condition**
25.1	Ice edge, 7	sst	290	20	5	205		Clear and broad
25.2	"	sst	230	30	7	190		Broad groove
25.3	"	sst	90	10	2	201		Broad groove
25.4	"	sst	230	35	5	180		Very broad gouge
25.5	"	sst	660	10	2	189		Clear, gouge
		Avge	300	21	4.2	193		
		S.D	214.2	11.4	2.2	10.0		

Table 4 (Continued)
Unweathered, (Cold?) ice abrasion near Manhaul bay ice lobe.

Measurement in mm.

No.	Site	Lith'y	Length	Width	Depth	Azmth	Sets	Condition
26.1	Ice edge, 8	sst	200	20	2	212		
26.2	"	sst	130	4	2	191		
26.3	"	sst	270	22	1	171		
27.1	Ice edge, 9	sst	350	30	3	192		
27.2	"	sst	580	28	3	196		mud lining
27.3	"	sst	800	75	18	185		plough, mud coating
27.4	"	sst	370	8 to 40	6	194		Nailhead, Tapering to north
28.1	Ice edge, 10	sst	1780	46	7	190		
		Avge	560	32.14286	5.25	191.375		
		S.D	537.9	22.7	5.5	11.4		
No.	Site	Lith'y	Length	Width	Depth	Azmth	Sets	Condition
29.1	Ice edge,11	sst	110	3	1	190		
29.2	"	sst	140	65	5	177		
29.3	"	sst	180	14	2	183		
29.4	"	sst	130	10	1	181		
29.5	"	sst	70	6	2	173		
		Avge	126	19.6	2.2	180.8		
		S.D	40.4	25.7	1.6	6.4		
No.	Site	Lith'y	Length	Width	Depth	Azmth	Sets	Condition
30.1	Ice edge,12	sst	170	30	2	173		mud lining
30.2	"	sst	420	90	8	173		Broad plough
30.3	"	sst	400	30	3	162		
31.1	Ice edge,13	sst	NA	NA	NA	179		Directions only
31.2	"	sst	NA	NA	NA	167		"
31.3	"	sst	NA	NA	NA	176		"
31.4	"	sst	NA	NA	NA	176		"
31.5	"	sst	NA	NA	NA	167		"
		Avge	330	50	4.3	171.6		
		S.D	138.9	34.6	3.2	5.8		
No.	Site	Lith'y	Length	Width	Depth	Azmth	Sets	Condition
32.1	NW1 site, 8	sst	360	14	5	177	2	unweathered.
32.2	"	sst	60	5	2	175		"
33.1	NW1 site1,13	sst	40	6	1	189	3	"
33.2	"	sst	140	6	1	195		"
33.3	"	sst	90	4	1.5	203		"
		Avge	138	7	2.1	187.8		"
		S.D	129.7	4.0	1.7	11.9		

