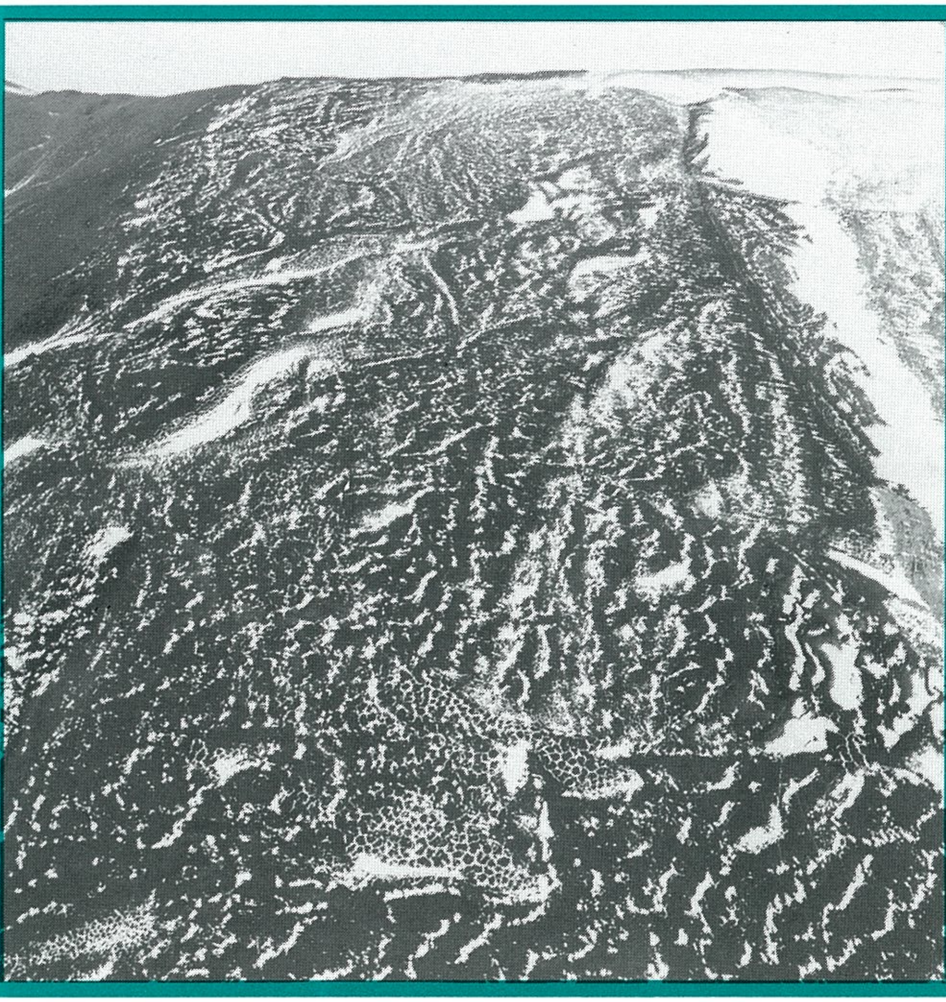
ISSN 0375 8192
Antarctic Data Series
No 19
AUG '97

Edited by Warren W. Dickinson



Field and Scientific Data Report: Sirius Group Study, Table Mountain, Antarctica, Nov-Dec 1996

VICTORIA
UNIVERSITY OF
WELLINGTON
*Te Whare Wananga
o te Upoko o te Ika a Maui*

a publication of:
ANTARCTIC
RESEARCH
CENTRE
School of Earth Sciences

FIELD AND SCIENTIFIC DATA REPORT: SIRIUS GROUP STUDY, TABLE MOUNTAIN, ANTARCTICA NOV-DEC 1996

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Antarctic Data Series No 19

A Publication of the Antarctic Research Centre:

School of Earth Sciences

Victoria University of Wellington

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Frontispiece: ***Looking north at Sirius Group deposits on Table Mt., 4 Dec 1996, by L. Cairns***

ACKNOWLEDGMENTS

My most sincere appreciation and thanks are given to the six other members of the event and contributors of this report, who were largely responsible for the success of the field season. All of the personnel at Scott Base were extremely helpful and provided the support that made the field season possible. In particular, Paul Woodgate in Christchurch and Bridget Troughton at Scott Base were most efficient in shipping extra drilling equipment at the last minute. Numerous discussions with Alex Pyne greatly helped in organizing the field season. Graeme Claridge provided much needed background information as well as the spark that initiated the diamond core drilling. Nine metres of drill rod provided by Jim Cowie and the Cape Roberts Project made the drilling of eight and nine meter holes possible. GPS locations were kindly provided by Terralink and the crew of Vince Belgrave, Lawrie Cairns, and Jerry Simonsen. And finally, sincere thanks to Peter Barrett for continual guidance and saving the PGSF bid from going under in the early stages. Salli Rowe designed the cover for the report. Funding for the event and science was provided by the Foundation for Research, Science and Technology under contract number DIC601.

Warren Dickinson August 1997

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INTRODUCTION

Warren Dickinson

Purpose and Objectives

The main goal of scientific research for the project is to understand the depositional and post-depositional history of the Sirius Group tillite in the Dry Valleys area (Fig. 1). This deposit is at the centre of an intense international debate concerning the extent of the East Antarctic ice sheet three million years ago. In the debate, the dynamic view, which hangs on the *in situ* occurrence of sparse marine diatoms in the Sirius, favours a nearly complete deglaciation of the East Antarctic ice sheet three million years ago. On the other hand, the stabilist view, which claims the diatoms are wind-blown, favours an ice sheet which formed nearly 14 million years ago and retained its shape through until the present day.

The Sirius has ice-free and ice-cemented horizons, yet only ice-free horizons have been sampled for diatoms. The main goal of the field work was to test a diamond drilling technique and core as deep as possible into the ice-cemented horizon of the Sirius at Table Mt (Fig. 1). By comparing the petrology and diatom flora in each horizon together with the stable isotopes of the ice-cement, it will be possible to determine how the diatoms were emplaced and resolve the debate. The ice contained in the Sirius may be the oldest in Antarctica and could provide a record of the climate and atmosphere 3-4 Ma.

Achievements

Six people of Event K047 completed the Antarctic field work in November and December 1996 (see appendices A & B). During 23 days in the field, a total of about 50 metres was drilled, and of this, about 42 metres of core was collected, giving an average recovery rate of 85%. On average, the core holes were 3.5 metres deep, but two of them reached depths of 9.5 and 8 metres. In addition, detailed glacial fabric analyses of the Sirius were made at 12 sites and enough geologic and geomorphic data were collected to provide a detailed map of about four square kilometres on the northwest flank of Table Mt. Hand-held aerial photographs were taken of the area from an altitude of about 3000 metres. Included in the photographs were four GPS positions referenced to the Table Mt trig but accurate to within 0.10 metres relative to each other.

Ground temperatures from the surface to a depth of 3.5 metres were measured in five holes. Measurements were taken at 25 cm spacings down the hole. These were taken for a duration of five days at one hole but for only one to two days at the other holes.

A full coring program at Mt Feather was not made due to the condition of the drilling equipment and high risk of minimal core recovery. However, two pilot cores, 0.8 m and 0.5 m deep established that drilling characteristics of the Sirius at Mt Feather (Fig. 1) were similar to those at Table Mt. This test also established that the success of coring depends largely on the use of compressed air as a cooling and flushing medium for drilling ice-cemented glacigenic deposits.

Another reconnaissance was made to look for Sirius deposits on Knobhead which is directly across the Ferrar Glacier from Table Mt (Fig. 1). Outcrops of Sirius were not found, but the soil regolith at a similar elevation on Knobhead was identical to that on Table Mt. This suggests that the Sirius may have also been deposited on Knobhead.

Preliminary Results and Discussion

Sirius Group deposits on Table Mountain appear to result from both advancing and retreating glaciers. Thin (1-2m) diamictites are interpreted as subglacial and mark glacial advance. Thick (>10m) sandstones with lenses of conglomerate are fluvial or proglacial and mark glacial retreat. The common sequence in both outcrop and core is for the diamictite to overlie the sandstones and conglomerates. Although this sequence may repeat and be partially eroded, it suggests glacial retreat was followed by glacial advance. In addition, the proportion of deposits, which are preserved, suggests that the retreating or deglacial environment was dominant at Table Mt. While the conglomerates probably represent high energy environments, the sandstones, which are volumetrically dominant, appear to have been deposited in low energy fluvial and lacustrine environments.

The diamictites and sandstones appear to control the ridge and hollow topography of the northwest slope of Table Mt. Ridges generally consist of glacial diamictite, covered by a boulder lag, while the hollows consist of a thick (1-3m) soil or regolith with sparse outcrops of sandstone containing thin lenses of conglomerate. However, this topography has been extensively modified by erosion and periglacial activity. The timing and exact nature of this modification remain unclear, however, several mass movements clearly cut across, and therefore postdate, the ridges and hollows (see frontispiece). The conditions that prevailed during this modification as well as those that generated the pervasive patterned ground in the area were clearly wetter and warmer than the present climatic conditions.

Two lines of lithologic evidence suggest that most of the Sirius sediment at Table Mt derives from 20 to 40 km further up the Ferrar Glacier. 1) The abundant coal grains in the sandstone facies probably came from the Weller Coal Measures, which, because of their regional dip and high stratigraphic position in the Beacon Supergroup, crop out 20 to 40 km west of Table Mt (P. Barrett pers. comm. 1997). In addition, there are clasts of Feather Conglomerate, which also crops out near the Weller Coal Measures. 2) Granitic rock fragments, which would derive from a relatively local source at Table Mt, are virtually absent in the Sirius sediments. Although Prentice (pers. comm., 1996) found granitic clasts in the Sirius, these appear to be restricted to a localized area on Table Mt and have not been found in the surrounding outcrops. Thus, the Sirius at Table Mt has an abundance of material that appears to derive from higher in the Ferrar catchment, but little material coming from local sources (P. Barrett pers. comm., 1997).

Petrographic analysis shows that authigenic zeolites, quartz, and calcite occur in various quantities throughout the pore network of Sirius sediments. Pores near the surface appear to result from freeze-thaw processes associated with periglacial activity, while those below three metres formed as the sediment was deposited. For authigenic minerals to precipitate, large volumes of water must have flowed through the pores. While large amounts of water are inconsistent with present climatic conditions, it is consistent with geomorphic observations and deposition of the sandstones and conglomerates. It is also consistent with the significant amounts of ice found in the pores and fractures of the core. Stable isotopic measurements of this ice may help determine the origin of this water.

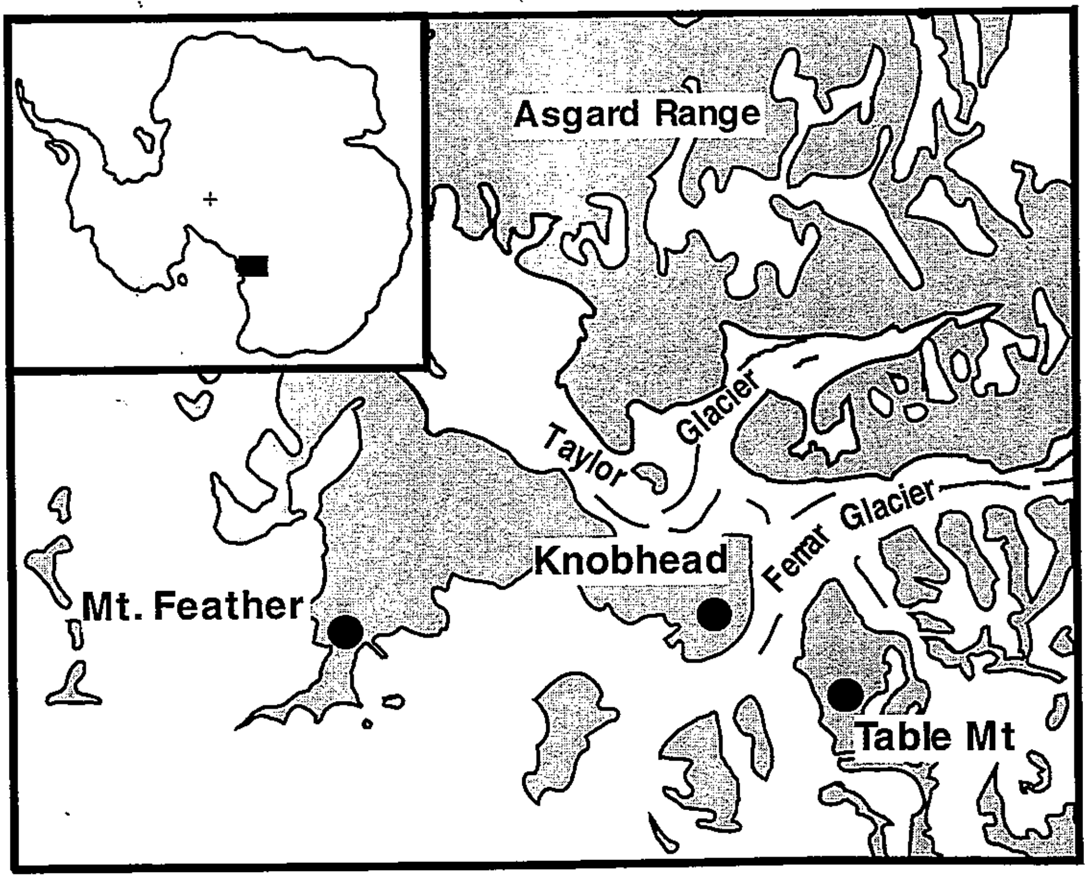


Figure 1. Dry Valleys area showing study locations.

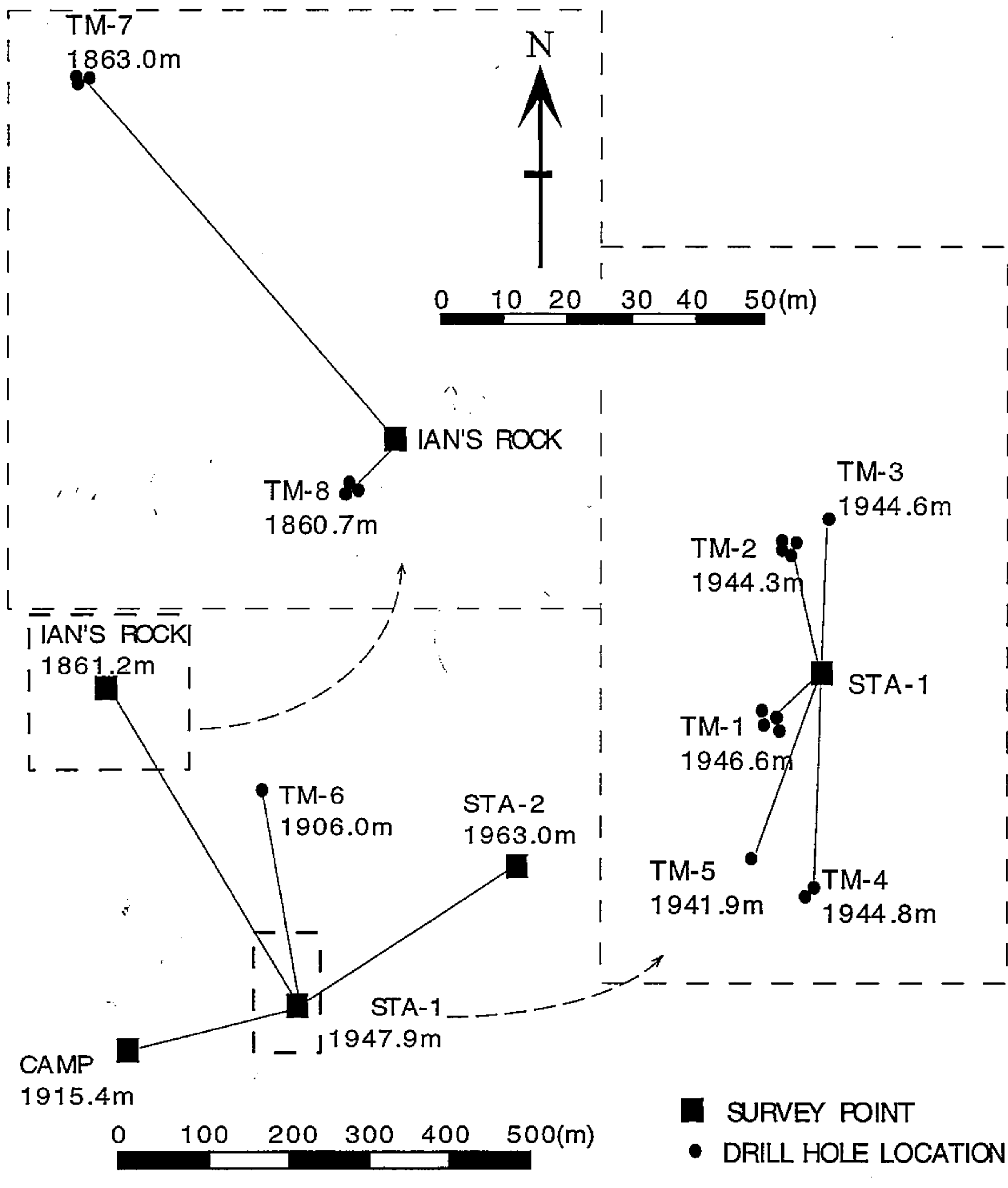


Figure 2. Map of GPS stations and core hole locations at Table Mt (drafted by Ian Jennings).

Unfortunately, the question of the origin of the diatoms in the Sirius cannot be resolved at Table Mt. for two reasons. First, the pore waters that mobilized and precipitated the authigenic minerals would also dissolve and remove diatom frustules. Second, the widespread evidence of periglacial activity, which may be relict of past conditions, could translocate wind-emplaced diatoms from the surface to several metres deep in the Sirius. While core samples from Mt Feather show no evidence of authigenic minerals and mobilization of siliceous materials, they do not penetrate deep enough below the zone of periglacial activity which is evident at the surface.

Recent publications confirm the existence of marine windblown Pliocene diatoms in the ice cap at the South Pole as well as in surface cracks on Palaeozoic rocks in the Dry Valleys area. This effectively discredits the use of diatoms to date the Sirius. However, the possibility remains that the rare Sirius diatoms could be *in situ* but blown, from an unknown source, into to the Sirius as it was being deposited.

Core Hole and GPS Locations

Core holes at Table Mt were drilled in three general areas: Station 1, TM-6, and Ian's Rock (Fig. 2). The Station 1 area (Fig. 3) was selected because it was relatively close to camp, and judging from the outcrop, the Sirius showed a variety of facies which totalled at least five metres thick. TM-1 penetrated three facies of the Sirius and the contact with the underlying Terracotta Siltstone.

Sites TM-2 to 5 were all within 30 m, the length of the compressed air hose, from TM-1 (Fig. 2). TM-2 and 3 were selected to core the Sirius regolith and relict patterned ground. The contact with the Terracotta was not penetrated with certainty in either of these holes. TM-4 and 5 were lateral but stratigraphically lower in the Sirius than TM-1. They were selected to intercept the contact with the underlying Terracotta Siltstone and were drilled before the arrival of additional NQ drill rod, which then allowed deepening of TM-1 and penetration of the contact. The contact was found to be too deep in TM-4 so TM-5 was drilled downslope and resulted in a complete penetration of the contact.

Having drilled core hole TM-1, the two other areas, TM-6 and Ian's rock, were chosen to be in a line of section across the presumed depositional strike of the Sirius (Fig. 2). TM-6 is about 250 m down slope from TM-1. Loose rock and fractures at the surface of the Sirius required several attempts to spud the hole in slightly different spots. When firm sediment was finally cored, the hole was drilled through the contact with the underlying Terracotta Siltstone.

Ian's Rock (Fig. 4) is about 225 m downslope from TM-6. TM-7 was drilled on the crest of a linear ridge of diamictite. This hole penetrated 9.52 m of Sirius but did not reach the underlying contact with the Beacon Supergroup. TM-8 was drilled to determine if lacustrine sediments were deposited in the topographic low next to the TM-7 ridge. The Sirius is not exposed in most topographic lows, however at TM-8 thinly laminated sediments are exposed under Ian's rock, a car sized boulder which protects them from erosion.

Four GPS locations (Table 1; Figs. 2-6) were selected to provide accurate core hole and aerial photographic positions. The locations had to be identifiable from hand held aerial photographs taken later in the day. The four locations were all measured relative to the established Table Mt trig.

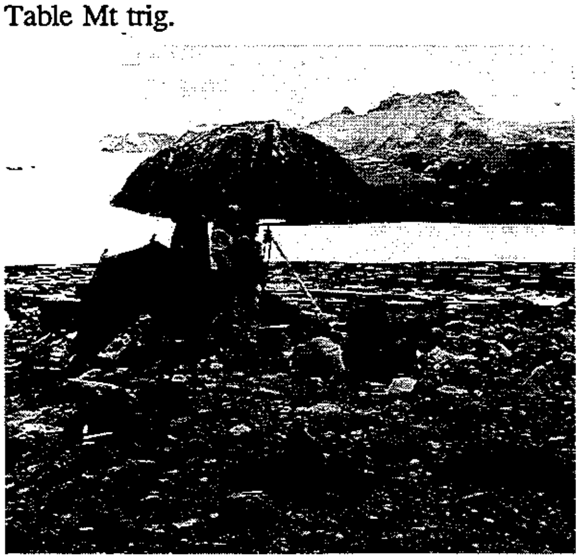


Figure 3. GPS receiver (arrow) at the Station 1 area (courtesy L. Cairns).

Table 1. GPS Positions[1]

STATION	LATITUDE (South)	LONGITUDE (East)	MSL ELEVATION	MAP DISTANCE
Table Mt Trig*	77 58 05.46687	162 02 34.71533	2185.0 m	
Camp	77 57 45.31151	161 58 16.49335	1915.4 m	
Sta-1	77 57 43.00383	161 58 45.58826	1947.9 m	
Sta-2	77 57 37.24841	161 59 24.57931	1963.0 m	
Ian's Rock	77 57 32.69082	161 58 02.01206	1863.0 m	
Sta-1 to Camp				201.4 m
Sta-1 to Sta-2				309.0 m
Ian's to Camp				402.5 m
Ian's to Sta-1				426.4 m
Ian's to Sta-2				552.7 m

[1]Data surveyed by Belgrave, Cairns, and Simonsen 4 Dec - 10 Dec, 1996
*Used as fixed control for the other sites.

The accuracy of the positions stated by Belgrave (pers. comm. 1997) is as follows:

> Latitude is accurate to the nearest 0.5 seconds and the longitude is accurate to about 2.0 seconds. These equate to around 15 metres on the ground. The absolute height relative to mean sea level is within 20 metres. This is absolute position on the earth's surface relative to the coordinate of the Table Mt trig which has the above tolerances. Each of the four stations measured at Table Mt are, however, accurate relative to each other to within 0.10 metres for position and height.

Figure 4. GPS receiver (arrow) at the Station 2 area (courtesy L. Cairns).

Figure 5. GPS receiver (arrow) with Ian's Rock behind it (courtesy L. Cairns).

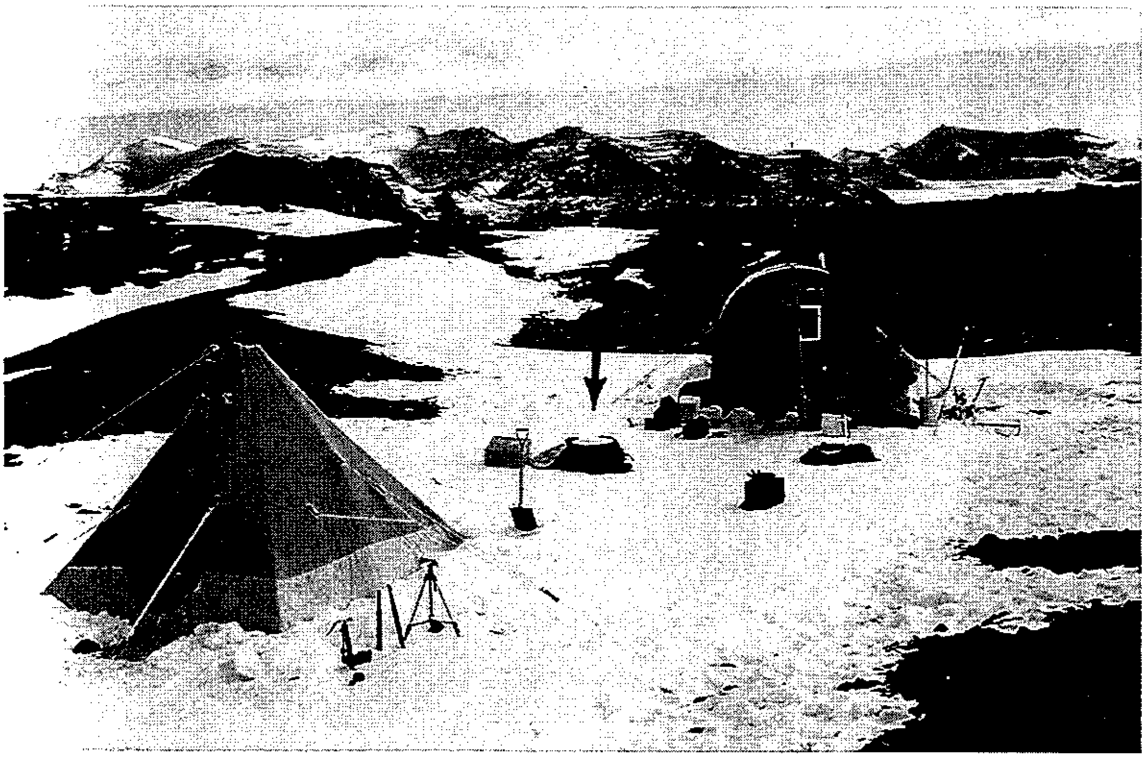


Figure 6. GPS receiver (arrow) at Table Mt camp site (courtesy L. Cairns).