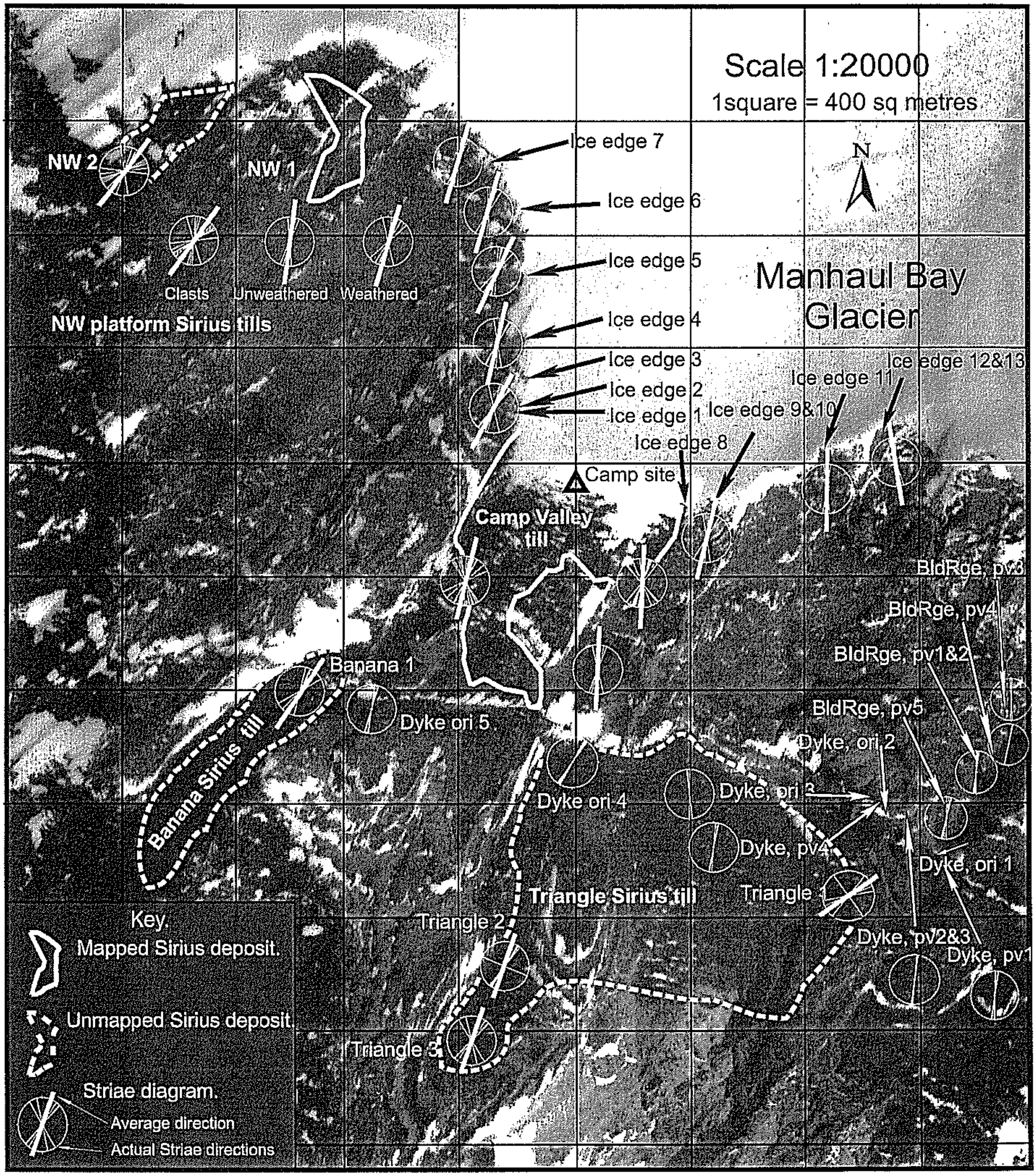
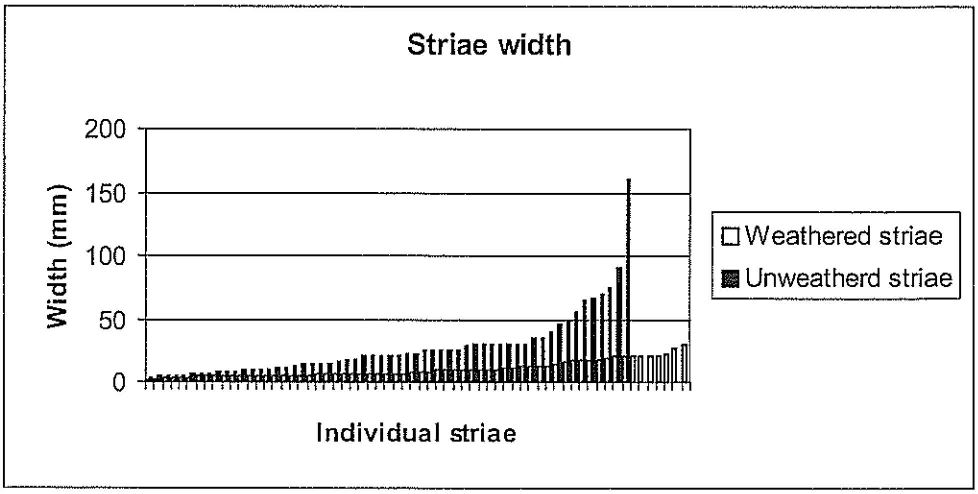


Figure 6. Photomap of central Allan Hills showing summary striae orientations and Sirius till deposits



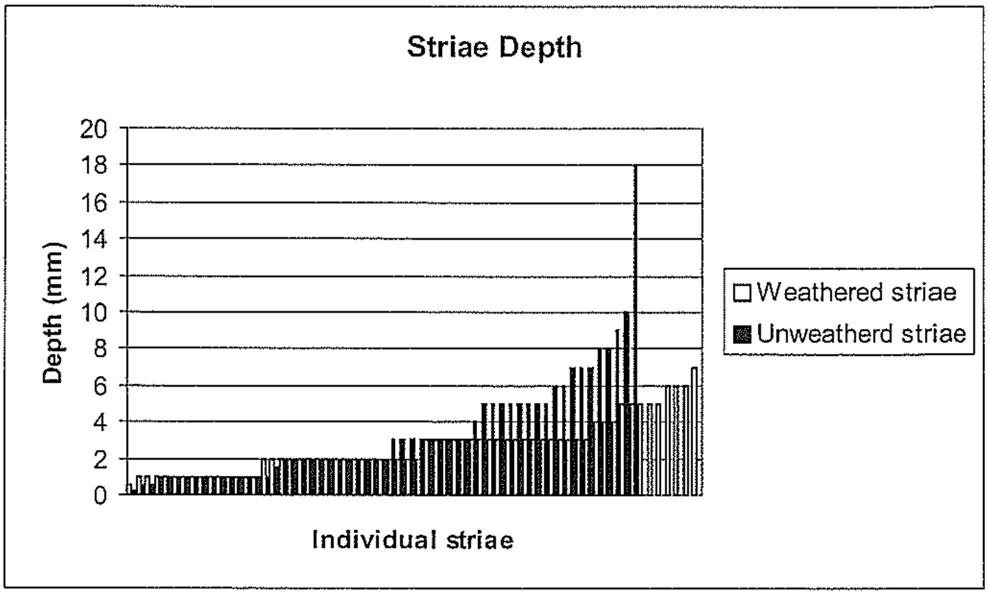


Figure 7, Graphs showing width and depth comparisons between weathered and unweathered striae. Note the much higher variability in range of width and depth measurements for unweathered (dry-based) abrasion marks.

INTERPRETATION OF BEDROCK STRIAE AND DISCUSSION.

Weathered striae.

The common pavements of weathered uniform, parallel striae on sandstone, paleosols and dolerite dykes are found widespread across the central Allan Hills. These are interpreted to be the result of one or more "wet" based ice advances over the entire area, significantly modifying the topography and depositing the Sirius till. This suggests a significantly warmer and thicker ice volume than at present. It seems likely that ice would probably have flowed from the plateau, north over Allan Hills although one site (BldRge pv 5) indicates flow from north to south.

Supporting this interpretation is the similarity and consistency in orientation of individual bedrock striae is characteristic of glacial striae formed at the base of relatively warm sliding ice. The distribution across a large area suggests one large glacial event or multiple glacial events of similar character and direction formed them. In addition, some striae occur on bedrock directly beneath the till and are similar in orientation to striae on lodged clasts within the till. The shape and striae on these clasts indicates ice flow from south to north.

Unweathered Striae (Ice edge sites).

The rare, unweathered, crude abrasion marks recorded at the Ice edge sites are interpreted to represent a rare example of "dry" based ice abrasion from the present cold (dry based) Manhaul Bay ice lobe advancing toward the south. Although the occurrence of "dry" based ice erosion is not widely documented or accepted, a range of factors supports this interpretation at Allan Hills.