FIELD LOGISTICS AND CONDITIONS

Jon DeVries

CARGO

Approximately 800 pounds of equipment was shipped from Wellington to Antarctica prior to the event. All equipment arrived on schedule and was found to be in good condition at Scott Base. Major pieces of equipment included:

1) Crate containing five Stihl chainsaw motors, with spare parts, assortment of drill bits and reamers, drilling tools
2) Air compressor
3) Sling container of drill rods and core tubes
4) Six insulated core storage containers

PREPARATIONS

Because Jon DeVries could provide field training to the event personnel, it was possible to cover exercises that were directly applicable to the conditions relevant to the field area of the event. Day one of Antarctic field training followed the standard exercises, but the use of fixed ropes on the steep rocky terrain of Observation Hill was covered on day two.

All of the drilling equipment was assembled, tested, and checked out in the vicinity of Scott Base. All other equipment (tents, radios, stoves etc) was checked at Scott Base and was fully operational before departure to the field.

EQUIPMENT

Generally all of the necessary field equipment was at Scott Base and in good working condition. All equipment was thoroughly checked before the event left for the field. Two of the primus stoves, which were issued, were found to be faulty. Of note is that one of them was brand new and had a faulty thread (manufacturing fault) where the burner screws into the fuel tank. This fault was not obvious and only showed up when the stove was hot which caused the thread to loosen and bleed off gas pressure.

The Polar Haven tent was a real bonus on this trip and made it possible to have a warm communal area for cooking and discussion of the day's events. In this particular case, we only set up camp once for the duration of the field season. The following points should be taken into consideration when using a Polar Haven:

1) Erect any other available tents (polar, mountain) before setting up the Polar Haven. This is in case the weather deteriorates.
2) Allow 2 hours to fully erect the tent with at least two people and ideally three.
3) Reasonably calm conditions are needed to erect the tent.
4) Allow 1 hour to take the tent down and pack it away with at least two people and ideally three.

Due to the nature of our field event which involved constant use of drilling gear, we requested extra spill kits and a tarpaulin to minimise environmental damage which could result from leaking oil or gas. However, we were only able to get one very old canvas tarpaulin and one extra spill kit (small size) before deployment. We finally acquired the large size, spill kit refills three days before returning to Scott Base.

To minimise the risk of environmental damage from this type of project, any machinery which is likely to have oil or fuel leaks should if possible have a drip tray. Further protection could then be given by the use of a tarpaulin.

One of the 20 litre containers of kerosene was contaminated with mineral turpentine which appeared to cause incomplete combustion in the primus stoves. All fuel containers 10 litres or larger should be able to either be fitted with a spout or a tap. All human waste needs to be triple bagged to be safe for handling and transportation.

TRANSPORT OPERATIONS

On the whole, helicopter operations ran smoothly once schedules had been worked out. Our main camp moves and some of the drill site moves were done with the 3 Squadron UH-1H and went very smoothly and efficiently. There was a one day delay, due to weather, for our pull-out of the field.

The set-up in the BH 212, with the rear facing seats and the permanently fitted auxiliary fuel tank, limited its effectiveness when it came to moving cargo as an internal load. The other problem with the rear facing seats was that it was difficult to give the pilot directions when trying to locate a landing site for close support work. The lack of any ground to air communication with the BH 212 made it difficult to work with when the helicopter was approaching our camp or drill site and when moving drill gear from site to site.

For a moderate sized event such as this one, it was extremely useful and efficient to have a spread-sheet with all the helicopter loads for the put-in (Table 1). This information was also made it much easier to figure out loads for the pull-out. A copy of Table 1 was given to Rex Hendry.

COMMUNICATIONS

After initial problems with an intermittent transmitter, communications with the Tait handheld radio and high-gain aerial, using the Mt Newall (Ch. 5) repeater, proved to be reliable from our camp site. High frequency communication was not successful from our location. The Tait radios were also used for communication between team members away from base camp.

In general the transfer of requests and information given over the radio were passed on to the appropriate people at Scott Base. However, on occasion this did not appear to happen. The format of the scheduled radio check-in was at times inconvenient for our event because we were still drilling. On numerous occasions when contacted for the evening check-in we explained our situation and requested leave of the weather and news. This was noted and given approval by the base operator. Then after the reading of the new and weather, we would be repeatedly called until we acknowledged the weather and news. This situation would not have been a problem except that we had to again stop work and go to the closest high point to transmit. A solution to this problem would be for Scott Base to contact all field parties and then pass on the weather and any messages to all parties, get an acknowledgment, and then anyone who wanted to listen to the news could do so. However, I believe the news is an important part of the communications set-up and should be continued.

FOOD

The quantities of food taken into the field were certainly adequate. With the addition of the extra food (tortillas etc.), which the event supplied, there was a good variety. Unfortunately, we didn't count on the meat eating appetite of the ravenous hell driller from the West Coast. Only major complaints were not enough cheese due to a supply problem, and too many munchy bars which was our fault.

DRILLING OPERATIONS

If the same system is used down to a depth of nine metres and at higher altitudes, the motor for the drill rig needs to be larger because it was working at its maximum capacity at 2000 metres. The Stihl 056 motor which was used to drive the compressor would probably be suitable. This system also needs modifications to the air cooling system. The simplest of these would be to extend the air intake away from the warm air environment created by the compressor.

The Winkie Drill tripod supplied by ANTNZ was also used beyond its safe working load at these depths. Unless the legs of the tripod can be braced at mid-height, the leg with the attached winch will bow out dangerously. The loading on the tripod was also increased by the addition of a block in the system to give a 2:1 ratio. The winch on the tripod is reasonably light weight and should be more robust for future drilling projects of this nature.

Table 1. Load schedule for K047 launch

	Weight	Quantity	Total	Load 1	Load 2	Load 3	Load 4
Camp Gear							
Scott Tent	85	3	255	170	-	85	-
Olympus	28	1	28	-	28	-	-
Sleep Kit	17	5	85	34	34	-	17
Kitchen	42	2	84	42	42	-	-
Stove	18	2	36	18	18	-	-
Shovel	4	3	12	8	4	-	-
Warratahs	21	1	21	21	-	-	-
Radios	21	2	42	38	4	-	-
Water Bot	3	2	6	-	-	6	-
Crapper	8	1	8	8	-	-	-
Safety	65	1	65	-	-	65	-
Spill L	7	1	7	-	-	7	-
Spill S	2	2	4	2	2	-	-
Flags	12	1	12	6	-	6	-
Towels	20	1	20	20	-	-	-
U Barrel	17	3	51	17	-	-	34
Books	23	1	23	-	-	-	23
Cheese	10	1	10	-	-	10	-
Oxy Bott	26	1	26	-	-	-	26
Acet	25	1	25	-	-	-	25
Gauges	5	1	5	-	5	-	-
Extinguish	35	2	70	35	35	-	-
Med Kit	14	1	14	14	-	-	-
Comp Oil	6	1	6	-	-	-	6
Med Ox	20	1	20	20	-	-	-
PolarHav	248	1	248	-	248	-	-
Kero Heat	30	1	30	-	30	-	-
Drill Gear							
Pipe Rack	825	1	825	-	-	825	-
Compress	370	1	370	-	-	-	370
Box 1	113	1	113	-	-	-	113
Box 4	112	1	112	-	-	112	-
D1	109	1	109	-	-	109	-
D2	38	1	38	-	-	38	-
Pallet	425	1	425	-	425	-	-
Tool Box	46	1	46	46	-	-	-
Food							
Box Red 1	52	1	52	52	-	-	-
Box Red 2	65	1	65	65	-	-	-
Box Red 3	74	1	74	74	-	-	-
Box 5	122	1	122	122	-	-	-
Box 6	118	1	118	-	118	-	-
Box 3	128	1	128	128	-	-	-
Booze	17.5	1	17.5	17.5	-	-	-
Fuel							
Kero 25L	50	1	50	-	50	-	-
Kero 15L	29	1	29	29	-	-	-
Kero 20L	39	1	39	-	-	39	-
Kero 60L	143	2	286	-	-	143	143
Premix60	140	4	560	-	-	140	420
Pax	200	5	1000	400	400	-	200
Survival	54	1	54	-	-	-	54
Pers Gear	70	5	350	140	140	-	70
TOTALS			**6195.5**	**1526.5**	**1583**	**1585**	**1501**
Pax				Jon	Ian	-	Pat
				James	Warren	-	-

SAFETY

The terrain of the area was relatively safe. All party members were either in visual or radio contact at all times when we were doing field work on Table Mountain. However, any project which involves the use of machinery has industrial type risks. The project was completed without any injuries which is a reflection of the teamwork and competence of those involved in the project. The only medical problem was an pre-existing eye condition, which could have been aggravated by the exhaust fumes from the drill motor.

In the future, if the same drilling system is to be used again, the exhaust system of the drill motor needs to be modified so that it is vented away from the drilling personnel. There is also a risk of burns from the present exhaust system. Another recommendation for projects of this nature is that all personnel involved in drilling should wear steel capped Sorrels and safety helmets with attached grade 5 hearing protectors.

WEATHER

In general, weather conditions at Table Mt were mild enough to allow field work nearly the entire time (Table 2). However, the conditions were often very localised with warm coastal air masses moving up the Ferrar Glacier and cold Polar Plateau air masses flowing down the glacier. When these two air masses met in the Table Mt area, they would cause a local build-up of Stratus or Stratocumulus clouds. This would commonly occur from mid morning to late afternoon. This weather pattern occurred about 30% of our total time in the field. These conditions would sometimes result in light snowfall.

During the field season, no winds above 25 knots were experienced even though reasonably strong katabatic winds could be seen and heard blowing down the Ferrar and Tedrow Glaciers. The wind was predominantly 5 knots from the south west.

Table 2. Weather at 0900 for days in field

Date	Temp °C	Wind Knots	Wind (Dir)	Cloud Cover	Cloud Type	Precipitation	Cloud Base	Pressure mB
25 Nov	-15	5	W	8/8	Sc	0	6200	-
26	-11	< 5	SW	8/8	Sc	0	6000	776
27	-11	5	N	8/8	Sc	0	7000	774
28	-13	5	SW	6/8	-	0	10000	772
29	-12	5	SW	1/8	C	0	-	767
30	-15	5	SW	7/8	Cs	0	15000	776
1 Dec	-12	< 5	W	5/8	C	0	-	767
2	-13	5	NW	8/8	Sc	light snow	< 6000	769
3	-10	0	-	0/8	-	0	-	-
4	-13	5	SW	1/8	Cs	0	-	778
5	-8.5	5	SW	0/8	-	0	-	770
6	-13	< 5	SW	7/8	Cs	0	17000	767
7	-12	10	W	7/8	Cs	0	17000	776
8	-13	< 5	-	7/8	Cs	0	18000	769
9	-15	5	SW	2/8	C & Sc	0	-	769
10	-15	5	NE	1/8	C	0	20000	774
11	-15	20	SW	1/8	C	0	20000	775
12	-15	< 5	-	8/8	Sc	0	10000	776
13	-14	< 5	S	8/8	S	light snow	< 6000	776
14	-12	20	SW	1/8	C & Sc	0	-	779
15	-12	< 5	NE	6/8	S	0	8000	777
16	-11	0	-	0/8	-	0	-	776
17	-13	< 5	NW	8/8	S	0	8000	776
18	-16	< 5	SW	8/8	S	0	8000	773

- Observation missing or not recorded

PRELIMINARY GEOLOGY AND SEDIMENTOLOGY OF THE SIRIUS GROUP, TABLE MOUNTAIN

James Goff and Ian Jennings

Summary and Interpretation

Sirius Group deposits on Table Mountain appear to result from both advancing and retreating glaciers. However, the topography is largely the result of glacial retreat and includes patterned ground, water-lain deposits, and mass movement features. Cores taken through the Sirius Group should help explain the role played by water in ice advance and retreat at the site, and in dating the event.

Fabric data from deposits at the southern end of Table Mountain indicate that this area was a confluence zone for ice emanating from the directions of the contemporary Tedrow and Ferrar Glaciers. However, the imprint of "Ferrar" ice dominates Sirius Group sediments at Table Mt. Other minor contributions of sediments were made from small mountain glaciers emanating from the saddle area between Table Mt and Navajo Butte. We believe that ice from these sources may have been sufficient to occupy an anomalous hollow which is devoid of glacial deposits. This hollow lies directly southeast of the long continuous ridge and highest outcrop of Sirius at Table Mt (Figs. 1 & 2)

Deposits that contain a small percentage of granitic clasts are found several hundred metres upslope from the prominent dolerite sill at Table Mt (Fig. 1). The abundance of granitic clasts appears to increase down slope suggesting it was sheared up by glacial flow immediately downglacier of a confluence zone. Fabric measurements, taken from south to north along the length of Table Mt, indicate a reorientation of ice flow from west to southwest. Reorientation was caused by Table Mt obstructing ice flow which has resulted in the deposition of thrust-faulted lodgment tills and associated deposits. Lodgment and thrust-faulting may represent a period of glacial advance.

Ice retreat and down wasting has left an extensive ridge and hollow topography. Ridges generally consist of glacial diamictite, covered by a boulder lag, while the hollows consist of either conglomerates or sandstones. The deglacial environment appears to be dominated by water-lain deposits of which the conglomerates and sandstones suggest that both high and low energy regimes were involved.

Four distinct mass movement features cut across the ridge and hollow topography (Flow Structures, Fig. 1). Patterned ground, pervasive throughout the Table Mt area, is most prominent on these mass movement features but less prominent on the ridge and hollow topography. It is not clear if the degree of prominence expressed by the patterned ground, represents different degrees of activity, different ground materials, or different periods of generation.

Specific Notes and Interpretations

a) Till came from Ferrar Glacier in the west and turned the corner at Table Mt. Sirius deposits are plastered on valley side - and all ridges are oriented from SW-WSW (as is much of the tillite) all these ridges parallel to Table Mt and may represent lateral/medial moraines. Highest lateral moraine (main ridge) may represent the maximum extent of Sirius up valley side. This is medial for Navajo Butte and Table Mt glaciers and the main Sirius. Ridges at right angles to main ridge may represent recessional moraines.

b) As ice retreated it left oversteepened slopes which were prone to mass movements and sliding. The mass movement features truncate the ridges and lower sill two places. No Sirius is found in areas of mass movement.

c) There are several areas where clasts of unique provenance are found. The area of granitic clasts may represent clasts sheared up by glacial flow from beneath sill and the end of ice front at time. This is nothing special, just localised layer of basal ice shear remained intact. This type of shear is likely when two glaciers join. On top of till ridges there are lineations of clasts that are weathered surface expressions of thrust faults.

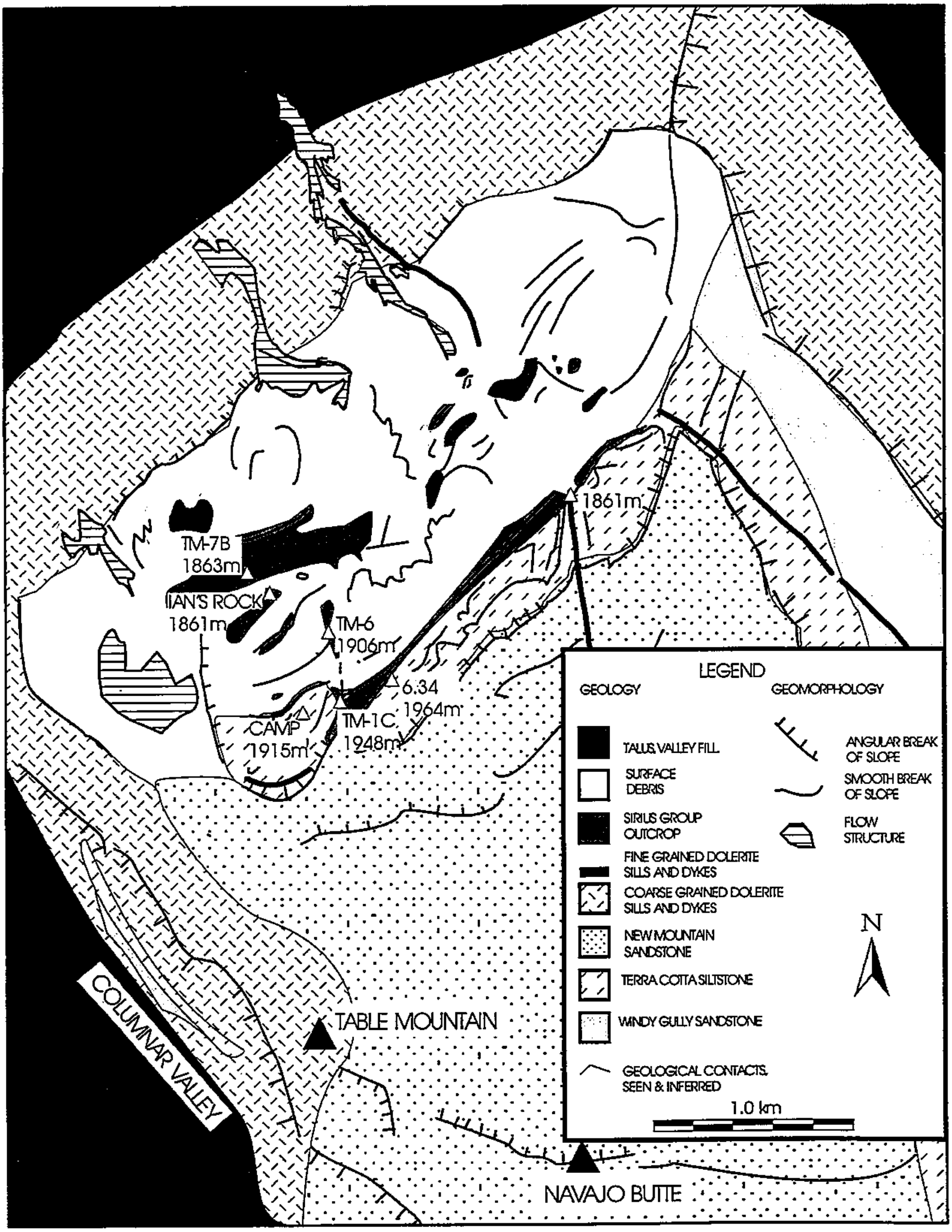


Figure 1. Geology of the northwest flank of Table Mt.

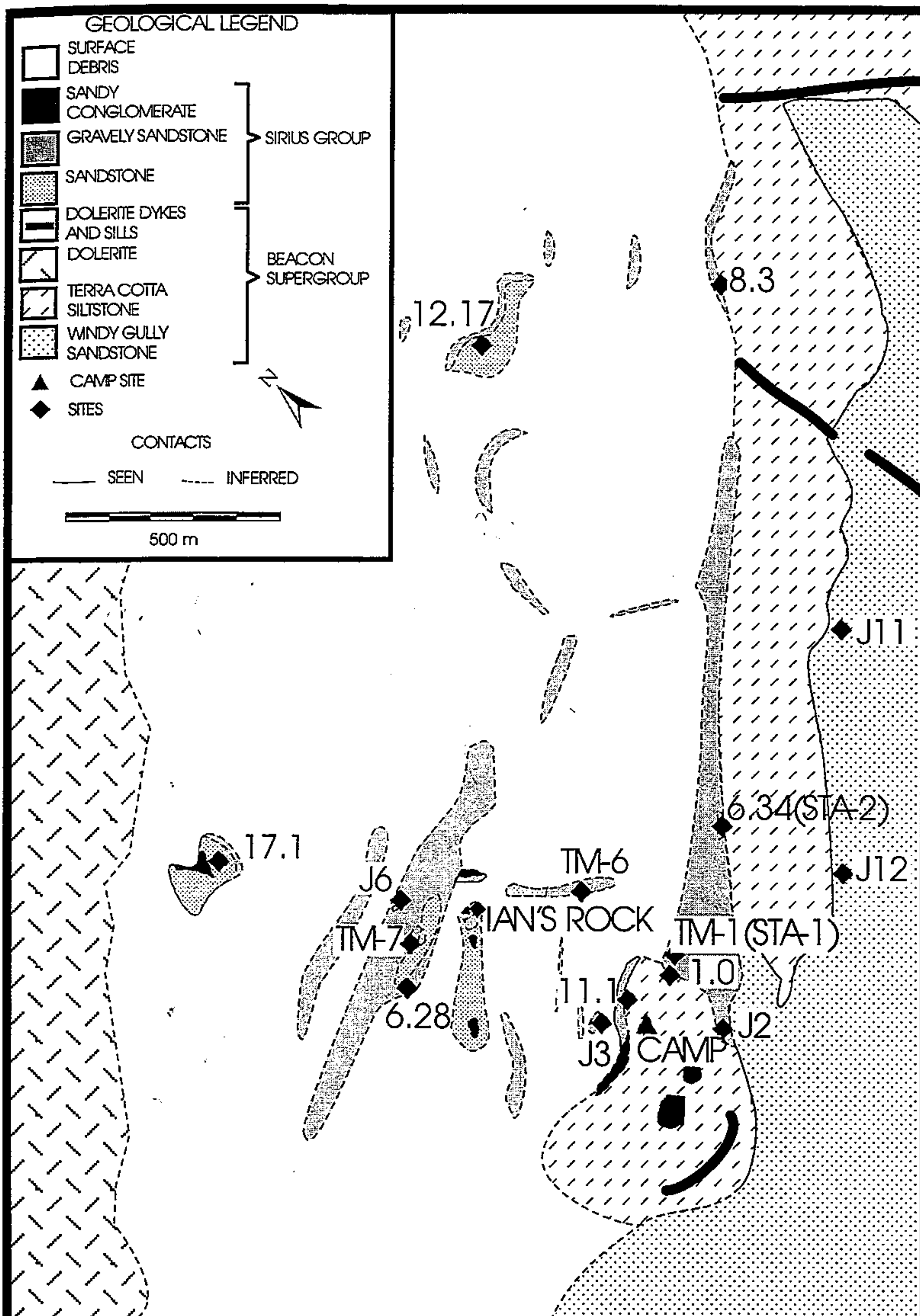


Figure 2. Geology and site locations of descriptions and samples.

d) Sirius tillite found on most ridges. In the hollows, the ridges are small and may represent frozen till blocks that melted out later were later surrounded by meltwater. Patterned ground is not found on top of ridges but found everywhere else. In hollows Sirius is mainly found under large boulders where it has been protected.

e) Large shears are actually thrust faults which are usually sand filled, and contain brecciated clasts. Thrust faulting generated by lodgement of large units of lodgement.

f) In general, patterned ground areas (excluding those in meltwater/mass movement sites) have thin veneer Sirius/reworked Sirius? Patterned ground is found nearly everywhere - most prominent on mass movement material, probably due to amount of water around after flow, made good patterns. Patterned ground appears to be a combination of freeze-thaw and ice wedging. Frost cracking evident in the New Mt sandstone; also freeze-thaw in sill material where weathered. Coarse clasts around edges of polygons, few fines in cracks. Patterned ground appears still active in some places, but not clear how to measure different degrees of activity

Ian's Rock Area (TM-8):

Ian's rock is one of many large (up to 5m dia) boulders which appears to be ice-rafted and protects underlying material. Such boulders do not appear to have been lodged. They are a mixture of iceberg rafting into moraine-dammed lake, or marooned iceberg rafted clasts surrounded by conglomerate - these may have fallen from the sides of adjacent tills ridges and be associated with general hummocky terrain during deglaciation. Most of the boulders such as Barrett's dropstone in the area, lie on and protect either conglomerates or fine grained, thinly laminated sediments -lacustrine? In places, the fine grained sediments are shaped/deformed around the base of the boulders. This gives the appearance that the boulders depress these sediments and may have been dropped into place. Presumably the boulders are ice marginal as opposed to ice contact. Today these large boulders are sometimes associated with low ridges within the hollows, so are distinguishable from the larger till ridges. Conglomerate is patchy - related to ice melt - and is most extensive in depression just south of Ian's Rock.

Soil Profile at TM-2:

The TM-2 drill site is in an area of patterned ground which is moderately well developed on most of the Sirius Group deposits. Polygons are 1.25 m in diameter and appear to retain their pattern on slopes up to 5-10°. One warm, sunny afternoon at the site, we noticed melt water trickling off rocks and into the ground. Digging into the ground we found the melt water penetrated to about 17 cm deep. Below is a description of the soil profile at this spot of meltwater penetration:

Top layer (0-5cm)
- Coarse boulders, a general coarsening upwards. Clast orientations wedge up beside the clast to west.

Upper section (5-10cm)
5YR 5/2 - More horizontal @15°, coarser clasts, many platey with beds deformed under platey clasts.

Middle section (10-20cm)
5YR 4/2 - bedding/lineations more vertical - 45-60°.

Lower section (20-30cm)
Reddish-Brown 5YR 5/3 - bedding/lineations - nearly horizontal, fine powdery appearance, poorly consolidated.

Sedimentological Sites

(note: refer to figure 2 for site locations; site elevations were measured by a barometric altimeter which was tied into GPS elevation at base camp)

Site: 1.0

Location:

Elevation is 1935 m on SW side of main ridge between camp and TM-1; 2.5 m above Sirius contact with Terra Cotta (contact = 1932.5 m); outcrop size = 2 sq m.

Description:

The outcrop is massive, light pinkish brown, bimodal, muddy, gravelly, medium to fine sandstone. Clasts make up 15-25% of the rock, and range in size from granules to cobbles, although the average size is about 5 cm. Clasts range from sub-rounded to angular, but are mostly sub-angular. These are matrix supported in a well sorted medium to fine sandstone. Clast lithologies are predominantly dolerite (60%) with some sandstone (30%), and quartz (10%). The outcrop is cut by a shear zone 2-3 cm wide containing shale breccia in a matrix of poorly sorted, muddy sandstone. The sides of the shear zone are sharp and planer. Shears planes filled with oriented sandstone fragments and coarse sand/gravel; Many striae, top and bottom of clasts, fissility throughout; squeeze flow into base of unit; Some flame structure. Overall Colour: Light grey 7.5YR 8/1.

Clasts: n=54

Sphericity: 0.59 Roundness: 0.55 Mean a-axis: 17.8 cm Eigenvector: 217°, S1= 0.75

Interpretation:

Predominantly lodgement - initially deposited from Tedrow direction, suggest that this has been reworked by ice from Ferrar. Stereonet indicates that while eigenvector suggests from SSW there are clasts from S to W. This spread on the skirt is indicative of lodgement, as are the signs of active lodgement (shear, water escape, striae). Shear planes indicate that main force came from west and both upper and lower striae indicate that there has been some reorientation. The striae from the west overlie striae from the SW so there appears to have been a reorientation of clasts or initial lodgement followed by reworking and subsequent lodgement from the west.

Site: TM-1 (GPS Sta-1)

Location:

Elevation is 1948 m on SW side near top of main ridge; about 15 m above contact with underlying Terra Cotta (contact = 1932.5 m). Outcrop size = 5 sq m.

Description:

This outcrop comprises three units, which are separated by two sub-parallel shear zones about 0.5 m apart. The shear zones are very thin (2-3 mm), and consist of poorly sorted, muddy, fine sandstone. The three units appear similar the unit at Site 1.0. However, they do not have the same clast content. In the lowest unit, clasts make up 5% of the rock. The second unit, which lies between the two shear zones, contains 15-20% clasts. The top unit contains 5% clasts.

Interpretation:

Three units are distinguished and they are separated from each other by sand-filled shear planes. Base unit is from Tedrow ice. Middle unit is from Ferrar dominating over Tedrow ice. Upper unit is from Ferrar ice. This site shows domination by Ferrar ice but Tedrow ice arrived first.

Unit: TM-1a (base)

Description:

Top and bottom striae; shear planes (sand-filled); some fissility. Overall colour: Light grey 7.5YR 8/1.

Clasts: n=51

Sphericity: 0.63 Roundness: 0.57 Mean a-axis: 11.6 cm Eigenvector: 290°, S1= 0.46

Interpretation:

Predominantly viscous lodgement - deposited from Tedrow direction, with some slight reworking in upper part of unit. Water in viscous slurry, lodging plus flow lobes of squeeze flow. Rollers and sliders evident in flow lobes. Much squeeze flow downglacier of lodged clasts, very wet. Water escaping into the shear plane above in several places. Squeeze flow/viscous lodge from SW. Eigenvector stereonet indicates that ice movement was from SW. Some rollers/sliders reduce strength of eigenvector - likely viscous rotation going on here - some clasts near vertical. Most striae are from SW although some striae (and clasts) in upper part of unit at contact shear plane are reoriented by flow from W.

Unit: TM-1b (shear)

Description:

Sand filled; flame structure into overlying and underlying unit: Light grey 7.5YR 8/1. Overall colour: Light grey 10YR 8/2; Estimated mean a-axis: 2cm

Unit: TM-1c (middle)

Description:

At least 3 upward shears of sand from below. Striae found on two clasts only. Overall colour: Light grey 7.5YR 8/2.

Clasts: n=52

Sphericity: 0.64 Roundness: 0.58 Mean a-axis: 29.2 cm Eigenvector: 272°, S1= 0.58

Interpretation:

Predominantly viscous lodgement - deposited from Ferrar - although some suggestion that there was an initial Tedrow deposition. Appears to be a Ferrar overriding of Tedrow ice. Some clasts rotated at top of viscous medium, with a second set of striae crossing produced when rotation caused by an overriding unit. Eigenvector stereonet indicates that ice movement was from W. Some rollers/sliders reduce strength of eigenvector - likely caused by viscous rotation - many clasts near vertical. Most striae are from W although some striae (but no clasts) in unit show ice from SW - these might be indicative of initial deposition by Tedrow ice.

Unit: TM-1d (shear)

Description:

Sand filled shear. General colour: Light grey 7.5YR 8/2. Estimated mean a-axis: 2cm

Unit: TM-1e (upper)

Description:

General colour: Light grey 7.5YR 8/1

Clasts: n=51

Sphericity: 0.63 Roundness: 0.58 Mean a-axis: 29.8 cm Eigenvector: 279°, S1= 0.69

Interpretation:

Strong lodgement from Ferrar direction. Some clast rolling during deposition. Large clast at LHS lodged and underlain material warped up/deformed beneath it in direction of movement. Strong lodgement deforming layers underneath. Eigenvector stereonet indicates that ice movement was from W. There is a fairly recognisable skirt around edge. Some rollers/sliders reduce strength of eigenvector, but also a rare clast oriented to SW - it seems likely that these have reoriented during post-depositional settling - some striae are found with crossing striae from W - these are on rollers which suggests that they were rolled during deposition and were originally oriented from W - not Tedrow ice.

Site: J2

Location:

Elevation is 1943 m about 115 m south of TM-1 on a sub-vertical face just below the ridge top. Outcrop area = 10 sq m.

Description:

The unit is a light pinkish-brown, poorly sorted, medium to fine sandy conglomerate. Clasts make up 10-15% of the rock, are matrix supported, and range in size from granules to large cobbles, although the average size is about 4 cm. Clasts range from sub-rounded to angular, but are mostly sub-angular. Clast lithologies are predominantly dolerite (70%) with some sandstone (10%), and quartz (20%). The unit is strongly stratified with fine laminated bedding that is sub-horizontal and on a mm to cm-scale. This is continuous other about 4 m. Some of this bedding is deformed into very gentle folds, and it has also been deformed both below and above many clasts. The unit also contains lenses of sandy conglomerate. These are 5-25 cm thick, and contain 30-50% clasts, supported in a matrix of well-sorted, fine sand. Clasts are predominantly pebble size, and are mostly dolerite, with some quartz, and sandstone.

General colour: Grey 2.5YR 7/1

Clasts: n=51

Sphericity: 0.62 Roundness: 0.57 Mean a-axis: 20.6 cm Eigenvector: 290°, S1= 0.60

Interpretation:

Predominantly flow till, iceberg rafted material related to Ferrar ice material. Reworking = diamictite, ice marginal. Dropstones adjacent to New Mt Sandstone. This is an ice marginal lake - sandwiched between lateral moraines (J1) and bedrock. Contains till balls and layers of coarse runoff/ice rafted deposits. All Sirius lithologies - transition to debris flows. Ploughed clasts from NW suggest sliding/ice rafting off lateral moraine - dropstones measured for orientation - mainly SW/W/NW - off lateral moraine. Some retention of fabric as short travel distance. Ice rafted clasts show deformation of underlying (wet) unit from NW. Same orientation for till balls - likely to represent one iceberg-rafted unit on top. Gravel rich units are flow noses of debris-rich material. Eigenvector stereonet indicates bimodal ice flow - predominantly from W but it seems like there has been considerable post-depositional movement - much flow and reworking in the diamictite. Striae indicate that there has been some input from S. This is either rotation of clasts (likely) or material from table Mt (unlikely - but possible).

Site: J3

Location:

Elevation is about 1900 m on ridge below and due west of campsite - James' Rock

Description:

Massive boulder with, large water escape structures around clasts with smaller boulders forced up to front of boulder where progress impeded by obstacle clast. Smaller clasts backed up behind as small jumbled boulder pavement - sand-filled water escape passes through this area. beyond water escape, clasts have been re-oriented and deformed - bending outwards near widest part of boulder - caused minor de-watering and formation of small boulder trains where clasts have stalled behind an obstacle clast. General colour: Light grey 10YR 8/1 (material nearest boulder); Dull yellow orange 10YR 7/4.

Clasts: n=51

Sphericity: 0.57 Roundness: 0.58 Mean a-axis: 34.6 cm Eigenvector: 270°, S1= 0.52

Interpretation:

Lodgement of large boulder into underlying "tillite" - reorientation of clasts indicate Ferrar ice direction, possibly Tedrow tillite underlying. Clast was lodges as opposed to dropped as shown by active forward motion of clast. Deformation seems likely to have strengthened fabric in direction of large boulder due to Ferrar ice. Gravel forms matrix in boulder pavement, sand has been winnowed out by water escape. Clasts in the Boulder pavement on downglacier side have been rotated in slurry, underlying striae are from Tedrow, overlying from Ferrar. Dip is greatest in clasts nearer to boulder. Eigenvector stereonet indicates multimodal ice flow - predominantly from W. This is weak, but there has been some reorientation by deformation and some clasts are vertical or have just fallen over to side. Rollers/sliders unlikely - appears to be old Tedrow signal. Suggestion of rippling effect away from boulder with a forward motion from Ferrar ice direction. Striae indicate change from Tedrow to Ferrar. Shear planes are all over the place - suggest that sufficient force has been applied to pull apart sediment and impart reverse shear.

Site: TM-6

Location:

Elevation is 1906 m on low broad ridge down hill toward Knobhead, about 270 m north of drillsite TM-1. Outcrop area = 20 sq m. Note at this site the descriptions are by Jennings and the interpretations and clast measurements are by Goff. Interpretations and descriptions may not be correctly matched.

Description:

Section is dominantly diamictite and can be broken into four units which appear to repeat each other. Clasts in the upper part of each unit have no top striae. In middle part of each unit they do but these appear to be rotated. At base of each unit the clasts have no striae on their down side. General colour of all units: 7.5YR 8/1.

Interpretation:

The four units have been interpreted as: a) Deformation - lowest, b) Lodgement - lower lodgement, c) Meltout - middle, d) Flow till - between meltout and upper lodgement. Looks like units of lodgement have been plastered in place. Lodging caused deformation, shear, flow, and sand-filled shears. Deposition appears to be viscous at base of section then it stalled (lodged), then the next unit is water flow at contact, and then the section repeats. Not clear which came first - lake or tillite. Seems to be till on top elsewhere, so scenario would appear to be ice advance over lake dammed lateral moraine and/or valley side. Flow from west is indicated by rare rat tails.

Unit: TM-6a (base)

Description:

Elev: 1898 m. This unit is a light yellowish brown, massive, well sorted, muddy, medium sandstone. The contact between this and the gravelly sandstone above was not seen due to surface debris. The sandstone contains lenses of pinkish grey, bimodal, medium sandy conglomerate. These lenses are up to 0.4m thick. Clasts within the lenses make up 60% of the rock, and range from granules to large pebbles, and have an average size of 4 cm. These are mainly sub-rounded and clast supported, in a matrix is well sorted, medium sandstone. Clast lithologies are predominantly dolerite with some sandstone.

Clasts: n=51

Sphericity: 0.56 Roundness: 0.58 Mean a-axis: 20.5 cm Eigenvector: 282°, S1= 0.59

Interpretation:

Sediment has been deformed by ice from the Ferrar direction. Possibly some influence from the Tedrow. Eigenvector stereonet indicates movement was from SW. Clasts indicate strong flow and some clasts have rotated as deformed.

Unit: TM-6b

Description:

Elev: 1904 m. The outcrop is cut by a 4-5 cm thick vein of well sorted, fine sandstone, that strikes 045 @08 NW. This vein was traced for about 1.5 m before in disappeared under surface debris. The vein was relatively planer but in places flows around large clasts.

Clasts: n=51

Sphericity: 0.58 Roundness: 0.59 Mean a-axis: 25.5 cm Eigenvector: 282°, S1= 0.91

Interpretation:

Strong lodgement and associated shear in underlying sediments. Eigenvector stereonet indicates that ice movement was from west. Strong unimodal fabric and striae indicate same flow direction. No rollers or sliders observed.

Unit: TM-6c (middle)

Description:

Elev: 1906 m, drill site TM-6. This unit contains a smaller percent of clasts (5%), and is massive. The unit is cut by two shear zones. The first is 5 cm wide and strikes 064 @13 N and is towards the top of the unit. This shear has sharp contacts with the unit, and is filled with well sorted sandstone that grades from medium sand in the centre, to fine sand at the edges. Above this shear the unit contains a greater proportion of clasts (10%), below it clasts make up 5% of the rock. The second shear is 30 cm thick and strikes 084 @ 03 N. This shear shows a fine stratification with granular-sized clasts oriented sub-parallel to the sides of the shear zones.

Clasts: n=51

Sphericity: 0.53 Roundness: 0.59 Mean a-axis: 21.2 cm Eigenvector: 280°, S1= 0.90

Interpretation:

Strong meltout from the Ferrar Glacier. Eigenvector stereonet indicates that ice movement was from west. Strong unimodal fabric - striae on bottom of clasts only - indicate same flow direction with rare rollers and sliders.

Unit: TM-6d (upper)

Description:

Elev: 1909 m. The outcrop is a greyish-brown, faintly stratified, muddy, gravelly sandstone. Clasts make up 10% of the rock, and range in size from granules to cobbles, although the average size is about 4 cm. Clasts range from sub-rounded to angular, but are mostly sub-angular. These are matrix supported in a well-sorted, medium to fine sandstone. Clast lithologies are predominantly dolerite (70%) with some sandstone (20%), and quartz (10%). Stratification is faint and discontinuous on a 20 cm scale. The stratification strikes 055 @ 14 NW. The unit also contains 1-2 cm thick lenses of well-sorted, slightly gravelly sandstone. Clasts within these lenses are granular sized, and mostly sub-rounded. These lenses could not be traced for more than about 1 m. The orientation of one of these lenses was measured, and strikes 065 @ 50 NW. Higher in the sequence the lenses become thicker (<25 cm) and some are clast-rich. Only one of these lenses was measured, and strikes 045 @09 NW. Above this level, the outcrop is obscured by the surface debris.

Clasts: n=51

Sphericity: 0.55 Roundness: 0.58 Mean a-axis: 21.2 cm Eigenvector: 280°, S1= 0.90

Interpretation:

Flow till, reworking post-depositional, no striae. Flow from till ridge? Eigenvector stereonet indicates that ice movement was from east. Fabric is a little diverse, but unimodal - opposite to general ice movement, this seems to represent flowage off the back of till ridge.

Site: TM-7

Location:

Elevation is 1863 m on ridge about 3-10 high and 75 m northwest of Ian's Rock GPS site.

Description:

Large boulders are scattered along the ridge. The outcrop is broken into two units which are separated by a sharp, erosional contact. The lower unit is a light yellowish brown, massive, well-sorted, muddy, medium sandstone. The upper unit is a light pinkish brown, massive, bimodal, muddy, gravelly, medium to fine sandstone. Clasts make up 20-25% of the rock, and range in size from granules to cobbles, with an average clast size of about 4 cm. Clasts range from sub-rounded to angular, but are mostly sub-angular. These are matrix supported in a well-sorted, medium to fine sandstone. Clast lithologies are predominantly dolerite (60%) with some sandstone (30%), and quartz (10%). Some sub-angular boulders of dolerite are interbedded into the unit at the top of the outcrop.

Each of the units also contain 15-25 cm thick lenses, of sandy, granular conglomerate, composed of 60-70% clasts. The contact between these lenses and the unit are both gradational and sharp. One unit also contains a small angular ripped-up clast (10 cm diameter) of granular conglomerate. Around this structure is a finely stratified sandstone that forms a flow structure. Towards the top of the outcrop, lobes of granular conglomerate intrude into the sandy gravel to form load casts. These extend up to 15 cm down into the lower unit. The top of the outcrop contains some horizontal stratified sandstone.

Interpretation:

Bottom section represents lake or ponded deposition and is separated by an erosional contact with the overlying conglomerate. This is overridden by ice with blocks of conglomerate sheared into overlying tillite, sand also sheared up. Initial overlying till was wet, viscous, and had many flow lobes and rolled clasts - gradually dewatering upwards. Shear planes filled with brecciated material, small pebble clusters lodged in planes and act as filters allowing sand to pass through. Sand in shear planes gets finer in direction of shear. Active ice overloading produced change from flow till to squeeze flow into shear planes with rare water escape structures. Active lodgement extreme and dewatering is shown as shear and not water escape. This may be due to lack of fines and increased friction leading to shear lubricated by water.

Unit: TM-7a (upper)

Description:

Clasts: n=51

Sphericity: 0.56 Roundness: 0.59 Mean a-axis: 18.8 cm Eigenvector: 284°, S1= 0.80

Interpretation:

Flow till from the west, driven by overlying lodgement. Eigenvector stereonet indicates movement was from west. Clasts indicate strong flow and some clasts have tilted over in flow and rolled over end of nose.

Site: J6

Location:

Elevation is about 1825 m and 81 m southwest of TM-7, but one ridge further down hill.

Description:

One unit with 4 subunits (thrust, upper till, sand shear, vortex). Also there are 2-3 thrust faults/shears at site. General colour: 7.5YR 7/1

Clasts: n=51

Sphericity: 0.55 Roundness: 0.58 Mean a-axis: 17.0 cm Eigenvector: 281°, S1= 0.79

Interpretation:

Strong lodgement of ice moving from Ferrar direction. Appears to have lodged into proglacial deposits of waterlain sediment. Brecciated sands are deformed and water escapes pass through one or all of the units. water escape crossed by shear which leads through to a vortex water escape. Active plastering of lodgement caused deformation of underlying beds - brecciated layers indicate thrust faulting - thrust moraine formation during recession? Eigenvector stereonet indicates unimodal ice flow - from west, top and bottom striae concur. There is some spread in the unimodality tending slight north of west, but shear (thrusts) indicate a predominantly west direction. Suggest some settling has occurred on oversteepened slopes.

Site: 6.28

Location:

Elevation is 1858 m on a ridge 3-10 m high, and 10-30 m wide that strikes east-west.

Description:

The outcrop consists of light pinkish-grey, massive, bimodal, coarse sandy, pebble conglomerate. Clasts are granular to cobble-size, poorly sorted, and predominantly well rounded. These make up 40-80% of the rock, and are clast supported in a matrix of well-sorted coarse sand. Cast lithologies are mainly dolerite (80%), with some quartz (15%), and sandstone (5%). The outcrop is nestled amongst a number of large (1-2m) boulders.

Site: 6.34 (GPS Sta-2)

Location:

Elevation is 1963 m, on southeast side of main northeast striking ridge. Outcrop area = 1 sq m.

Description:

This outcrop is typical of outcrops along the main ridge which is the northwest border of a large hollow. Barrett's wall, a dolerite dike, is near north end of this hollow. The Terra Cotta siltstone crops out in the hollow and is not covered by glacial deposits. However, snow occupies the hollow during many field seasons but was absent in Nov-Dec 1996. At this site, the outcrop is a diamictite with sand-filled shears and has two distinct units. The lower unit is yellowish brown, strongly stratified, well sorted, fine sandstone, with few clasts. Laminar bedding is on a mm to cm-scale, and is horizontal. The upper unit is a light whitish-brown, well sorted, muddy very fine sandstone. This unit has no stratification but has a viscous texture, and contains clasts that have flow structures around them.

Clasts: n=51

Sphericity: 0.54 Roundness: 0.60 Mean a-axis: 13.8 cm Eigenvector: 277°, S1= 0.73

Interpretation:

Strong lodgement of ice moving from Ferrar direction. Deposit has lodged/sheared up at the top of the main ridge adjacent to hollow. The hollow may have been occupied by "clean" ice from the east which originated between Navajo Butte and Table Mt. Eigenvector stereonet indicates multimodal ice flow - predominantly from west, top and bottom striae concur. There appear to be some rolled/slid clasts and some overtopping and vertical rotation. This may be either due to rotation in a slurry or due to overtopping of a moraine ridge and settling. Strong shear indicating active lodgement from west.

Site: 8.3

Location:

Elevation is 1992 m northeast of the study area, on the southeast side of a long, northeast striking ridge. Outcrop area = 2 sq m.

Description:

The Sirius at this site can be divided into two units. The lower unit is pinkish grey, bimodal, sandy conglomerate. Clasts make up 30-40% of the rock, and range from granule to pebble size, with an average clast size of about 2.0 cm, although one boulder-sized clast of shale is visible in this unit. Clast lithologies are 80% dolerite, 15% sandstone and quartz, and 5% shale. These are matrix supported in moderately sorted, medium to coarse sand. This lower unit grades into the upper over about 10 cm with a steady decrease in clast content. The upper unit is a pink, well sorted, gravelly, medium sandstone. Clasts make up 20% of the rock, and range from granule to pebble size, with an average clast size of about 4.0 cm. Clast lithologies are 90% dolerite, 8% sandstone and quartz, and 2% shale. These are matrix supported.

Site: 11.1

Location:

Elevation is 1917 m on the 2-3 m high ridge about 20 m northwest of the campsite. Nerida's Site 2.

Description:

The low ridge is an excellent outcrop to see lateral changes in the Sirius. The Sirius at this site consists of two diamictite units in "razor sharp" contact with the underlying Terra Cotta siltstone. The lower unit is a breccia 20-25 cm thick containing blocks of Terra Cotta siltstone. Striae on Terra Cotta indicate flow from west. The upper unit contains a number of small lenses of stratified sandstone. These are light yellowish-grey, strongly stratified, well sorted, medium to coarse sandstone. Laminar bedding is on a 1-2 mm scale, and strikes 173 @ 10 NW. The upper and lower contacts of these lenses are generally gradational. The lenses average 20 cm thick and are about 3 m long. Some of the larger lenses grade into a sandy, conglomerate with 60- 70% clasts, that are clast supported in a matrix of well-sorted, fine sand. Clasts are predominantly fine pebble-size, but contains some small cobbles (<15 cm). Lithologies are mostly dolerite, with some quartz, and sandstone. Some of the conglomerate lenses display a slight coarsening upward. Towards the southwest along the ridge, the these conglomerate lenses become larger and more numerous until, about 100 m away from the site, the upper diamictite unit becomes a sandy conglomerate facies. The clast lithology of this conglomerate is predominantly New Mountain Sandstone (60%). This is sub-angular to angular and range from coarse sand, to small boulder-size.

Interpretation:

The lower diamictite is interpreted as meltout while the upper one is interpreted as lodgment. The site seems to represent a mix of material from both Ferrar and Tedrow direction. Tedrow direction is weak, lots of water. Ferrar is strong and overwhelms the Tedrow.