The shape and appearance of these striae are very different from the uniform, parallel sets formed by sliding ice, suggesting a significantly different abrasion process formed them. The very limited distribution of unweathered striae around the perimeter (mostly within 20m) of Manhaul Bay ice lobe suggests a connection between this "dry" based lobe and the abrasion marks. Supporting this connection is the "fan" out of average striae orientations and decrease in range of striae directions away from the centre of the ice lobe, suggesting growth of the lobe, rather than unidirectional sliding. In addition, some striae occur on the southern (interpreted downglacier) side of prominent hard asperities such as concretions. These may have providing tools to create abrasion if they protruded into the shear zone of the deforming "cold" ice.

The fresh, unweathered surface of these abrasion features with loose crushed mud coating smeared on the surface is commonly associated with larger amounts of sandstone debris "plastered" on the northern side of in situ Beacon strata abutments at the Manhaul Bay glacier margin (Photo 7). These deposits may represent a dry-based subglacial deposit and further indicates that the margin of the Manhaul Bay glacier has had a more southerly limit in the past and is currently ablating and retreating. The scarcity of these features further inland is interpreted to be the result of removal by wind erosion.

Additional evidence.

Other features also support the interpretation of a dry-based ice advance across the landscape. Large sandstone boulders up to several meters in diameter occur widespread over the central valley and even on top of the Boulder ridge and as far south as Trudge valley.

(Photo 8). No abrasion marks were associated with these. This may be expected if the boulders had been dragged by sliding ice. These boulders are therefore interpreted to have been plucked from the Beacon Strata and passively transported by dry-based ice as in has grown across the area and deposited as the ice has subsequently ablated. Some of these boulders appear to form faint boulder trains. One example is visible trailing from an area of rubble on the southern (interpreted lee) side of the Boulder ridge (Photo 9). These trains suggest ice movement from north to south, overtopping the Boulder ridge and reaching at least 2500m south of the present Manhaul Bay glacier margin. Finally, large piles of loose sandstone rubble are present on exposed bedrock surfaces with little evidence of wind erosion suggesting very recent deposition or exposure from ice cover (Photo 10).

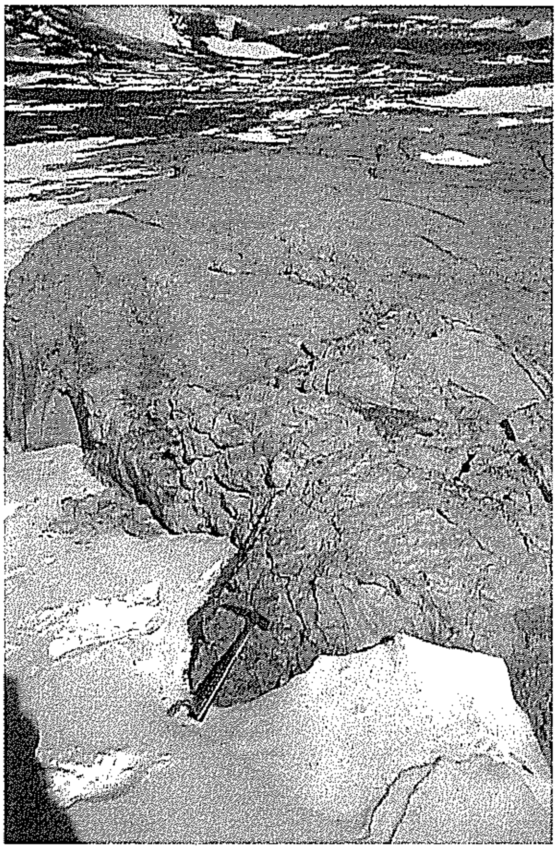


Photo 7. Crushed sandstone smeared onto Beacon abuttment at the Manhaul Bay Ice edge, looking south. Photo by Cliff Atkins.