Unit: 11.1a (lower)

Description:

The lower unit is 25 cm thick and forms a basal section of greyish brown, muddy, very fine to medium sandy conglomerate. Clasts in this basal section make up 30-60% of the rock. Clast lithologies consist of 90% Terra Cotta siltstone (which is more like a shale than a silt), 8% dolerite, and 2% quartz. These range from clast to matrix supported. The shale clasts are angular and range in size from granules to large cobbles. This lower unit grades into the upper unit over about 25 cm with a rapid decrease in the amount of shale.

Clasts: n=51

Sphericity: 0.56 Roundness: 0.56 Mean a-axis: 14.2 cm Eigenvector: 259°, S1= 0.94

Interpretation:

Possible meltout from Tedrow direction - possibly waning in comparison to Ferrar ice. Eigenvector stereonet indicates strong movement from southwest. Slight skirt, but strong fabric, lack of striae suggest meltout.

Unit: 11.1b (upper)

Description:

The upper unit is a light brown, sandy conglomerate medium to fine sandy conglomerate. Clasts make up 30% of the rock, and range from granules to cobbles, although the average size is about 3.0 cm, and some boulders <1.5 m are present. These clasts are matrix supported, and range from sub-rounded to angular, but are predominantly sub- angular. Clast lithologies are dolerite (70%), sandstone (10%), and quartz (20%).

Clasts: n=51

Sphericity: 0.54 Roundness: 0.59 Mean a-axis: 12.2 cm Eigenvector: 281°, S1= 0.80

Interpretation:

Strong lodgement - some settling, perhaps caused by underlying instability in meltout. Eigenvector stereonet indicates unimodal flow from the west, with dispersal in a skirt suggesting lodgement. Upper and lower striae were also indicative of flow from the west and suggest lodgement. Some overtopping and reverse modality, perhaps due to settling.

Site: 12.17

Location:

Elevation is 1882 m near the northwest boundary of the study area and east of Swiss camp.

Description:

The outcrop lies on a ridge about 2.5 m high and 100 m long. This ridge strikes east-north-east (075), and is slightly "S" shaped in plan. The ridge is made up of two units. One is a predominantly of light, pinkish-grey, massive, bimodal, medium-coarse, sandy conglomerate. The second unit is a yellowish-brown, strongly stratified, well-sorted, medium sandstone. This sandstone is only seen on the south-east side of the ridge. The conglomerate appears to sit on top of the sandstone, and the contact looks to be erosional, with large (30 cm) load casts of conglomerate intruding into the sandstone. The conglomerate also contains sub-horizontal lenses about 10 cm thick of sandstone. Clasts make up 60-80% of the conglomerate, and are granular to cobble-size, poorly sorted, and angular to rounded, but predominantly sub-angular. The clasts are self supporting in a matrix of well-sorted coarse sandstone. Clast lithologies are mainly dolerite (90%), with some quartz (8%), and sandstone (2%). The sandstone unit has mm-scale beds which are continuous over about 1.5 m. The beds are parallel and oriented (strike 143 @ 07 SW) and show both plastic and brittle deformation.

Clasts: n=51

Sphericity: 0.55 Roundness: 0.59 Mean a-axis: 19.8 cm Eigenvector: 280°, S1= 0.74

Interpretation:

Strong lodgement of ice moving from Ferrar direction. Lodgement has occurred over a moraine-dammed lake, the oversteepened tillite has settled slightly. Lake sediments deformed by overloading from lodgement - material flowed off edge of tillite - thrust moraine. Some beds near vertical. Sand-filled water escape plus shear, fillings becoming coarser towards till/sand interface. The conglomerate appears to have flowed and disaggregated everywhere. Edge of moraine-dammed lake area. Eigenvector stereonet indicates bimodal fabric, with ice flow predominantly from west, top and bottom striae concur. There appears to have been some reorientation to the SW which seems most likely to have occurred by settling along the moraine ridge, some clasts are vertical and tend to bear this out since they are near the edge of the deposit. Shear planes are indicative of active lodgement with some effect from the oversteepening off the side of the moraine.

Site: J11

Location:

200 m east of hollow, opposite Navajo Butt.

Description:

Clasts: n=43

Sphericity: 0.57 Roundness: 0.52 Mean a-axis: 18.2 cm Eigenvector: 221°, S1= 0.75

Interpretation:

Weak meltout of a thin veneer of subglacial material. A subglacial "ground moraine" from the Navajo Butt glacier. This has melted out from a weak and thin glacier. There is only one top striae which has not associated bottom striae and this may have rotated. Largely unconsolidated and subject to weathering there is little of this material available for study. In general ice came from south. Eigenvector stereonet indicates bimodal fabric, with ice flow predominantly from south southwest. Some rolling/sliding and a strong fabric suggests that the deposit is a meltout. Striae are equivocal because of possible reworking, but unconsolidated nature of tillite tends to suggest that this is the most likely scenario.

Site: J12

Location:

400 m south of J11

Description:

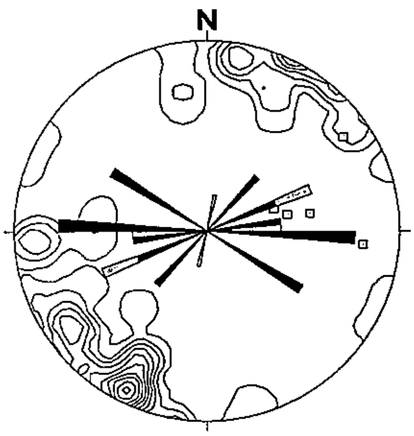
Clasts: n=43

Sphericity: 0.64 Roundness: 0.52 Mean a-axis: 16.9 cm Eigenvector: 233°, S1= 0.77

Interpretation:

Weak meltout of a thin veneer of subglacial material. Unconsolidated tillite, similar to that reported at J11 but with numerous green shale clasts. Most likely meltout in origin. Sampled in similar location to Navajo Butt till so bears fabric more associated with main valley flows, originally from south. Eigenvector stereonet indicates bimodal fabric, with ice flow predominantly from southwest. Some settling may have taken place although fabric is generally strong, settling most likely related to unconsolidated nature of tillite.

Stereonet Plots of Eigenvectors, Striations, Fabric, and Shear Plane Poles



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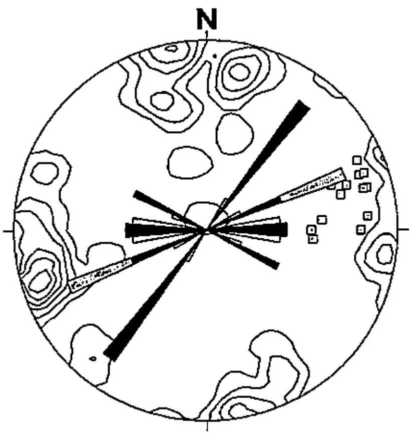
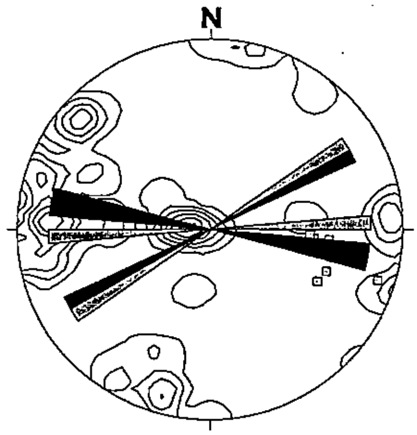
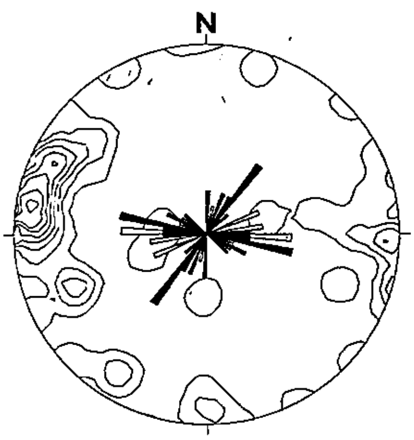


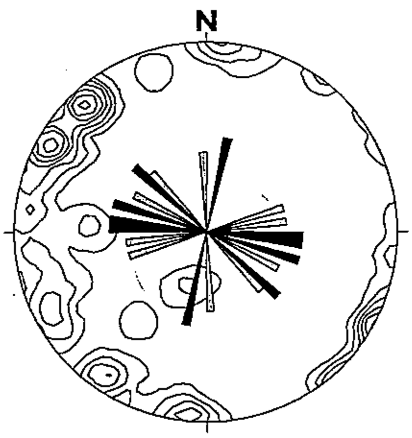
TM-1a



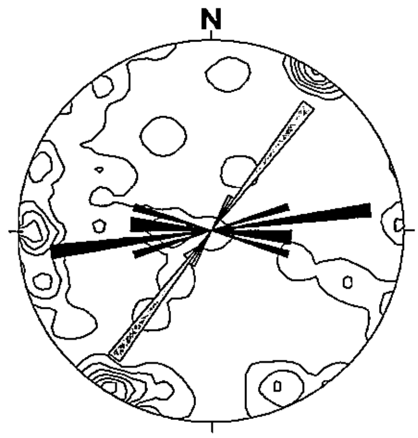
TM-1c



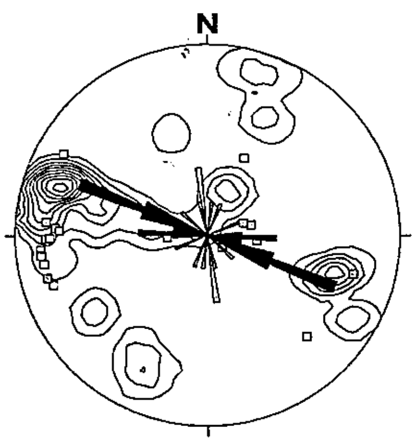
TM-1e



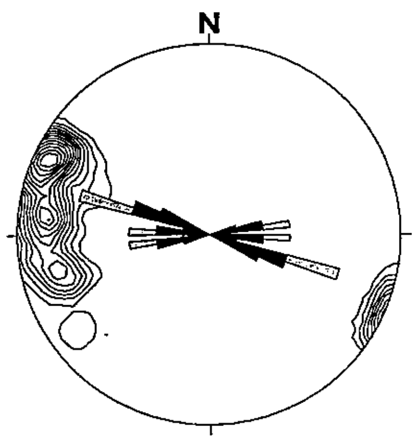
J2



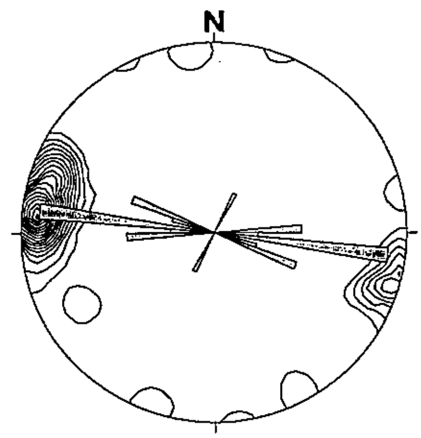
J3



TM-6a

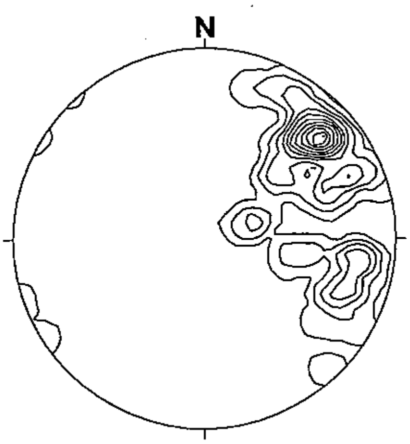


TM- 6b

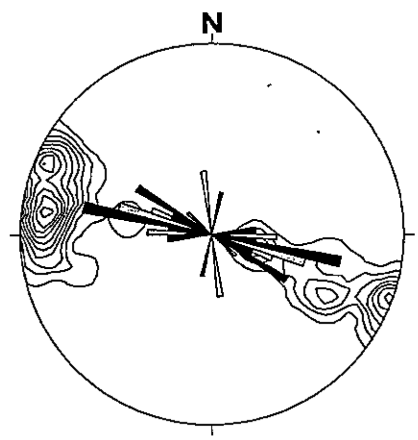


TM-6c

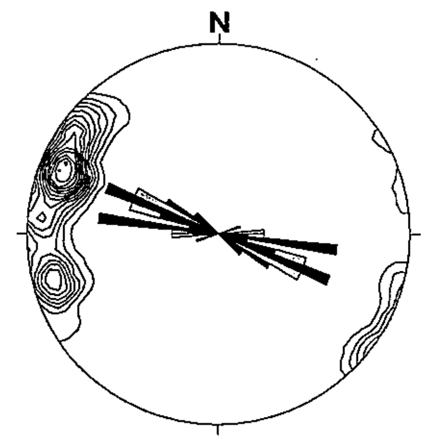
Stereonet Plots of Eigenvectors, Striations, Fabric, and Shear Plane Poles (continued)



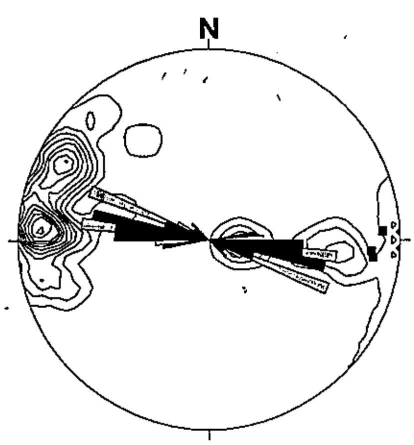
TM-6d



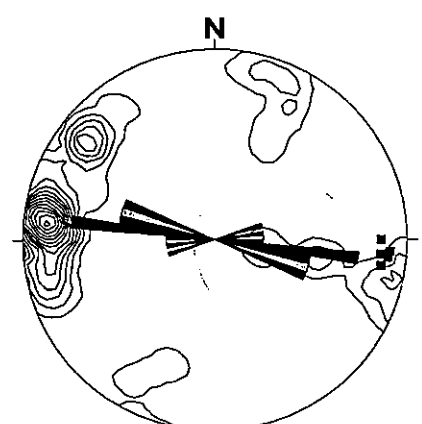
TM-7a



TM-7b



J6



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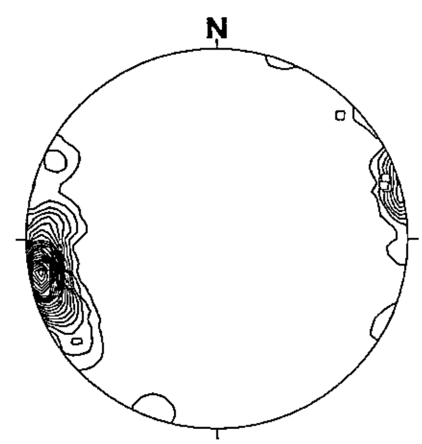
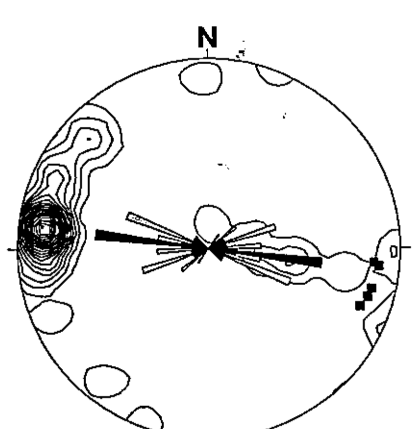
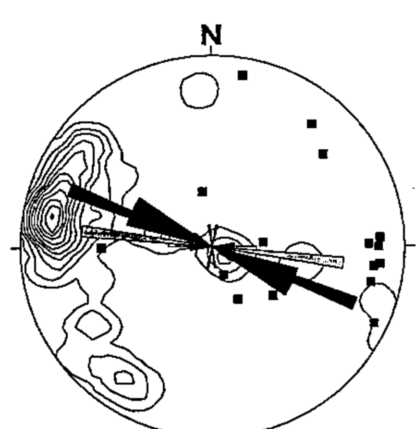


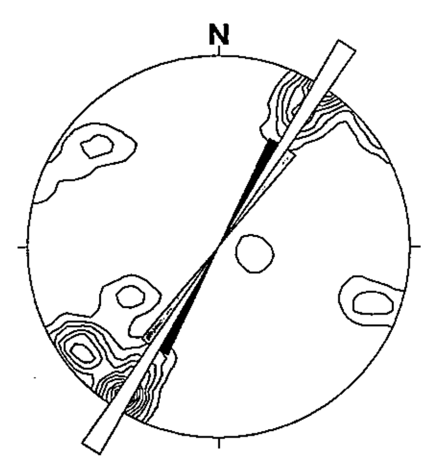
11.1a



11.1b



12.17

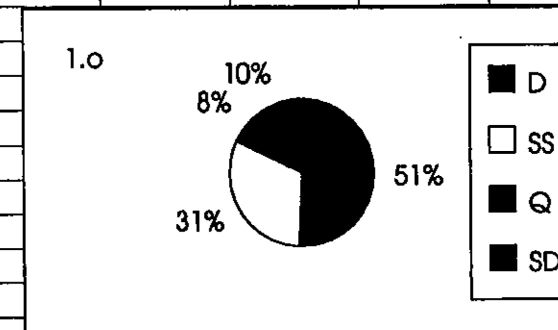


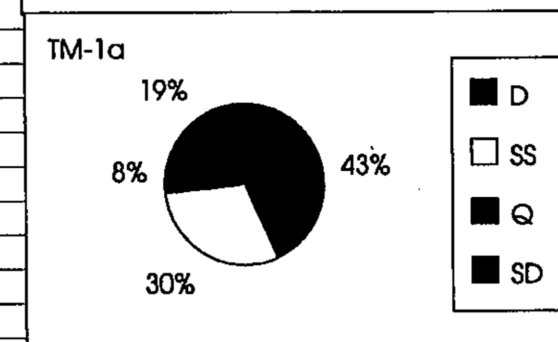
J11

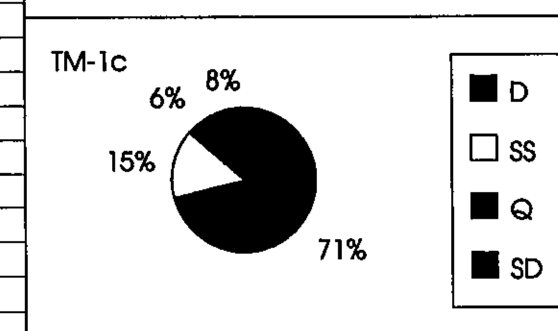
Lithologies and Plots for Site Samples

1.o	D	SS	Q	SD	Total	
	26	16	4	5	51	
TM-1a	D	SS	Q	SD	Total	
	23	16	4	10	53	
TM--1c	D	SS	Q	SD	Total	
	37	8	3	4	52	
TM-1e	D	SS	Q	SD	Total	
	29	8	3	11	51	
J2	D	SS	Q	SD	Total	
	36	9	3	3	51	
J3	D	SS	Q	SD	Total	
	39	8	0	4	51	
TM-6a	D	SS	Q	SD	Total	
	34	13	2	2	51	
TM-6b	D	SS	Q	SD	Total	
	23	20	7	1	51	
TM-6c	D	SS	Q	SD	Total	
	27	14	6	4	51	
TM-6d	D	SS	Q	SD	Total	
	26	14	6	5	51	
TM-7a	D	SS	Q	SD	G	Total
	37	9	3	1	1	51

D = Dolerite
SS = Siltstone
Q = Quartz
SD = Sandstone
G=Granite
GSS=Green Siltstone

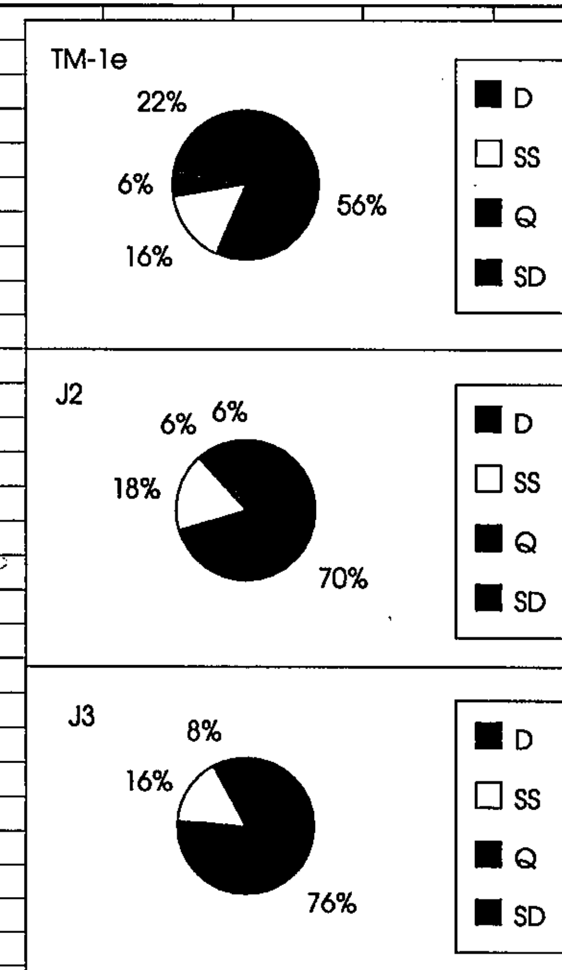




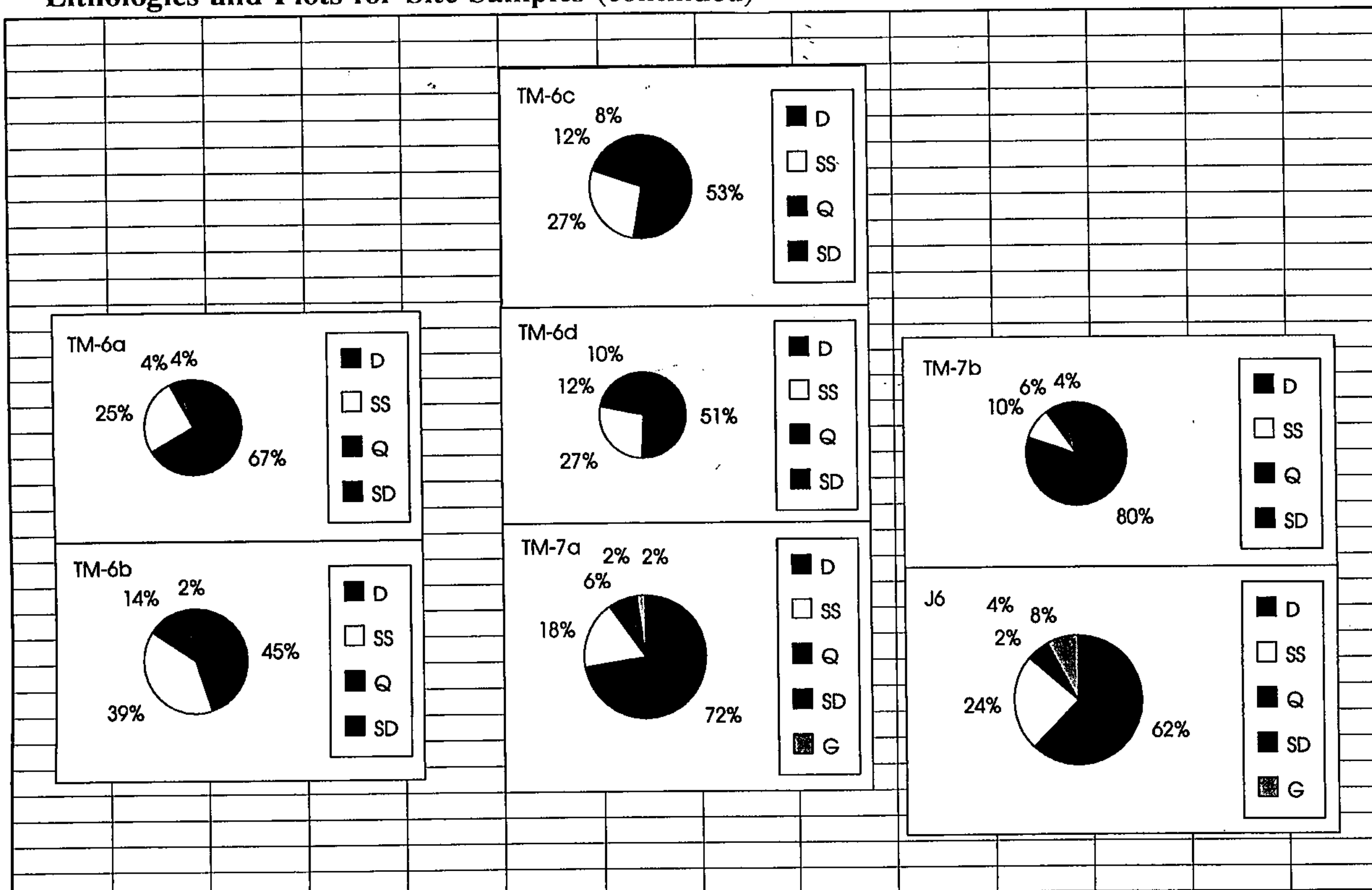


Lithologies and Plots for Site Samples (continued)