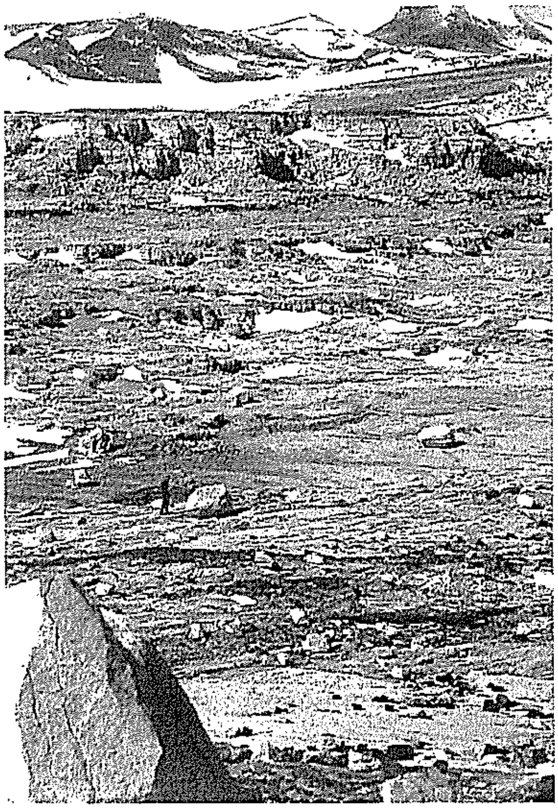


Photo 8. Large Sandstone boulders strewn across the central Allan Hills area, Person in centre for scale. Note the 2m high boulder on top of the ridge (Boulder ridge) in the distance. Photo by Cliff Atkins.

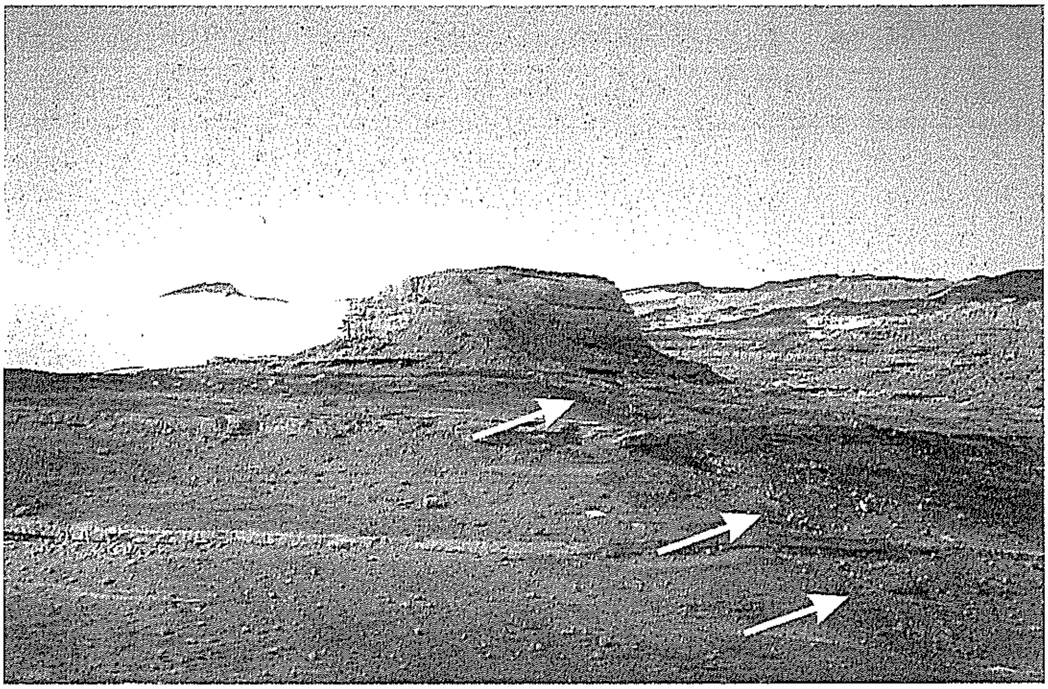


Photo 9. Southern end of the Boulder ridge. Faint boulder trains are visible leading south from the ridge (arrows). Photo by Cliff Atkins.

Photo 10. Pile of loose sandstone debris, with Manhaul Bay ice lobe behind. View looking north. Photo by Cliff Atkins.

SUMMARY.