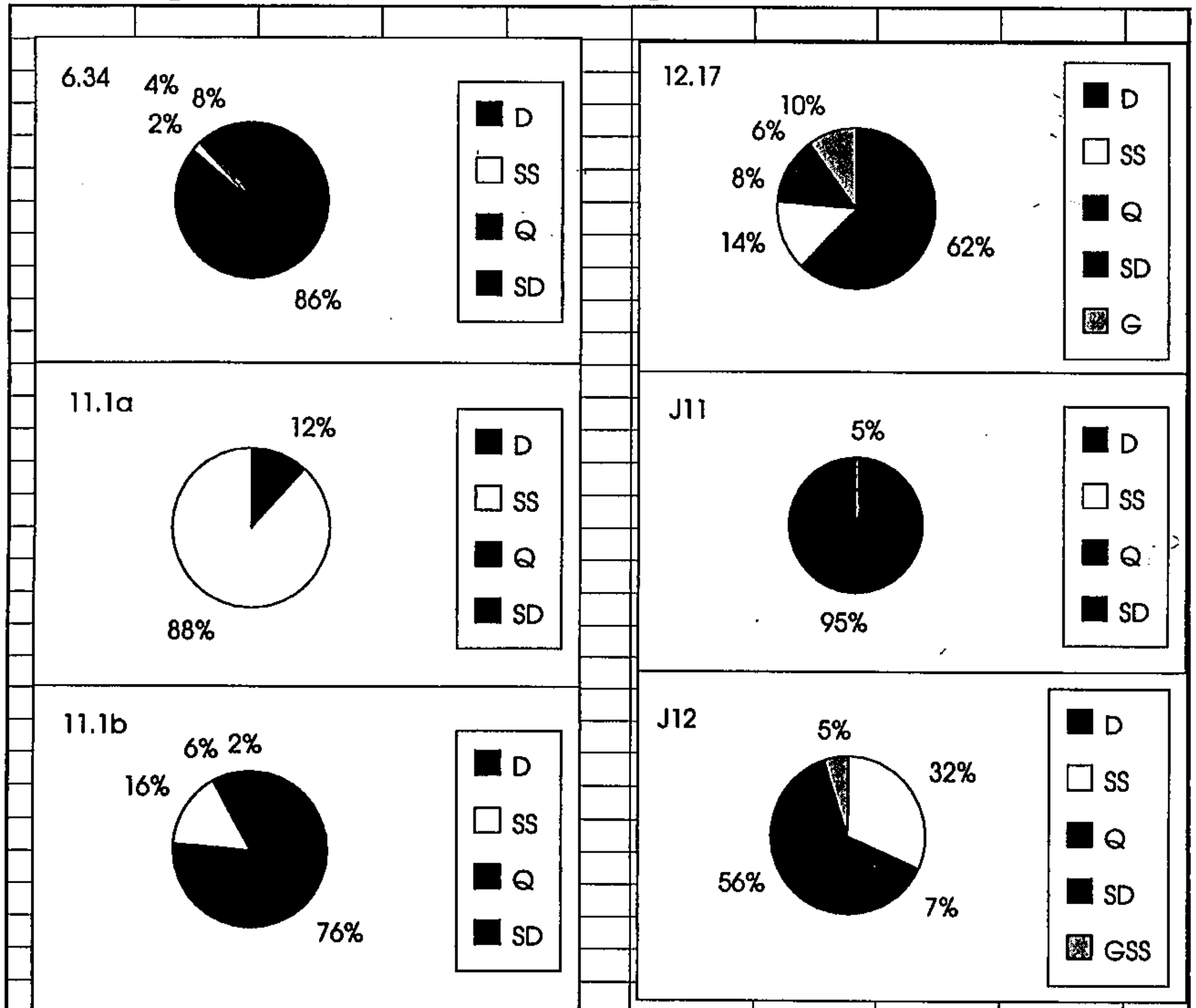
TM-7b	D	SS	Q	SD	Total	
	41	5	3	2	51	
J6	D	SS	Q	SD	G	Total
	32	12	1	2	4	51
6.34	D	SS	Q	SD	Total	
	44	1	2	4	51	
11.1a	D	SS	Q	SD	Total	
	6	45	0	0	51	
11.1b	D	SS	Q	SD	Total	
	39	8	3	1	51	
12.17	D	SS	Q	SD	G	Total
	32	7	4	3	5	51
J11	D	SS	Q	SD	Total	
	0	0	2	41	43	
J12	D	SS	Q	SD	GSS	Total
	0	13	3	23	2	41

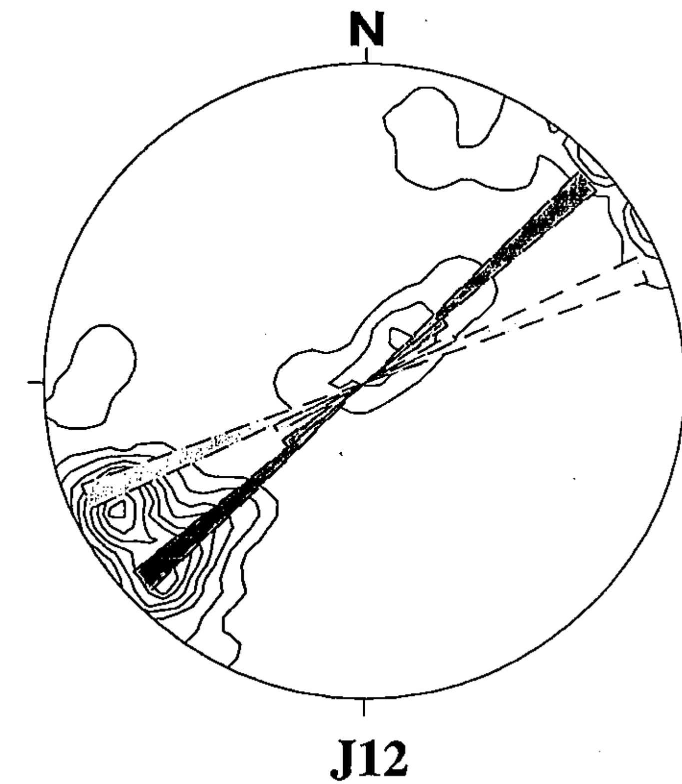


Lithologies and Plots for Site Samples (continued)



Lithologies and Plots for Site Samples (continued)



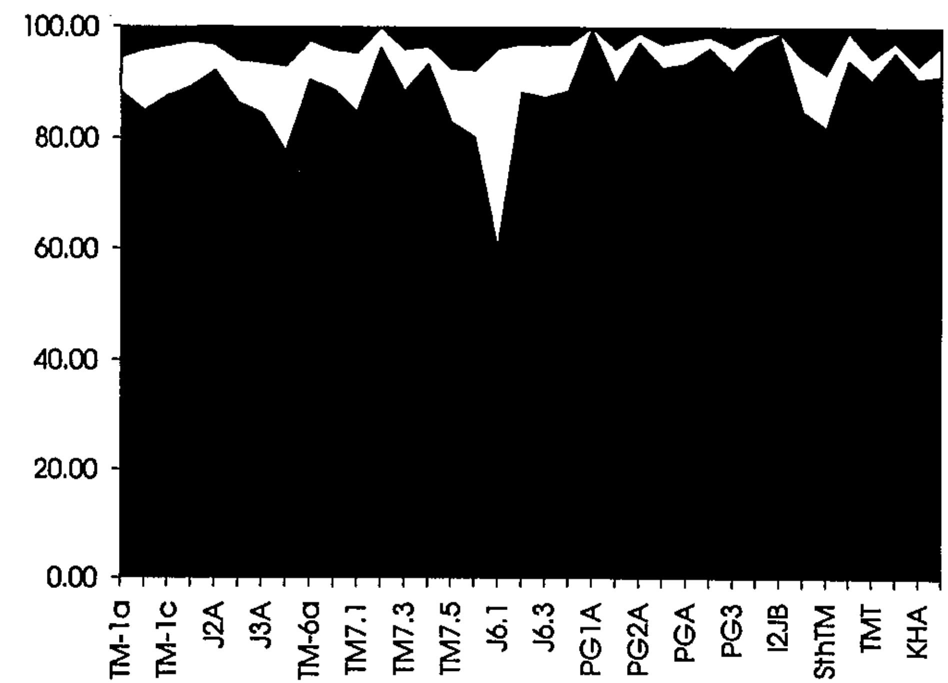


Grainsize Data for Site Samples

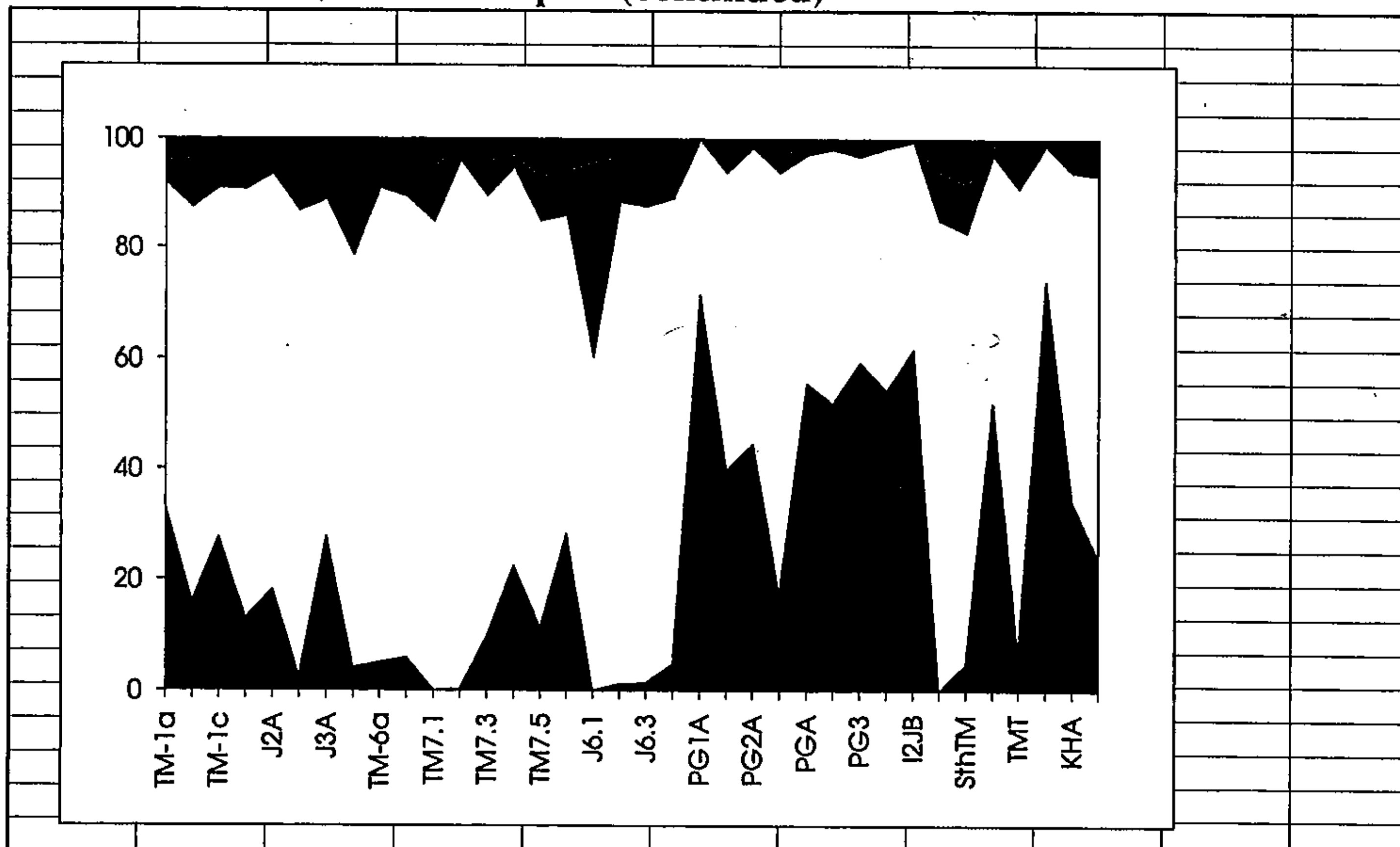
	Gravel	Sand	Silt	Clay	Total		Sand	Silt	Clay	Total
TM-1a	32.9	59.2	4.2	3.7	100		88.23	6.26	5.51	100
TM-1b	16	71.4	9.2	3.4	100		85.00	10.95	4.05	100
TM-1c	27.4	63.6	6.5	2.5	100		87.60	8.95	3.44	100
TM-1d	13	77.7	7	2.3	100		89.31	8.05	2.64	100
J2A	18.1	75.5	3.8	2.6	100		92.19	4.64	3.17	100
J2B	2.5	84.2	7.4	5.9	100		86.36	7.59	6.05	100
J3A	27.5	61.3	6.5	4.7	100		84.55	8.97	6.48	100
J3B	4.2	74.4	14.7	6.7	100		77.66	15.34	6.99	100
TM-6a	5.1	85.9	6.6	2.4	100		90.52	6.95	2.53	100
TM-6b	6	83.4	6.8	3.8	100		88.72	7.23	4.04	100
TM7.1	0	84.8	10.5	4.7	100		84.80	10.50	4.70	100
TM7.2	0.2	96	3.8	0	100		96.19	3.81	0.00	100
TM7.3	9.7	79.9	6.8	3.6	100		88.48	7.53	3.99	100
TM7.4	22.5	72.3	2.5	2.7	100		93.29	3.23	3.48	100
TM7.5	11.4	73.5	8.5	6.6	100		82.96	9.59	7.45	100
TM7.6	28.1	57.7	8.6	5.6	100		80.25	11.96	7.79	100
J6.1	0	60.3	35.8	3.9	100		60.30	35.80	3.90	100
J6.2	1.2	87.2	8.6	3	100		88.26	8.70	3.04	100
J6.3	1.4	86.1	9.4	3.1	100		87.32	9.53	3.14	100
J6.4	4.8	84.3	8	2.9	100		88.55	8.40	3.05	100
PG1A	71.3	28.6	0.1	0	100		99.65	0.35	0.00	100
PG1B	39.9	54.1	3.7	2.3	100		90.02	6.16	3.83	100
PG2A	44.6	53.9	1	0.5	100		97.29	1.81	0.90	100
PG2B	17.5	76.4	3.6	2.5	100		92.61	4.36	3.03	100
PGA	55.7	41.4	1.9	1	100		93.45	4.29	2.26	100
PGB	52	46.2	1	0.8	100		96.25	2.08	1.67	100
PG3	59.4	37.4	1.7	1.5	100		92.12	4.19	3.69	100
I2JA	54.4	44	0.9	0.7	100		96.49	1.97	1.54	100
I2JB	61.6	37.9	0.2	0.3	100		98.70	0.52	0.78	100

Grainsize Data for Site Samples (continued)

TM6	0	85	9.3	5.7	100		85.00	9.30	5.70	100
SthTM	4.9	77.9	9.2	8	100		81.91	9.67	8.41	100
NthTM	52	45.1	2.5	0.4	100		93.96	5.21	0.83	100
TMT	6.9	84.2	3.7	5.2	100		90.44	3.97	5.59	100
NBT	73.8	25	0.5	0.7	100		95.42	1.91	2.67	100
KHA	33.9	60	1.6	4.5	100		90.77	2.42	6.81	100
KHB	23.8	69.6	4.2	2.4	100		91.34	5.51	3.15	100



Grainsize Data for Site Samples (continued)



CORING PERMAFROSTED GLACIGENIC SEDIMENTS

P. Cooper, J. Ashby, B. Webster, and W. Dickinson

INTRODUCTION

A programme of permafrost coring was carried out on Table Mountain from 28 November to 14 December 1996. The equipment was designed, built and supplied by Webster Drilling and Exploration Limited of Wellington, New Zealand. On-site supervision and operation of the drilling equipment was carried out by Pat Cooper of Coopers Drilling Services whilst contracted to Webster Drilling.

Core drilling of permafrosted sediments is common and well understood in most Arctic environments (Kudryashov and Yakovlev, 1991) and in some alpine environments (Haeberli et al, 1988). Onshore in the Dry Valleys area, glacigenic deposits of the Taylor Valley were cored between 1973 and 1975 by the Dry Valleys Drilling Project (McGinnis 1981) and again in 1980 and 1984 (Robinson and Milton, 1985). All of this coring involved the use of heavy, non-portable drilling equipment. This paper describes a technique for diamond coring permafrosted glacigenic sediments with a portable air drilling system.

From the standpoint of drilling, the lithology of the Sirius is highly variable and may range from a conglomerate of loosely held clasts, to lenses of ice. The Sirius sediments become permafrosted generally below 50 cm, however, this depth may vary depending on the available moisture and degree of sublimation which depends largely on slope angle and orientation. Below this depth, ice-filled fractures and lenses of ice up to four centimetres thick are common. The diamictites, which crop out mostly on ridges, consist of rounded to sub-rounded clasts in a matrix of mud or sand. Some diamictites are clast supported while others are not. At Table Mt, most of the clasts are dolerite and their hardness usually depends on their size and degree of post-depositional alteration. Although clasts of 6 - 10 cm could be altered and soft, generally, the larger the clasts the harder they were. Sandstone sequences were generally soft and friable and contained ice-filled pores.

Coring the Sirius at Table Mountain was largely an on-site experiment because such permafrosted glacigenic sediments do not exist near workshop facilities and supplies of drilling equipment. During the 23 days in the field, a total of 49 m was drilled and 42 m of core was recovered. Holes averaged 3.5 m deep but two holes were 8 and 9.5 m deep.

Considering the budget restraints and limited helicopter support, the drilling project was extremely successful. With moderate adjustment and modification, the existing equipment could be refined into a highly reliable and portable Antarctic drilling unit.

EQUIPMENT AND METHODS

The main drilling equipment consisted of the following items:

1) Stihl powered drilling unit, rated at 180rpm, with a four metre tripod, hand winch, blocks, torque bar, and air swivel.
2) Compressor unit rated at 50cfm and 30psi powered by two Stihl 056 engines.
3) Drilling rods of both HQ and NQ sizes.
4) Core barrels, 1 metre HQ wireline and both NQ and HQ single tube, plus assorted tungsten and diamond core bits.
5) Miscellaneous equipment: helicopter sling basket, tools and tool boxes, air hoses, tongs, gas welder, and core boxes.

All drilling equipment had to be hand portable, and available in the field camp. For ease of repair and reduction of spare parts, both the drilling assembly and compressor were powered by the same model engines. Off the shelf HQ and NQ diameter core barrels and drill rods were used with a flushing medium of compressed air.

The drill rods were rotated by a Stihl 056 motor mounted on frame with a torque bar which was pinned to the ground. Bit weight was controlled by the weight of the operator and any additional weight from the helpers. Pulling and lifting of the drill assembly was controlled by a hand winch via a single running block attached to a four metre tripod (Fig. 1).

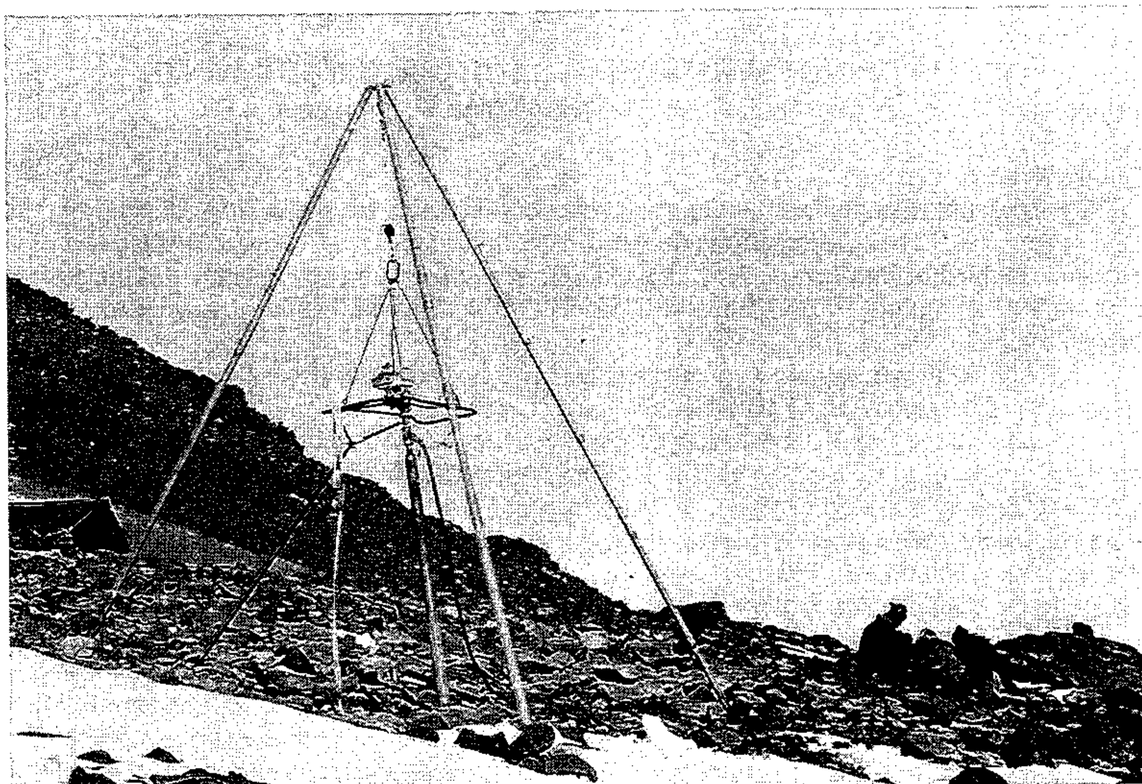


Figure 1 Portable drilling unit with four metre tripod supporting the Stihl driven drill on a frame with a torque bar.

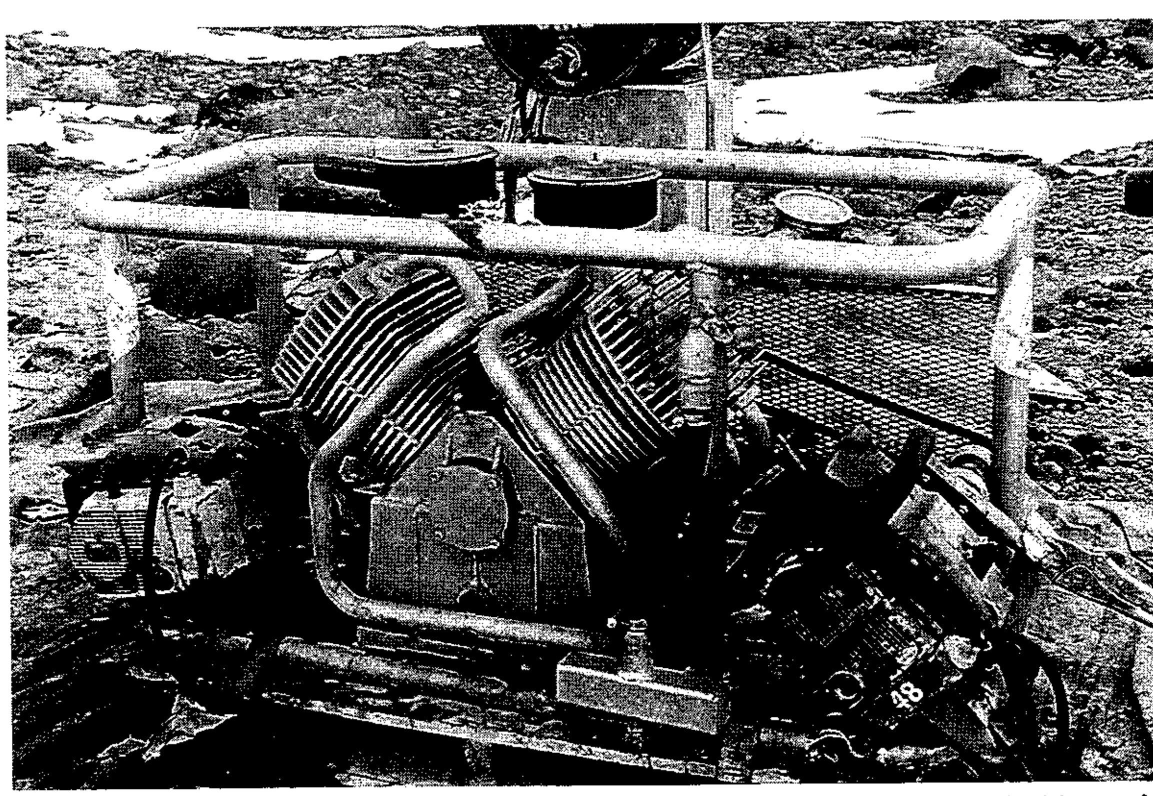


Figure 2 Portable air compressor driven by two Stihl 056 engines. Note that fuel is gravity fed from drum container.