Geological investigations from the Allan hills during the 1997 season have documented several Sirius Group glacial deposits and mapped two in detail. These are the lowest occurrence of the Sirius Group in the Transantarctic Mountains. Information on the composition, distribution and character of the diamictites, combined with observations of deformed substrate and measurement of glacial striae suggest they were deposited by wet-based ice flowing from the south, overriding Allan Hills. It is clear that there is much scope for more study to fully understanding timing and style of glacial history at Allan Hills.

In addition to the Sirius Group deposits, recognition of other glacial features suggest there has been at least one recent advance of the present Manhaul Bay glacier to the south. Rare abrasion marks around the Manhaul Bay perimeter, primitive subglacial deposits "plastered" onto bedrock, sandstone boulders scattered across bedrock platforms, boulder trains and isolated debris mounds are interpreted to be rare examples of erosion and deposition by cold dry-based ice.

Table 5, Sample list. K 042, 1997, Allan Hills, Antarctica

Field No.	VUW No.	Description
AH 1	37401	Large fossilwood stump
AH 9a	37402	Glossopteris
AH 10	37403	Glossopteris
AH 15	37404	N.W platform 2, bulk sample Sirius Till.
AH 16	37405	Sirius opposite top of banana deposit.
AH 17	37406	Yellow Sirius, mid banana deposit.
AH 18	37407	Granite clast at top of Triangle Sirius deposit.
AH 19	37408	Sirius Till near top of Triangle Sirius deposit.
AH 20	37409	Boulder (cemented sst) upside down in middle of Triangle Sirius.
AH 21	37410	NW 1 site 5 Fabric site, clasts, N.W 1 platform Sirius Till.
AH 22	37411	NW 1 site 5 Fabric site, bulk sample,N.W 1 platform Sirius Till.
AH 23	37412	Camp valley site 50 Fabric site, clasts, Camp Valley Sirius Till.
AH 24	37413	Camp Valley site 50 Fabric site, bulk sample, camp valley Sirius Till.
AH 25	37414	Camp Valley 4 Fabric site, clasts, camp valley Sirius till.
AH 26	37415	Camp Valley site 4 Fabric site, bulk sample, camp valley Sirius Till.
AH 27	37416	Pollen sample, upper till, Trudge valley.
AH 28	37417	Pollen sample, lower till, Trudge valley.
AH 29	37418	Sirius Till, Trudge valley.
AH 30	37419	Bulk sample, lower till, Trudge valley.
AH 31	37420	Bulk sample, middle till, Trudge valley.
AH 32	37421	Bulk sample, upper till, Trudge valley.
AH 33	37422	Striated Permian boulder.
AH 36	37423	Striated clast,N.W 2 platform Sirius Till.

EVENT DIARY

December 2	Party arrives in Christchurch.
Dec 3-4	Flight to Scott base delayed due to weather.
Dec 5	Party flies to Scott Base.
Dec 6-8	Antarctic field training and preparation at Scott Base.
Dec 9	Barrett, Schluchter and Atkins put in and set up camp at edge of Manhaul glacier. Bowman and Tschudi put in with second helo.
Dec 10	Reconnaissance of glacial deposits in central valley.
Dec 11	Mapping, description and sampling of Sirius deposits. Sampling for surface age dating.
Dec 12	Barrett returned to Scott Base for medical attention.
Dec 13-17	Continuation of mapping, description and sampling Sirius deposits on NW platform and Camp Valley. Documentation of abrasion features. Barrett returns from Scott Base on 16^{th}.
Dec 18	Schluchter, Tschudi relocated to Beacon valley for further sampling. TVNZ film crew arrives and joins camp. Reconnaissance of other diamict deposits and "Banana" Sirius deposit.
Dec 19	Mapping, description and sampling of Sirius deposits, abrasion features completed.
Dec 20	Atkins, Barrett and Bowman return to Scott Base. Schluchter and Tschudi return from Beacon Valley to Scott Base.
Dec 21-22	Clean up and debrief.
Dec 23	Party returns to New Zealand.

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