The purpose-built, portable compressor produced 50 cubic feet of air per minute at 30 psi, which was pumped down the hole via an air swivel (Fig. 2). A dial thermometer was used to monitor air temperatures at various points through the air system. Fuel consumption for the one drilling and two compressor engines is estimated at 60 litres per seven days.

Single tube core barrels of both HQ and NQ calliper were used. The NQ barrel had a core lifter spring in the bit face. However, due to limited engineering facilities on-site, subsequently modified HQ and NQ barrels and bits did not contain lifter springs. To retain the core in these bits, dry blocking was used, but this method is not recommended because of the high risk of getting stuck in the hole. A NMLC bit (Fig. 3A) and dual-tube, 1.5 metre core barrel was also tested, and while providing excellent core recovery and presentation, it proved to get easily stuck in the hole.

RESULTS AND DISCUSSION

The flushing and cooling of the drill bit with compressed air was found to be critical. At all times the drill bit must be kept at sub zero temperatures to prevent melting of core and nearly instantaneous freeze in of the bit should rotation stop unexpectedly. Cooling of the bit depends on the temperature and volume of air entering the hole as well as the kerf and diameter of the bit (Table 1). For a given air supply, a thin kerf and small diameter bit runs cooler than a thick kerf and large diameter bit. Although the air supplied by the compressor was sufficient for the depths (maximum 9.5 metres) that were drilled, only thin kerfed bits could be used. Undoubtedly, a larger and more reliable air supply would allow the use of triple tube core barrels with larger kerfed bits.

Table 1. Air temperatures (C°) while drilling

CORE HOLES	TM-1C	TM-7B	TM-8A
Ambient air	-12	-14	-15
Air into Compressor	-10	-4	-8
Air into Drill Hole	-5	-4	+2
Air out of Drill Hole	-8	-10	-8
Drilling Depth (m)	4.1	5.3	0.3
Approximate Formation Temperature*	-23	-24	-7

*Measured after completion and extrapolated to the drilling depth.

Initial drilling showed that with the rather limited air supply, experimentation and modification of bit types was necessary to properly core the variety of lithologies contained in the Sirius. Diamond bits must be used to core hard and firmly cemented dolerite clasts, but tungsten bits must be used to core ice lenses and soft friable sands. Core recovery of conglomerates in ice-free horizons, which usually occur from the surface to 50 cm deep, was not possible. Loose clasts which are jarred from this horizon and fall into the hole must be either pulverized by further drilling or scooped out of the hole if core is to be recovered. However, if the clasts are small or soft in this ice-free horizon, a large diameter, winged tungsten bit will probably give the best core recovery.

Through trial and error it was found that the conventional triple-tube, HQ core barrel did not provide enough annulus for the given air supply to clear ice bound cuttings. In addition, the large kerfed bit produced too much friction and resulted in melting around the core. This made it necessary to use single-tube core barrels with thin kerfed bits. Although single tube barrels subjected the core column to rotational forces and also abrasion by the flushing medium, they proved to be our most reliable tools (Table 2). Bits were eventually run without reamers so as to provide maximum clearance directly from the bit face.

Table 2. Drilling log for core holes

Hole	Start Depth (m)	End Depth (m)	Run Length (m)	Core Recovery (m)	Percent Recovery	Bit Type	Comments
TM-1	0	0.45	0.45	0.45	100	HQ TT SS	Kerf on bit was too large and
	0.45	0.93	0.48	0.42	88	HQ TT SS	melted formation. Bit became
	0.93	1.35	0.42	0.34	81	HQ TT SS	frozen in place at 1.58 & hole
	1.35	1.58	0.23	0.16	70	HQ TT SS	was abandoned.
			1.58	**1.37**	**87**		
TM-1A	0	0.80	0.80	0.64	80	NQ ST SS	Rescue/relief hole to recover
	0.80	1.10	0.30	0.30	100	NQ ST SS	bit at TM-1.
	1.10	1.36	0.26	0.22	85	NQ ST SS	
			1.36	**1.16**	**85**		
TM-1B	0	0.39	0.39	0.35	90	NQ ST SS	Rescue/relief hole to recover
	0.39	0.54	0.15	0.18	120	NQ ST SS	bit at TM-1.
	0.54	0.72	0.18	0.18	100	NQ ST SS	
	0.72	0.93	0.21	0.21	100	NQ ST SS	
	0.93	1.22	0.29	0.26	90	NQ ST SS	
	1.22	1.30	0.08	0.08	100	NQ ST SS	
			1.30	**1.26**	**97**		
TM-1C	0	0.90	0.90	0.60	67	NQ ST SS	
	0.90	1.06	0.16	0.30	100	NQ ST SS	
	1.06	2.04	0.98	1.00	100	NQ ST SS	
	2.04	2.60	0.56	0.57	100	NQ ST SS	
	2.60	2.90	0.30	0.30	100	NQ ST SS	
	2.90	3.70	0.80	0.82	100	NQ ST SS	
	3.70	4.60	0.90	0.86	96	NQ ST SS	
	4.60	6.04	1.44	1.39	97	NQ ST SS	
	6.04	6.80	0.76	0.80	105	NQ ST IM	Temporary end; waiting on
	6.80	7.29	0.49	0.35	100	NQ ST IM	pipe
	7.29	7.93	0.64	0.57	89	NQ ST IM	Shale contact
			7.93	**7.56**	**95**		
TM-2	0	0.16	0.16	0.16	70	NQ ST TG	
	0.16	0.30	0.14	0.07	100	NQ ST TG	
	0.30	0.38	0.08	0.08	100	NQ ST TG	
	0.38	0.49	0.11	0.06	55	NQ ST TG	
	0.49	0.53	0.04	0.05	125	NQ ST TG	
	0.53	1.23	0.70	0.68	97	NQ ST TG	
	1.23	1.50	0.27	0.18	67	NQ ST TG	
	1.50	1.68	0.18	0.16	89	NQ ST TG	
	1.68	1.90	0.22	0.22	64	NQ ST TG	
	1.90	1.92	0.02	0.02	100	NQ ST TG	
			1.92	**1.68**	**83**		
TM-2A	0	0.30	0.30	0.13	43	NQ ST TG	Mostly ice and loose clasts
			0.30	**0.13**	**43**		
TM-2B	0	0.40	0.40	0.20	50	NQ ST TG	Ice and loose clasts
			0.40	**0.20**	**50**		
TM-2C	0	0.40	0.40	0.25	63	NQ ST TG	Ice and loose clasts
			0.40	**0.25**	**63**		
TM-3	0	1.46	1.46	1.24	85	NQ ST TG	Only top 0.50 m of core saved;
	1.46	2.24	0.78	0.70	90	NQ ST TG	quality too poor below
			2.24	**1.94**	**87**		
TM-4	0	1.46	1.46	1.24	85	HQ ST TG	Hole is 40m lateral to site 1.
	1.46	1.89	0.43	0.43	100	HQ ST TG	Attempt to core basal contact,
	1.89	3.00	1.11	0.69	62	HQ ST TG	but not reached in this hole.
			3.00	**2.36**	**77**		
TM-4A	0	0.85	0.85	0.68	80	HQ ST TG	Outcrop fractured
	0.85	1.30	0.45	0.34	76	HQ ST TG	
			1.30	**1.02**	**78**		

Hole	Start Depth (m)	End Depth (m)	Run Length (m)	Core Recovery (m)	Percent Recovery	Bit Type	Comments
	0	0.44	0.44	0.44	100	HQ ST TG	Hole about 5m downslope from
	0.44	0.94	0.50	0.50	100	HQ ST TG	TM-4. Attempt to core
TM-5	0.94	1.22	0.28	0.28	100	HQ ST TG	contact.
	1.22	1.50	0.28	0.30	107	HQ ST TG	
	1.50	2.15	0.65	0.40	62	HQ ST TG	Shale contact reached
			2.15	**1.92**	**89**		
	0	0.47	0.47	0.21	45	NQ ST SS	Site is about 400m west and
	0.47	0.83	0.36	0.36	100	NQ ST SS	downslope of site 1.
	0.83	2.00	1.17	1.17	100	NQ ST SS	
TM-6	2.00	2.90	0.90	0.90	100	NQ ST SS	
	2.90	3.69	0.79	0.68	86	NQ ST SS	
	3.69	4.10	0.41	0.38	93	NQ ST SS	Ice shale contact at 3.69 m
			4.10	**3.70**	**90**		
	0	0.30	0.30	0	0		Pulverized core, no core log
TM-7	0.30	0.54	0.24	0	0		taken hole abandoned
			0.54	**0**	**0**		
	0	0.57	0.57	0.41	72	NQ ST TG	
	0.57	0.89	0.32	0.31	97	NQ ST TG	
	0.89	1.77	0.88	0.88	100	NQ ST TG	
TM-7A	1.77	2.79	1.02	0.95	93	NQ ST TG	
	2.79	3.40	0.61	0.64	105	NQ ST TG	
	3.40	3.87	0.47	0.46	98	NQ ST TG	Good coring, but decided to
	3.87	4.80	0.93	0.93	100	NQ ST TG	move 0.5m sideways and core
			4.80	**4.58**	**95**		with HQ for deep hole test.
	0	1.40	1.40	1.04	74	HQ ST TG	
	1.40	3.00	1.60	1.55	97	HQ ST TG	
	3.00	4.20	1.20	1.29	108	HQ ST TG	
	4.20	5.10	0.90	0.75	83	NQ ST TG	
	5.10	5.57	0.47	0.47	100	NMLC	
TM-7B	5.57	5.73	0.16	0.16	100	NMLC	Stuck in hole, overdrill with
	5.73	6.12	0.39	0.39	100	NQ ST SS	HQ. Both became stuck but
	6.12	6.85	0.73	0.70	96	NQ ST SS	able to free.
	6.85	7.60	0.75	0.74	99	NQ ST SS	
	7.60	8.52	0.92	0.92	100	NQ ST SS	
	8.52	9.52	1.00	1.00	100	NQ ST SS	Core jammed, decided to
			9.52	**9.01**	**95**		terminate hole; estimated 10m
							was tripod max
	0	0.10	0.10	0.10	100	HQ ST TG	Loose clasts in surface
TM-8	0.10	0.40	0.30	0.14	47	HQ ST TG	pulverizing core. Abandoned
	0.40	0.55	0.15	0.10	67	HQ ST TG	hole when in large clast
			0.55	**0.34**	**62**		
TM-8A	0	0.4	0.40	0.31	78	NQ ST SS	Abandoned in large clast
			0.40	**0.31**	**78**		
	0	0.38	0.38	0.10	26	NQ ST IM	Difficult recovery due to large
	0.38	1.07	0.69	0.00	0	NQ ST IM	loose clasts in upper part of
	1.07	1.76	0.69	0.10	14	NQ ST SS	hole.
	1.76	2.55	0.79	0.50	63	NQ ST SS	
	2.55	3.73	1.18	0.56	47	NQ ST SS	
TM-8B	3.73	4.72	0.99	0.92	93	NQ ST SS	
	4.72	5.15	0.43	0.36	84	NQ ST SS	
	5.15	5.47	0.32	0.31	97	NQ ST SS	
	5.47	5.73	0.26	0.26	100	NQ ST SS	
	5.73	5.90	0.17	0.17	100	NQ ST SS	Abandoned in large clast
			5.90	**3.28**	**56**		
Total			**49.69**	**42.07**	**85**		

TT Triple Tube
ST Single Tube
SS Surface set diamond bit
IM Impregnated diamond bit

HQ Diameter core
NQ Diameter core
TG Tungsten bit

Evaluation of Core Bits

1) NQ Single Tube Impregnated Diamond (57mm core, 9mm kerf, 75mm hole; Fig. 3B)
Used in the conglomerate unit, problems were experienced in getting this bit to cut. Low weight on the bit and low revolutions per minute were the main causes. When encountering ice lenses penetration rates dropped to zero. When drilling clasts penetration rates dropped as low as 300mm for 2 hours.

2) NQ Single Tube Surface Set Diamond (57mm core, 9mm kerf, 75mm hole; Fig. 3C)
This bit worked very well in almost all down hole conditions encountered. The only exception was in coring ice lenses. Tungsten surfaced bits were run once these areas were encountered. Penetration rates of 100mm for one minute were not uncommon and good core recovery usually resulted.

3) NQ Single Tube Tungsten Multiple Wings (57mm core, 10mm kerf, 77mm hole; Fig. 3D)
This bit was fabricated on site. It was designed to minimize friction at the cutting surface and to provide independent passage of air for efficient cooling of the bit. The kerf was reduced to 10mm and a total of three tungsten cutters employed. This tool proved to be the ideal way to successfully core and recover the sections of formation dispersed with ice lenses. Bit cooling and hole clearing were much improved over the smaller annulus of the diamond tools supplied.

4) HQ Single Tube Tungsten multiple wings (75mm core, 11mm kerf, 96mm hole; Fig. 4A)
This bit was also fabricated on site similarly to the NQ tungsten. Previous problems of melt out experienced with the HQ triple tube were not evident and generally good penetration rates and core recovery resulted. Hole clearing was much improved and down hole resistances kept to a minimum.

5) HQ Triple Tube Impregnated Diamond (61.1mm core, 17.5mm kerf, 96mm hole; Fig. 4B)
All attempts at drilling this coring system resulted in melt-out occurring at the bit face due to insufficient air supply for cooling a diamond bit of this kerf size.

Conclusions and Recommendations

Critical to successful coring is a reliable supply of sub-freezing air and properly designed core barrels and bits. Dual tube barrels providing a core size of at least 60mm and having at least a 6mm annulus are recommended. However, a single tube barrel with appropriate bits should be included as a backup tool. Both tungsten and surface-set diamond bits with kerfs as thin as possible should be used. Channels rather than tubes should be used to conduct air to the bit face. At this point it is not clear how well a thin-kerfed diamond impregnated bit would work, but such a bit should at least be tested.

The advantages of using both HQ and NQ calliper drill rod outweigh the disadvantage of extra weight and equipment. HQ is recommended for drilling from the surface to a depth of 4 to 6 metres. However, when the HQ drill rod is then used as casing, it needs to be hung from the surface with an appropriate tool to prevent it from slipping down the hole. NQ rod will suffice for coring deeper than 6 metres. In addition, a grabber tool that can fish loose clasts off the bottom of the hole is highly recommended for maximum core recovery.

For a reliable air supply, the compressor engines need to be replaced with a Rotax engine and an improved drive system. Although this means carrying another set of engine parts, the proven reliability of the Rotax to provide efficient power to weight ratio in polar environments outweighs the problems associated with an additional parts inventory.

For future shallow coring projects of glacigenic deposits in Antarctica, the above recommendations and modifications are considered essential. These modifications may then be used with either of two options.

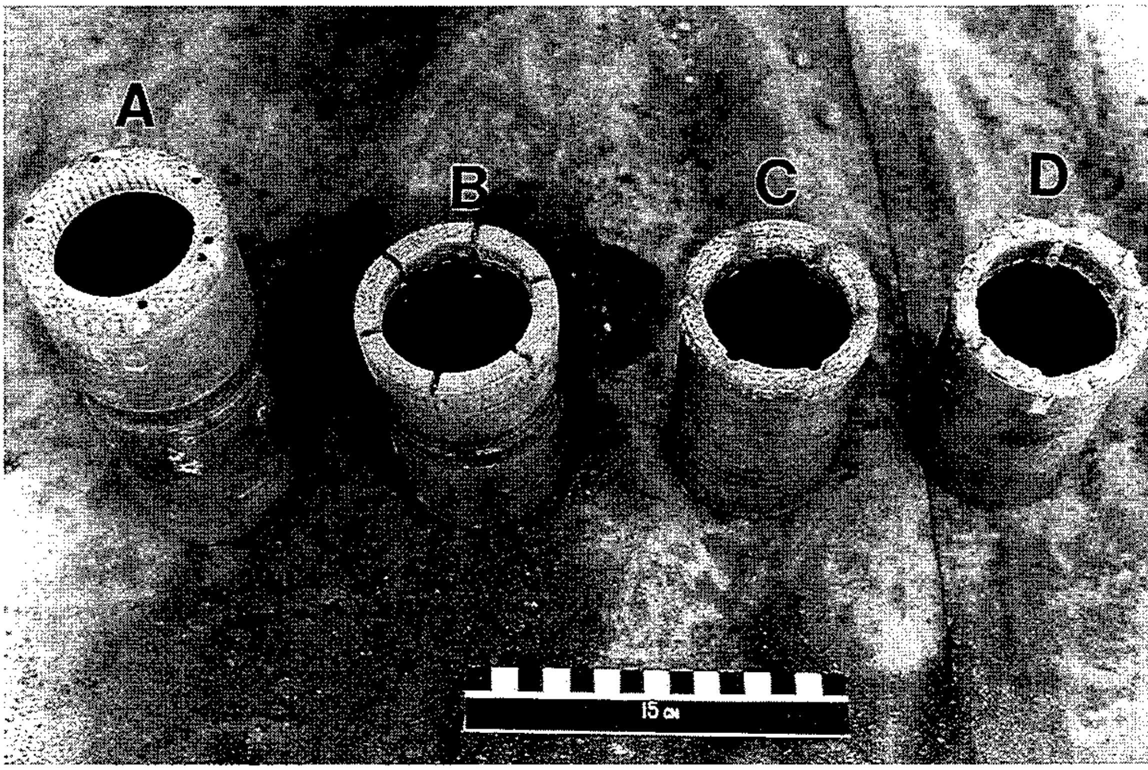


Figure 3 NQ calliper bits used for coring. A) Reamer with NMLC diamond surface-set bit. Note tube nozzles to conduct air to bit face. B) Impregnated diamond bit with channels to conduct air. C) Surface set diamond bit with channels. D) Multiple wing tungsten bit with channels.

Figure 4 HQ calliper bits used for coring. A) Single tube, multiple wing tungsten bit with channels to conduct air to bit face. B) Triple tube impregnated diamond bit with channels and tube to conduct air.

Option One

With minimal expenditures, the existing drill motor and tripod could be made stronger and more reliable. This option, together with the above recommendations, provides an inexpensive drilling system that could produce core samples from depths of no greater than 10 metres. This is considered to be the maximum depth, given the weight that the strengthened aluminium tripod could safely hold. This drilling system requires a high degree of labour and allows minimum control over weight on bit and rpm parameters.

Option Two

This option provides for core recovery up to depths of 50 metres under a wide range of permafrost formations. The modified compressor would be supplemented with an after cooling unit to further lower the temperature of the flushing medium. The drilling unit would consist of a heli portable, top drive unit similar to the Webster HP-150 complete with a wire line winch. This would assist in the moving of the rig and compressor short distances with the addition of a snatch block.

This unit is able to control the correct weight on bit and rotation speeds to result in high quality core and recovery. For rig moves close helicopter support would be essential in polar environments, although the Webster HP-150 can be utilised in an optional people portable mode, whereby the rig breaks down into five modules, the heaviest weighing 113 kilograms. This module is the Ruggerini diesel engine module which could also be replaced by a Rotax gasoline engine well suited to polar environments. The operation of this unit would require two persons. The equipment requirements of this option are readily available within New Zealand.

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CORE DESCRIPTION

Warren Dickinson and Ian Jennings

During 23 days in the field, a total of 49.7 metres was drilled, and from this, 42 metres of core was collected. There were three main drill sites, and a total of 19 holes were drilled with the deepest being 9.52 metres (Table 1).

Table 1. Summary of core holes at Table Mt.

AREA	CORE HOLE	SURFACE ELEVATION (m)	TOTAL DEPTH (m)	CORE RECOVERY (m)
STATION ONE	TM-1	1946.6	1.58	1.37
	TM-1A	1946.6	1.36	1.16
	TM-1B	1946.6	1.30	1.26
	TM-1C	1946.6	7.93	7.56
	TM-2	1944.3	1.92	1.68
	TM-2A	1944.3	0.30	0.13
	TM-2B	1944.3	0.40	0.20
	TM-2C	1944.3	0.40	0.25
	TM-3	1944.6	2.24	1.94
	TM-4	1944.8	3.00	2.36
	TM-4A	1944.8	1.30	1.02
	TM-5	1941.9	2.15	1.92
TM-6	TM-6	1906.0	4.10	3.70
IAN'S ROCK	TM-7	1863.0	0.54	0
	TM-7A	1863.0	4.80	4.58
	TM-7B	1863.0	9.52	9.01
	TM-8	1860.7	0.55	0.34
	TM-8A	1860.7	0.40	0.31
	TM-8B	1860.7	5.90	3.28
TOTAL			**49.69**	**42.07**

Core Handling

At the end of a drill run, the drill-string assembly was brought out of the hole and laid on rocks to keep it off of the ground. After unthreading the bit and core catcher, core would usually slide out of the single tube barrels. However, moderate hammer blows on the core barrel would free the core if it was stuck. The core was then placed in one metre lengths of 65mm (ID) split-plastic tubes, which were laid out on a pallet for on-site logging. Because the air temperature at Table Mt did not exceed -8.5°C, there was little danger of the core melting while being logged unless it sat in direct sun for an extended period of time.

Brief and very generalized descriptions were given to the core in the field. However, particular attention was given to measuring the core and interpretation of core loss and gain during each drill run. After logging, the split-plastic tubes were taped together around the core, marked, and wrapped in lay-flat plastic. The one metre lengths of wrapped core were placed into insulated (50mm thick polyfoam) plywood boxes (1.2 x 0,4 x 0.4m) which were partially buried and covered with snow to protect them from the heat of sunlight.

The core boxes were flown from the field to Scott Base and placed in a freezer kept at -18°C. For the nine hour flight to Christchurch, about 15 kg of dry ice was packed into each of the core boxes. On arrival the boxes were then stored in the NSF freezer for about 2 weeks before being trucked to the freezer at Industrial Research Ltd, Lower Hutt where they presently (Sept, 1997) remain. Although recording thermometers were not in the boxes, snow from Table Mt, which was in the boxes, showed no signs of melting.

Under the present conditions, it is clear the core cannot be kept frozen indefinitely. There is evidence that the ice in the pores and fractures of the core is slowly evaporating. Wrapping the core in plastic inhibits this evaporation, but it also hampers access to sampling and examination. Although friable when unfrozen and dry, most parts of the core hold together with careful handling. However, depending on the amount of ice, a few parts of the core will virtually disintegrate if thawed. Eventually, these few parts of the core will probably have to be sacrificed for long term storage at room temperature.

Before the core could be sampled, it had to be photographed and described in detail. In preparation for this, it was found that sedimentary structures could be best seen by simply cleaning the outside of the frozen core with a wire brush and rasp. Splitting the core by sawing it in half was tedious and time consuming. It also necessitated the use of a non-freezing liquid lubricant, which would contaminate the core. A core-splitter, which was later used for sampling, produced split surfaces that showed less detail than the scrubbed outside of the core.

Core Logs and Photographs

Cores TM-1C, TM-6, and TM-7B were selected for detailed logging because they were the deepest in each of the three areas. Field logs show that adjacent cores have similar lithologies.

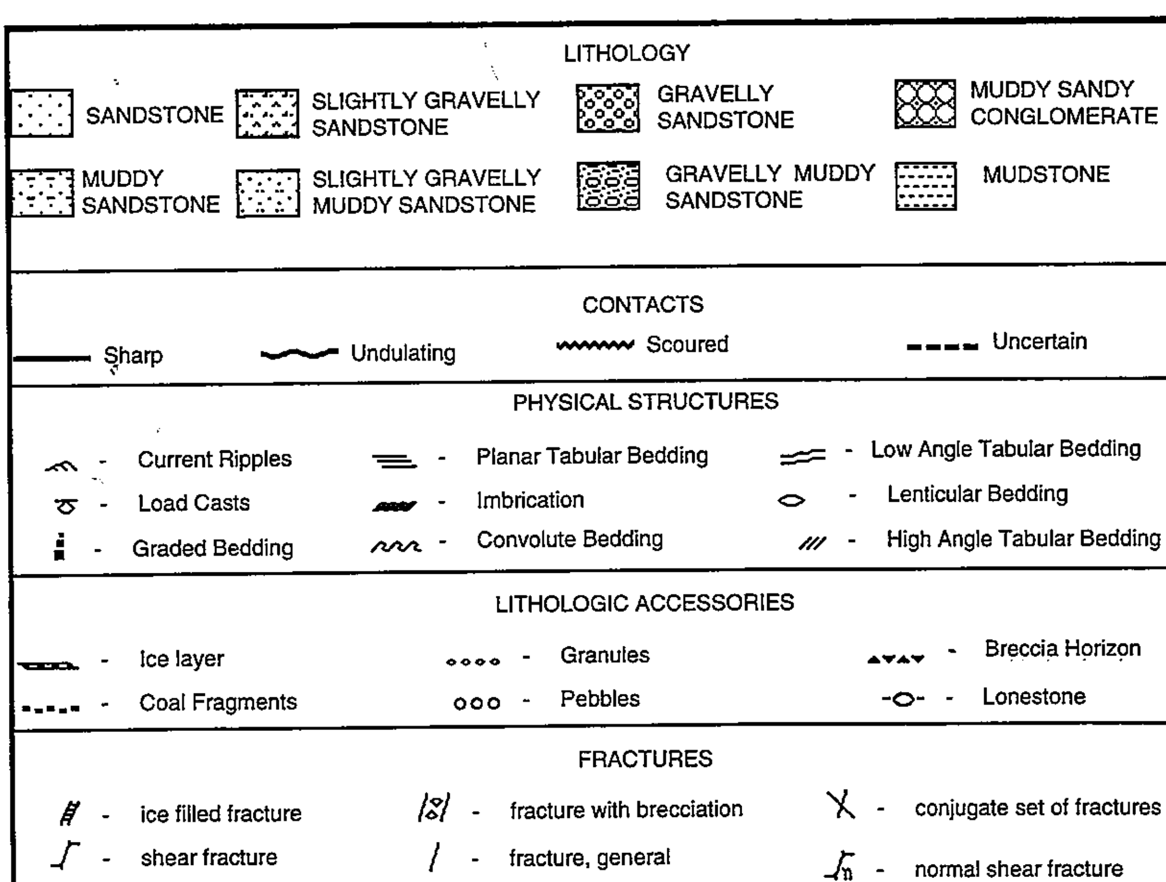


Figure 1. Symbols used for core logs of TM-1C, TM-6, and TM-7B.

Site Bluff area

DATE CORED Fri 29 Nov

CORE # TM - 1

TIME CORED aft - evening

HQ tripple wall core barrel

Box No.	CORE	DEPTH (m)	MEDIAN GRAIN SIZE (GRAVEL / SAND / SILT / CLAY; g / vc / c / m / f / vf)	LITHOLOGY	COLOUR	Stratification	Clasts	OTHER DESCRIPTION
BOX 1		0						
	①							
		0.45–0.51	lost .06	X X	X	X	X	
	②							
		0.93						
		1.00						
		1.04–1.12	lost .08	X X	X X X	X	X	END OF SPLIT
	③							Bit is melting formation; Korf = too lg
		1.35–1.42	lost 0.07	X X	X	X	X	
	④		melt rind (~2mm) around core					Bit frozen in Hole & abandoned
		1.58						EOC

Site Bluff area DATE CORED Nov 30

CORE # TM -1A TIME CORED AM

NQ drill rod diameter; drilled as a rescue hole for TM-1

Box No.	CORE	DEPTH (m)	MEDIAN GRAIN SIZE (GRAVEL : SAND : SILT : CLAY; g : c c m f f)	LITHOLOGY	COLOUR	Stratification	Clasts	OTHER DESCRIPTION
BOX 1	①	0 – .62						See description TM-1C
		.62 – .78	lost 0.16	X	X	X	X	X
	②	.78 – 1.10 (1.00)						
	③	1.10 – 1.32						
		1.32 – 1.36	lost 0.04	X		EOC		

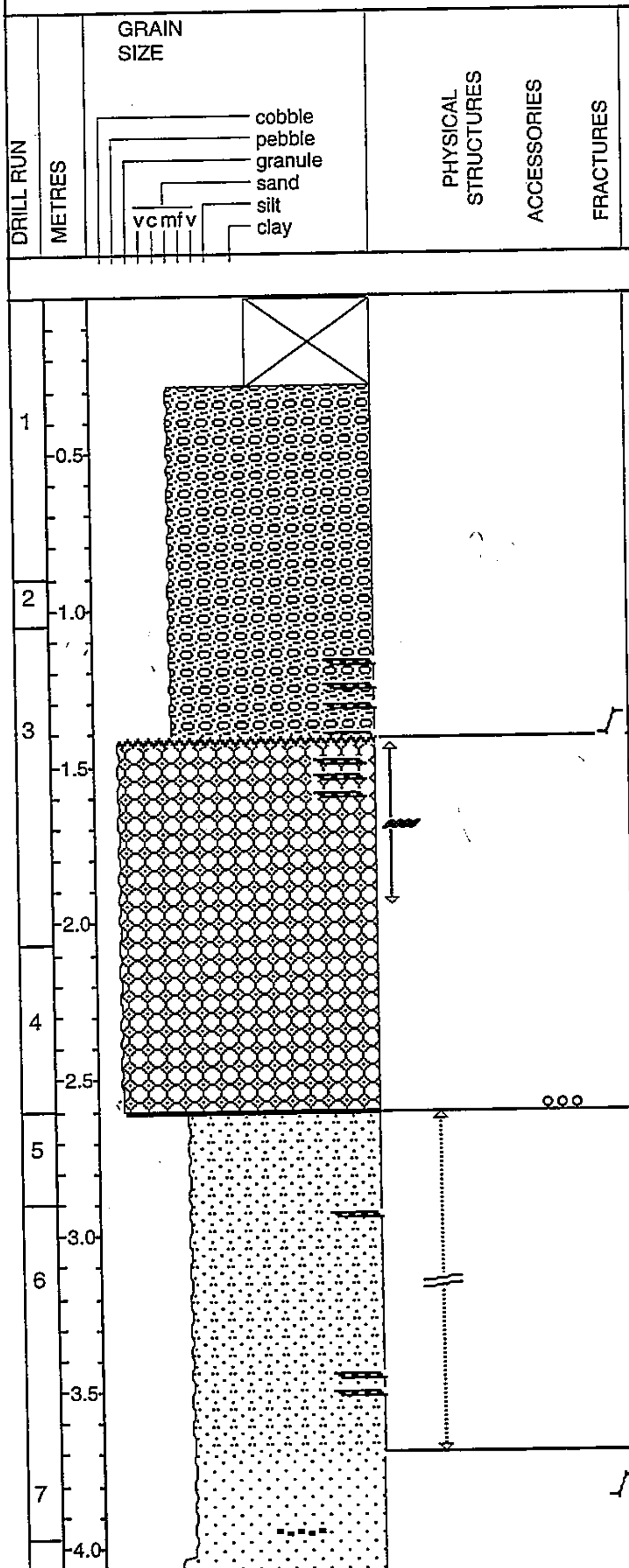
Site Bluff area DATE CORED

CORE # TM-1B TIME CORED

NQ drill rod - hole drilled to recover TM-1

Box No.	CORE	DEPTH (m)	MEDIAN GRAIN SIZE (GRAVEL : SAND : SILT : CLAY; g c cm f f)	LITHOLOGY	COLOUR	Stratification	Clasts	OTHER DESCRIPTION
Box 56		0						See TM-1C for descriptions
		Lost .01						
	①	0.36						
	②	0.39						
		0.54						
	③	0.72						
	④	0.93						
	⑤	1.22						
	⑥	1.30						

TM-1C



VISUAL CORE DESCRIPTION

UNIT 1; 0.30-1.42m
Massive, bimodely sorted, gravelly, **muddy, SANDSTONE** (yellowish grey 2.5Y 8/2 to Pinkish grey 5YR 8/1). Clasts up to 70mm form 20% of the rock and are matrix supported. Clasts range from angular to sub-rounded but are dominantly sub-angular. Lithologies are mostly dolerite with some quartz, siltstone and sandstone. A large dolerite clast at 1.03m has a coating (1-2mm) of **muddy, fine SAND** (Pinkish grey 5YR 7/2). Ice lens are common in the bottom 20cm. At 1.24m and 1.30m ice is inclined at 30 , at 1.37m an ice lense is sheared by a fault dipping 15 .

The base of the unit is sharp and erosional.

UNIT 2; 1.42-2.60m
Massive to weakly stratified, poorly sorted, **medium sandy CONGLOMERATE** (Pinkish grey 5YR 8/1). Clasts range from 10% in the top 10cm, to 60% at the bottom of the unit, but average 40%, and increase in size with depth(<45mm). The unit is are clast supported, and clasts range from angular to rounded but are dominantly angular. Lithologies are mainly dolerite with some reddish brown sub-angular siltstone up to 20mm. Mud content in the unit decreases with depth. Ice lenses present in the top 20cm dip about 10 . Between 1.5 - 1.95m imbrication is strong (10-15).

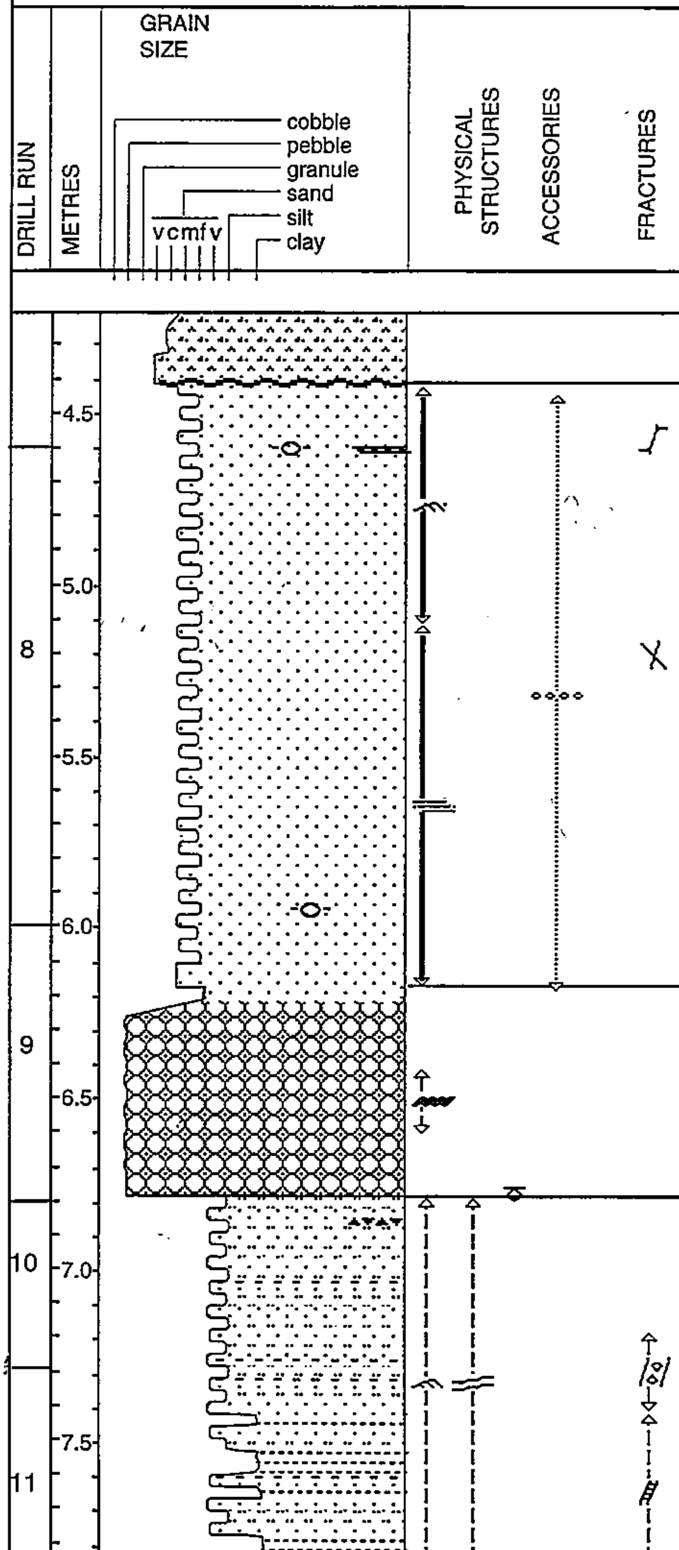
The lower contact is sharp and disconformable, and is rich in dolerite and quartz clasts.

UNIT 3; 2.60-3.70m
Massive to weakly stratified (mm-3cm scale), poorly sorted, **slightly gravelly, muddy, medium SANDSTONE** (Pinkish grey 5YR 8/1). Rear lonestones up to 40mm range from angular to sub-angular and are dominantly dolerite, with some grey siltstone, quartz and black coal. Ice lenses are present at 2.93m, 3.45m, and 3.50m, the later two dip at 25 . Bedding is planar.

The lower contact is gradational.

UNIT 4; 3.70-4.41m
Strongly stratified (mm scale), poorly sorted, **fine SANDSTONE** (Light grey 2.5Y 8/1). Rear granule sized coal clasts are present throughout the core and form at concentrated lense at 3.95m. The unit is cut by a shear dipping 25 at 3.80m. Bedding is planar (<5) to cross-bedded. The bottom 15cm grades into a massive, poorly sorted, **slightly gravelly, coarse SANDSTONE.** The lower contact is sharp and wavy.

TM-1C



VISUAL CORE DESCRIPTION

UNIT 4; 3.70-4.41m
Strongly stratified (mm scale), poorly sorted, **fine SANDSTONE** (Light grey 2.5Y 8/1). Rear granular sized coal clasts are present throughout the core and form at concentrated lense at 3.95m. The unit is cut by a shear dipping 25 at 3.80m. Low angle bedding (<5) is parallel, and cross-bedded. The bottom 15cm grades into a massive, poorly sorted, **slightly gravelly, coarse SANDSTONE.**
The lower contact is sharp and wavy.

UNIT 5; 4.41-6.20m
Weak to strongly stratified (cm scale), interbedded, poorly sorted, **fine SANDSTONE** (Pinkish grey 5YR 8/1), and well sorted, **coarse SANDSTONE** (Light grey 2.5Y 8/1). Rare granule-sized lonestones of dolerite are seen throughout the unit; one large lonestone (4cm) is at 5.20m. Granule-sized coal clasts form a lens at 4.54m. Ice lenses inclined at 30 are present at 4.60m and 5.94; ice is also at 6.20m. The unit is cut by a shear dipping 30 at 4.57m and by a conjugate set at 5.20m. Bedding ranges from cross-bedding (<30) in the top 70cm to panar towards the bottom.

The lower contact is gradational.

UNIT 6; 6.20-6.78m
Massive, poorly sorted, **coarse sandy, CONGLOMERATE** (light grey 5.7Y 8/1). Clast up to 20mm range form 30% of the rock in the top 10cm, to 70% at the base. These are matrix supported at the top of the unit but become clast supported at 6.28m. Clasts are angular to rounded but are dominantly sub-rounded. Lithologies are mainly dolerite with some siltstone and quartz. A slight clast imbrication (5-40) is visible between 6.40-6.60m.

Lower contact is sharp and wavy with clasts implanted into lower unit.

UNIT 7; 6.78-7.86m
Interbedded, weak to very strongly stratified (mm scale), highly fractured and deformed, well sorted, **medium SANDSTONE** (light grey 7.5YR 8/1), poorly sorted, **muddy, fine SANDSTONE** (Light brownish grey 7.5YR 6/2) and **MUDSTONE** (grey 5Y 6/1). Bedding ranges from planar <5 , to cross-bedded. Shearing is common, and is sub-horizontal to 45 . In the lower 40cm shears are ice filled. At 7.42m a vertical ice filled fracture has been compressed horizontally by a factor of 2.

Site Patterned Ground Area DATE CORED Mon 2 Dec

CORE # TM - 2 TIME CORED PM

Box No.	CORE	DEPTH (m)	MEDIAN GRAIN SIZE (GRAVEL / SAND / SILT / CLAY; g c cm f f)	LITHOLOGY	COLOUR	Stratification	Clasts	OTHER DESCRIPTION
		0						
	①		colluvium clay-pebble material mostly cse sd; Hi ice content est 60%		Pot Spl 8-12 cm			Wx/Colluvium composed of Sirius material - being reworked by patterned at some point in time
		.16	16 – 23 loss .07					
	②	.25	↓ inc % of ice	vert lineation in sand apparent	Pot Spl 30-33			
	30 ③		33					
			50% ice ice segregation of material					
	38 ④							
	.49		46 – 49 loss 3cm loss					
	⑤		ICE	Pot Spl 50-53				
	.53		55- LOST .53-.55					
			Ice W/sand					
			68	Pot Spl 66-69				
			Ice rare sd					
BOX 2	⑥		84 clast/ice deformation	Pot Spl 84-89				
		1.00	98 contact	CONTACT				
			Sirius clast-rich diamict grey unit					
			120					
	1.23		123 Ice lense	Pot Spl 120-125				
			125 ICE					
	⑦		grey diamict lg clasts upto 6 cm (A axis)					
			141					
			Single clast					
	1.50		151					
		.09 / 1.59	compact Sirius matrix: supported; many lg clasts upto 5 cm dia					
	⑧		Lodgment					
	1.68		clasts upto 6cm dia					
	⑨		v hard matrix					
			1.79					
			1 lg dolorite clast					
		1.84	Loss 1.84 - 1.92					
⑩	1.90	1.92	192 PoA EOC	drilled 2cm in 15min decided to stop because we were drilling lg clast approx 10cm				
			Should recover 1.68m					

Site Pattern Ground Area DATE CORED Mon 2 Dec

CORE # TM - 2A TIME CORED PM
TM - 2B
TM - 2C

Box No.	CORE	DEPTH (m)	MEDIAN GRAIN SIZE (GRAVEL, SAND g c c m f f, SILT, CLAY)	LITHOLOGY	COLOUR	Stratification	Clasts	OTHER DESCRIPTION
Box 6	①	0 – 0.13	TM - 2A: clasts of dolerite, grit + clay all ice cmted; ice lamina + beds upto 3cm					Re-worked sirius; colluvium
Box 6	①	0 – .06 – 0.20	TM - 2B; Ice	AA				AA
Box 6	①	0 – .02 – 0.25	TM - 2C; ICE			AA		

Site Patterned Ground Area DATE CORED Dec 2, Tue

CORE # TM-3 TIME CORED 1:30 - 2:00p

Jon took B+W photos of site

Box No.	CORE	DEPTH (m)	MEDIAN GRAIN SIZE (GRAVEL, SAND, SILT, CLAY; g c cm f f)	LITHOLOGY	COLOUR	Stratification	Clasts	OTHER DESCRIPTION
BOX 6		0	0.02 clast-rich ice					
			clast-poor ice					
			~~0.23~~					
			dolerite clast					
			Med sd; clast-poor ice → lg clasts @ btm					
		0.50					EOC	Drillers log shows 2.24 as end of hole; but only top 0.50 m of core was saved. Core quality below 0.50 is so bad it was not kept

Site lateral to TM-1 site

DATE CORED 3 Dec Tue

CORE # TM-4

PQ diameter

TIME CORED 4:30 - 6:00p

Box No.	CORE	DEPTH (m)	MEDIAN GRAIN SIZE (GRAVEL / SAND / SILT / CLAY; g c c m f f)	LITHOLOGY	COLOUR	Stratification	Clasts	OTHER DESCRIPTION
BOX 7	①	0 – 0.85	med-cse sd, few clasts (5cm dia) minor ice lenses; poss wtr lain					
		0.85 – 1.07 (1.00)	lost 0.22	X	X	X	X	
		1.07 – 1.46	AA	1.15 — Split run				
	②	1.46 – 1.84	clasts, lodgment deformed ice lenses					
		1.84 – 1.89	lodgment (no ice)					
	③	1.89 – 2.00	X Lost .42	X	X	X	X	

Site | DATE CORED

CORE # TM-4 con't | TIME CORED

Box No.	CORE	DEPTH (m)	MEDIAN GRAIN SIZE (GRAVEL, SAND g c c m f f, SILT, CLAY)	LITHOLOGY	COLOUR	Stratification	Clasts	OTHER DESCRIPTION
BOX 7	③	2.00 – 2.31	Lost .42	X	X	X		
		2.31	fn matrix sltstn? csen downward					
		~~2.55~~						Split run
			Ice lenses 2.73 – 2.83; lg clast @ contact w/ Terra cotta					
		2.91	Contact? w/ Terra Cotta					
		3.00						EOC

Site

DATE CORED Dec 3

CORE # TM-4A NQ TIME CORED 5:30p

(GLAD WRAPPED)

Box No.	CORE	DEPTH (m)	MEDIAN GRAIN SIZE (GRAVEL / SAND / SILT / CLAY; g c cm f f)	LITHOLOGY	COLOUR	Stratification	Clasts	OTHER DESCRIPTION
BOX 6	①	0	Diamict No clast < 3cm a-axis Sandy matrix, massive & compact					
		0.48	less compact rare clasts < 1cm; sandier than above					
		0.69 – 0.85	LOST .16 cm					
	②	0.85 – 1.00	AA; Some wtr lain features					
		1.19 – 1.30	lost 0.11					
		2.00						

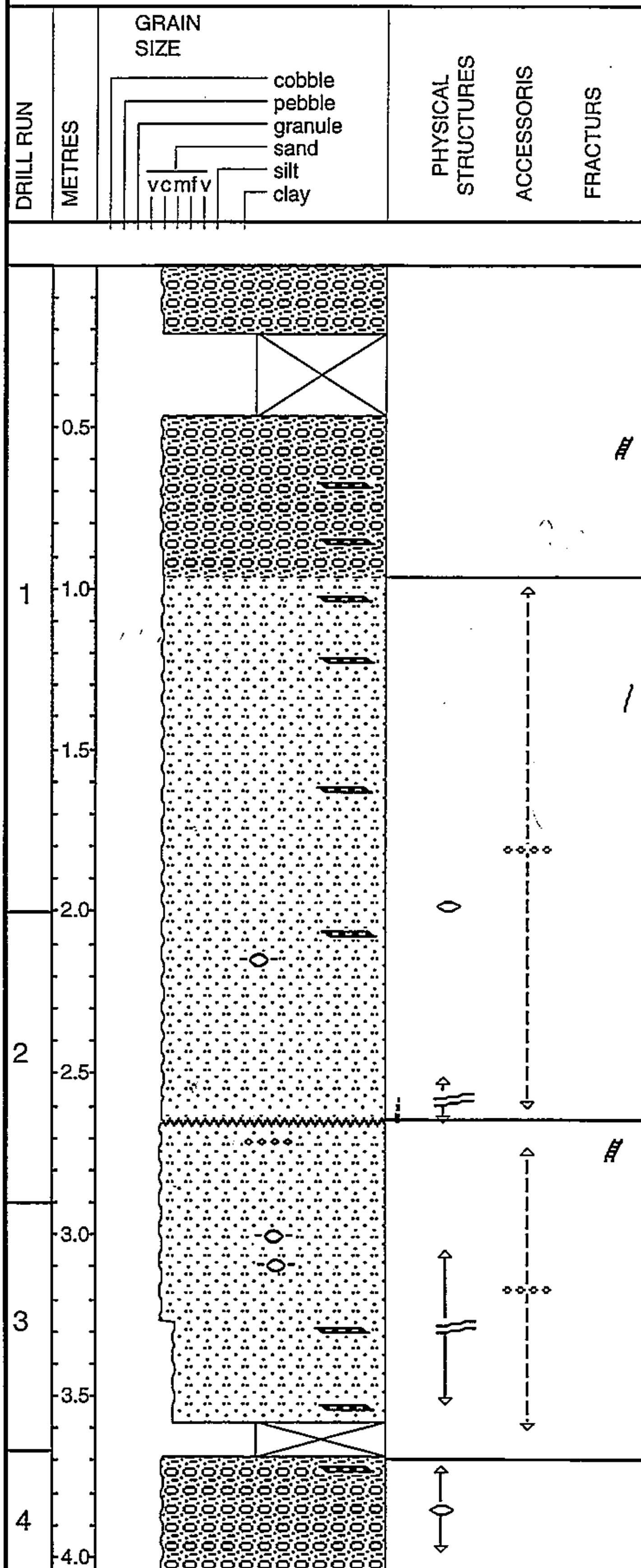
Site Lateral to TM-1 DATE CORED Dec 4

CORE # TM-5 HQ TIME CORED 11:30 A

just down slope from TM-4
attempt to core contact

Box No.	CORE	DEPTH (m)	MEDIAN GRAIN SIZE (GRAVEL, SAND, SILT, CLAY; g c c m f f)	LITHOLOGY	COLOUR	Stratification	Clasts	OTHER DESCRIPTION
		0	Sirius w/ minor ice lenses					
	①	0.12	Ice w/ minor clasts (shale + Sirius)					
		0.40	inc. clasts of shale					
	②	.44						
			Shale clasts w/ ice					
BOX 8	③	.94 / 1.00	Shale clasts w/ice AA	increasing shale clasts				
	④	1.22	AA					
		1.50	Minor ice & mostly Terra Cotta					
	⑤	1.59	Terra Cotta wo/ice — 1.73 split run					
		1.92						EOC
		2.00	Lost .23	X	X	X	X	
		2.15						

TM-6



VISUAL CORE DESCRIPTION

UNIT 1; 0-0.96m
Massive, bimodally sorted, gravelly, muddy, coarse SANDSTONE (light grey 2.5Y 8/1). Clasts up to 50mm form 5-10% of the rock and are matrix supported. Clasts range from angular to sub-rounded but are dominantly angular. Lithologies include dolerite with some siltstone. The unit contains ice lenses at 0.85m, and 0.68m. These are typically underlain by a fine layer (1-3mm) of fine bedded (mm scale), moderately sorted, muddy, coarse SANDSTONE (light brownish grey). The lower contact of these beds is very sharp and marked by a layer of white clay. The unit is cut by an ice filled shear dipping 45 at 0.55m. The base of the unit is gradational and is placed were the gravel content becomes <5%.

UNIT 2; 0.96-2.66m
Massive to strongly stratified (1-2cm scale), poorly sorted, slightly gravelly, muddy, coarse SANDSTONE (Light grey 5Y 7/2). Clasts up to 4 mm form 5% of the rock. Clasts range from angular to sub-angular and are matrix supported. Lithologies include dolerite and black siltstone. Rare lonestones (<1cm) are present between 2.15-2.25m. Ice layers are present at 1.04, 1.23, 1.62, and 2.07. At 1.34m the unit is cut by a shear dipping 32, at 2.66m the unit is cut by an ice filled shear. Bedding comprises of dark grey, and black coloured bands interbedded with white clay. Bedding ranges from inclined (12) at the base to sub-horizontal towards the top of the unit. Particularly strong bedding is seen at 2.50m. The bottom 5cm is a poorly sorted, very coarse SANDSTONE.

The lower contact is sharp and erosional.

UNIT 3; 2.66-3.58m
Massive to strongly stratified (1-2cm scale), poorly sorted, slightly gravelly, muddy, coarse SANDSTONE(Light grey 5Y 7/2). Clasts up to 4mm form 5% of the rock. Clasts range from angular to sub-angular and are matrix supported. Lithologies include dolerite and black siltstone. Rare lonestones are present between 3.00-3.10m. The unit contains ice layers at 3.30m and 3.50m. Bedding ranges from 24 at the base to 12 at 3.03m and comprises of dark grey and black coloured bands interbedded with white clay. Above this the unit is massive.

The lower contact is not seen due to core loss.

UNIT 4; 3.69-4.07m
Strongly stratified (2cm scale), bimodally sorted, gravelly, muddy, coarse SANDSTONE (Light grey 2.5Y 8/1). Granular-sized clasts form 10% of the rock and are matrix supported. Lithologies are dominantly grey siltstone with some dolerite. Lonestones >50mm are present at 3.70m and 4.00m. The unit contains ice layers at 3.72m and 3.75m. Bedding is lenticular and at a low angle.

Site Barrett Dropstone Area DATE CORED Dec 7

CORE # TM-7A TIME CORED 12 P.

NQ size

Box No.	CORE	DEPTH (m)	MEDIAN GRAIN SIZE (GRAVEL / SAND / SILT / CLAY; g c cm f f)	LITHOLOGY	COLOUR	Stratification	Clasts	OTHER DESCRIPTION
BOX 10		0 – 0.16	lost 0.16 (Prob because not permafrosted)					
	①	0.16	Med cse sd; Bedding; Deformation? Iff	Iff = 23, 28, 41, 44, 47 & 57 cm @ btm				
	②	0.57	Cgl, sd matrix; 71 - 76 - ice matrix; 76 - 80 cgl w/sd matrix; 0.88 lost 0.01; 0.81 - 0.88 rare cgl in ice					into ancient pg? under sand - we get cong. + ice = prior to ice advance, warm conditions.
	③	0.89	cse sd, coal clasts, cglomeratic clasts 1-7mm; bedding; coal clast 106-107, 123-124					
		1.00; 1.07	Cse sd w/clasts, better sorted than above					
		1.50						
	④	1.77	cse sd w/ dropstn (1.92m @ 2cm dia); crude bedding; coal clasts;					
		2.00						

Site — DATE CORED

CORE # TM-7A continued — TIME CORED 2:00

Box No.	CORE	DEPTH (m)	MEDIAN GRAIN SIZE (GRAVEL / SAND / SILT / CLAY; g c c m f f)	LITHOLOGY	COLOUR	Stratification	Clasts	OTHER DESCRIPTION
BOX 11		2.00						
		2.07 – 2.10	0.03 loss spinout		X	X	X X	
			Numerous dpstn (up to 6 cm)					
		2.25 – 2.29	0.04 loss (SPINOUT)		X	X	X X	
	4		Sd, crude bedding; rare dpstns < 1 cm; Iff 2.53 – 2.59					
			AA w/vert Iff					
	5	2.79	Sd, med well sorted, fn upward seq, bedding visible; rare dpstn 2.83 – 2.84, Iff 2.77 – 2.81					
		2.87	well sorted med → coarse Sand; rare clasts – coarse bedding 3/4 cm; Some deformation – silty sand lens.					
		3.00						
		3.07	IFF – 3.06			medium → coarse Sand, Coarse bedding		Sirius potential Ash
		3.09	ASh? silt layer – grey					
		3.18 – 3.23	lenses of fine sandy – silt – ASh?					
		3.24	Fine silty – sand; fine lenses of cool, possible ASh?					rec 0.03 extra add to spinout loss in run 4
		3.26	ice layer					
	6	3.40	med – fn gn sd well sorted; some buff layers poss ash xno.					between 3.40 & 3.44, 3.65 – 3.66 main ash potential } CONTACT WITH WINDY GULLY SS !
		3.87	3.87 – 3.89 poss ash layer					
	7		IFF 3.90 – 3.92					
		4.00						

Site

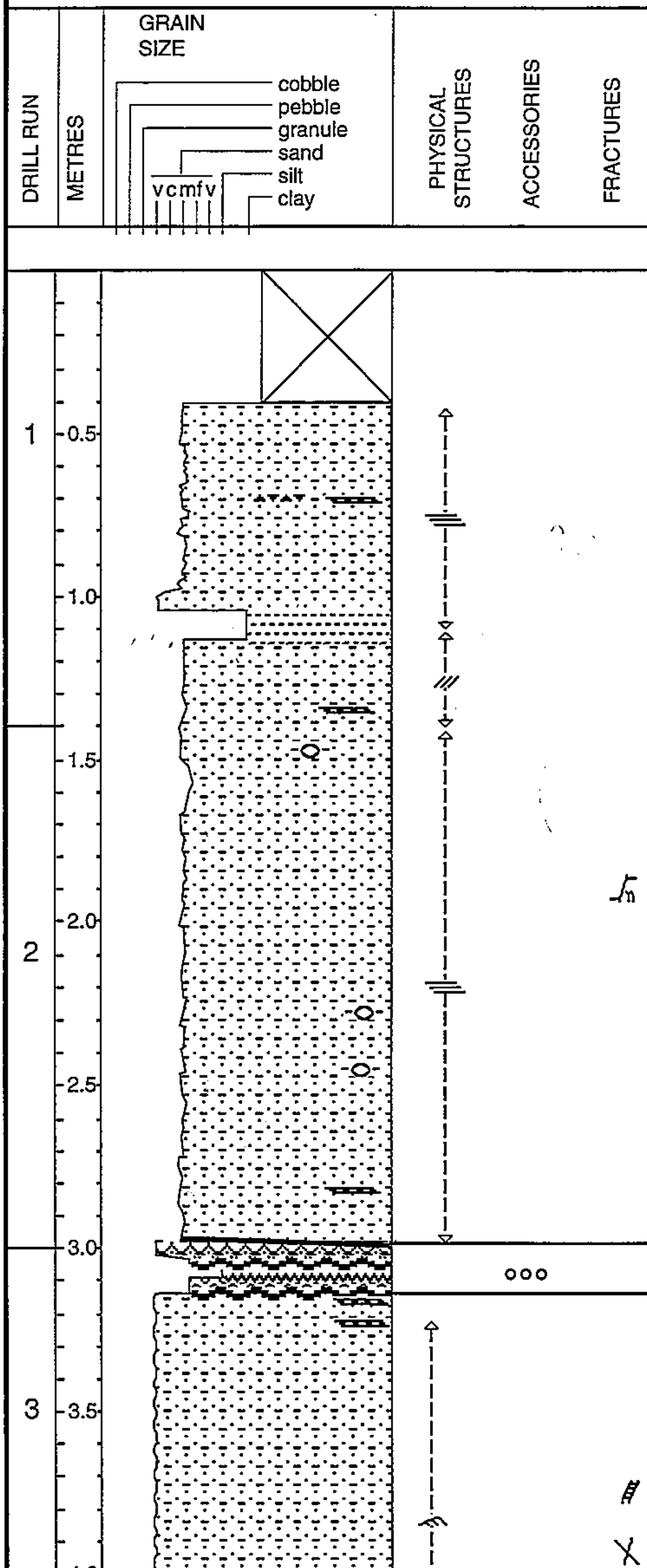
DATE CORED

TIME CORED

CORE # TM-7A continued

Box No.	CORE	DEPTH (m)	MEDIAN GRAIN SIZE (GRAVEL, SAND, SILT, CLAY; g vc c m f vf)	LITHOLOGY	COLOUR	Stratification	Clasts	OTHER DESCRIPTION
BOX II	7	4.00 – 4.80	Cse sand, faint bedding Ice in pores Sm coal bits – length of core Poss wtr escape structures w/ash					EOC (4.80)

TM-7B



VISUAL CORE DESCRIPTION

UNIT 1; 0.40-2.98m

Weakly to strongly stratified(mm scale), poorly sorted, **muddy, medium SANDSTONE** (Light grey 2.5Y 8/1). Containing beds (<4cm) of poorly sorted, **muddy, very coarse SANDSTONE** (Light grey 2.5Y 8/2), and **muddy, very fine SANDSTONE** (Light brownish grey 7.5YR 6/2) A prominent **SILTSTONE** (Light brownish grey 7.5YR 6/1)layer 10cm thick is present at 1.05m. The unit contains few lonestones of dolerite and black coal that range from angular to sub-rounded, but are predominantly sub-angular. The unit contains ice lenses at 1.10m, 2.35m, and 2.80m. A thick (3cm) ice lens at 0.70m contains rounded sandstone pebbles. The unit is cut at 1.90m by a normal fault dipping 45 . Bedding is dominantly horizontally but increases to 40 between 1.10-1.40m. The unit becomes granular-rich towards the base.

The lower contact is sharp and inclined at 45 .

UNIT 2; 2.98-3.14m

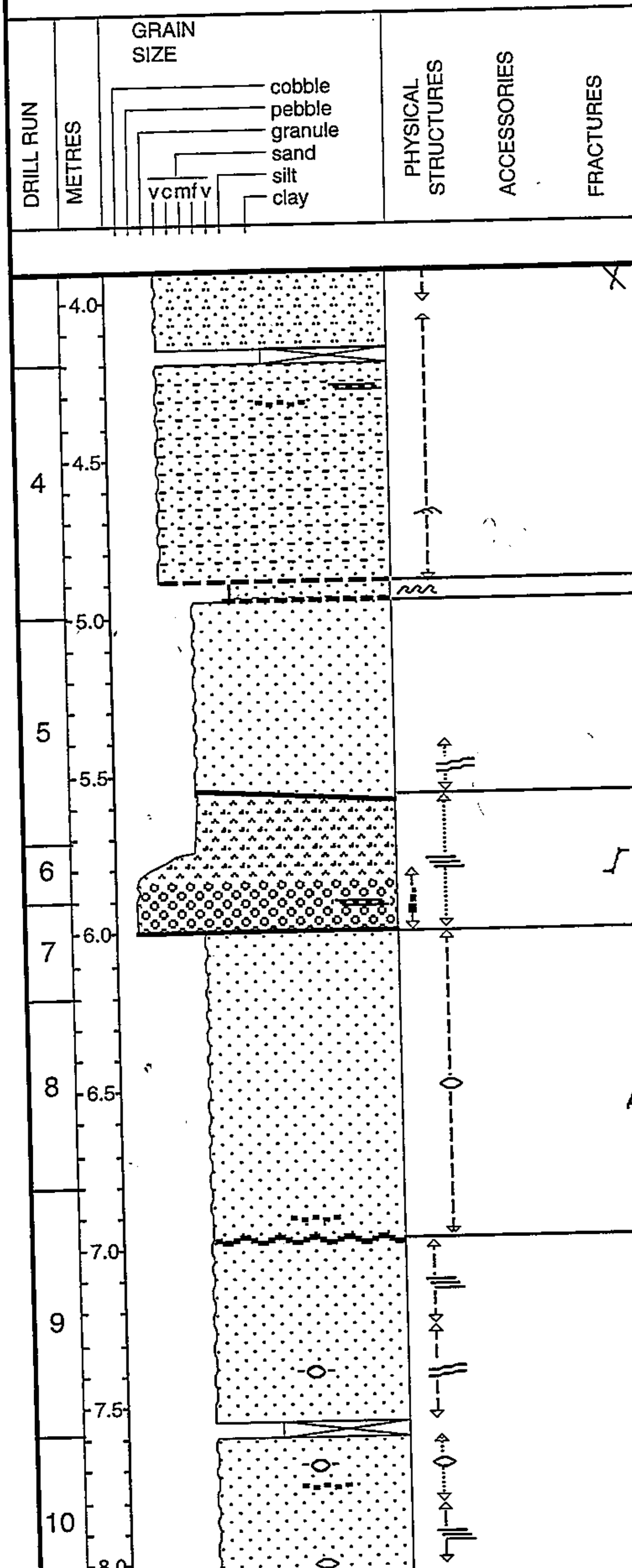
Interbedded, poorly sorted, **very coarse sandy CONGLOMERATE** (Light grey 2.5Y 8/1) and poorly sorted, **gravelly, very coarse SANDSTONE.** Contacts are sharp and wavy. Clasts comprise 2-50% of the unit, and range from angular to sub-rounded but are dominantly sub-angular. Lithologies are dolerite and black siltstone. Between 3.10-3.14m the unit is bed (3cm) **very fine sandy MUDSTONE** (dark brownish grey 2.5Y 8/1), containing sub-rounded sandstone pebbles (<2cm). Lower contact is sharp and wavy.

UNIT 3; 3.14-4.89m

Moderate to strong, small scale (mm-4cm scale) cross-stratified. well sorted, **muddy, very coarse SANDSTONE** (Light grey 5Y 7/2). lonestones make up less than 1% of the rock. The unit contains a 1mm thick lens of coal at 4.31m. Coal clasts are dominantly angular. Ice lenses are present at 3.14m, and 3.23m. Ice filled fractures dipping 26 at 3.75m and 3.94m. Cross-bedded lamination ranges from horizontally to 20 .

The lower contact is damaged by drilling.

TM-7B



VISUAL CORE DESCRIPTION

UNIT 3; 3.14-4.89m
Moderate to strong, small scale (mm-4cm scale) cross-stratified. well sorted, muddy, very coarse **SANDSTONE** (Light grey 5Y 7/2). lonestones make up less than 1% of the rock. The unit contains a 1mm thick lens of coal at 4.31m. Coal clasts are dominantly angular. Ice lenses are present at 3.14m, and 3.23m. Ice fills fractures dipping 26 at 3.75m and 3.94m. cross-bedded lamination ranges from horizontally to 20.

The lower contact is damaged by drilling.

UNIT 4; 4.89-4.95m
Massive, poorly sorted, muddy, very fine **SANDSTONE** (dark greyish brown 5Y 7/2).
Lower contact is damaged by drilling.

UNIT 5; 4.95-5.75m
Massive to weakly stratified(mm scale), well sorted, **medium SANDSTONE** (Light brownish grey 7.5YR 6/2). Bedding is inclined between 5-10 in the bottom 10cm of the unit.
Lower contact is sharp and inclined.

UNIT 6; 5.75-6.00m
Massive to strongly stratified(mm scale), poorly sorted, gravelly, coarse **SANDSTONE**, that grades into a poorly sorted, slightly gravelly medium **SANDSTONE** (light grey 2.5Y 8/1), at 5.80m. Clasts up to 1.5cm make up 3-25% of the rock, are matrix supported, and range from sub-angular to sub-rounded. Clasts are dominantly dolerite with some quartz and siltstone. The unit contains a large lonestone (2cm) at 5.60m. An ice lens dipping at 10 is at 5.90m. The unit has a fracture dipping at 45 at 5.77m.
The lower contact is sharp.

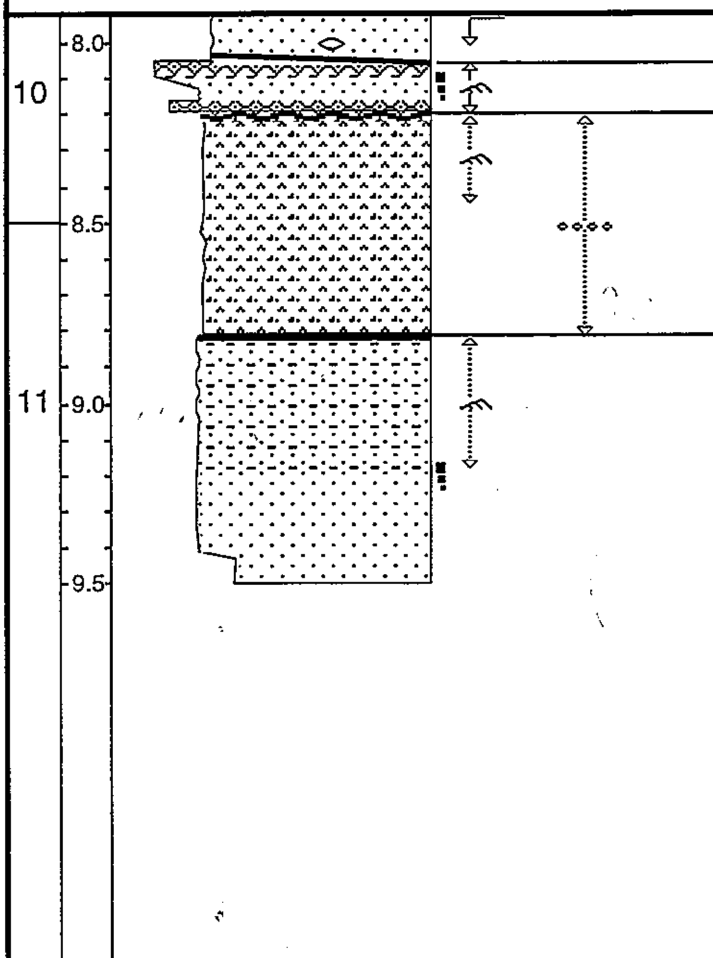
UNIT 7; 6.00-6.97m
Moderately stratified(mm-2cm scale), well sorted, **fine SANDSTONE** (pale yellow 5Y 8/3). The unit contains few coarse sand-sized lonestones of coal. Between 6.85-6.95m coal forms lenses. An ice filled fracture at 6.54 dips 20. Bedding is lenticular and inclined < 20.
Lower contact is sharp and wavy.

UNIT 8; 6.97-8.05m
Very weak to strongly stratified(mm scale), well sorted, fine **SANDSTONE** (pale yellow 5Y 8/3). The unit contains few granular sized lonestones at 7.39m and 7.69m, which have horizontal imbrication. At 7.75m coal clasts form a thin lens. At 7.95m fine (mm-scale) planar bedding in-fills a small channel. Bedding through-out the unit ranges from planar to lenticular < 25.

Lower contact is sharp and inclined at 15.

TM-7B

DRILL RUN	METRES	GRAIN SIZE (cobble, pebble, granule, sand v c m f v, silt, clay)	PHYSICAL STRUCTURES	ACCESSORIES	FRACTURES	VISUAL CORE DESCRIPTION



UNIT 9; 8.05-8.21m
Interbedded, poorly sorted, very coarse sandy **CONGLOMERATE** (pale yellow 5Y 8/3), and cross-bedded (mm-scale), well sorted, **medium SANDSTONE** (pale yellow 5Y 8/3). Clasts within the conglomerate are clast supported,rounded to sub-rounded and comprise of quartz and dolerite. Bedding within the sandstone ranges from horizontal to 30 . The base of the unit is a thin lens (1.5cm) of poorly sorted, **muddy, fine SANDSTONE** (Light grey 2.5Y 8/1).
The lower contact is sharp and wavy.

UNIT 10; 8.21-8.81m
Massive to weakly stratified, bimodally sorted, **slightly gravelly, muddy, fine SANDSTONE** (pale yellow 5Y 8/3). Pebble sized (1cm) clasts of coal are rounded to sub-rounded and comprise 2% of the rock. The upper part of the unit is cross-bedded then becomes massive at 8.45m. Lower contact is sharp and horizontal.

UNIT 11; 8.81-9.50m
Massive to weakly stratified(mm scale), moderately sorted, **medium SANDSTONE** (pale yellow 5Y 8/3). Contains few granular sized lonestones of coal and sandstone that range from sub-angular to sub-rounded. From 8.81-9.18m the unit is cross-bedded, inclined 10-15. . At 9.20m the unit grades into a poorly sorted, **muddy, medium SANDSTONE** (Light grey 2.5Y 8/1). At 9.40m the unit becomes interbedded with well sorted, **muddy, very fine SANDSTONE** (Light brownish grey 7.5YR 6/2).

Site Ian's Rock

DATE CORED 9 Dec

CORE # TM-8 (HQ) + TM-8A (NQ)

TIME CORED 4.00p

Box No.	CORE	DEPTH (m)	MEDIAN GRAIN SIZE (GRAVEL, SAND, SILT, CLAY; g c c m f f)	LITHOLOGY	COLOUR	Stratification	Clasts	OTHER DESCRIPTION
			TM-8					
BOX 15	①	0	Med sd + clasts;	frax		wo/ ice		
		.10	Cgl clasts 0.1 → v lg					
	②	0.20	0.16 loss soft sd + ice but broken clasts grind up core					X X X
		0.36	Cgl clasts 0.1 → v lg					switch to NQ
	③	0.40						
		0.50						
		0.55		Abandoned in lg clast				size of clast = unknown ∴ cannot tell how long to drill thru, drilling v slow in dol clast because cannot put much wt on bit
			TM-8A					
Box 15	①	0	lg >3cm dol clasts in sd matrix; no ice					Added this section of core to top of TM-8B
		0.31	X X X					
		0.40			Abandoned in lg clast			

Site

DATE CORED Dec 11 96

CORE # TM - 8B
NQ

TIME CORED 3 - 7p

Box No.	CORE	DEPTH (m)	MEDIAN GRAIN SIZE (GRAVEL : SAND : SILT : CLAY; g c c m f f)	LITHOLOGY	COLOUR	Stratification	Clasts	OTHER DESCRIPTION
BOX 16	①	0 – 0.28	.28 loss due to loose clasts; 0.31 of core from TM-8A was added to this section of loss. TM-8A is 2m from TM-8B					
		0.28 – 0.38	lg dol clasts upto 15cm dia in unconsol cse sd matrix, No ice					
	②	0.38 – 1.07 (50, 1.00)	Lg Clasts in unconsol sed as seen from side of bore hole. Cse matrix & clasts – no recovery as loose clasts were grinding up core. no recovery 0.38 - 1.07					
	③	1.07 – 1.66	1.10 — abrupt change Sharp contact – seen in side of hole; no core rec from this contact. Tan med/fn sd – as seen in side of hole. lost 0.59 due to clasts grinding core AA					
		1.66 – 1.76	Sirius clasts in v/soft fn gn sd not cmted; no ice poss reworked sirius clasts					
	④	1.76 – 2.00	0.29 loss (due to grinding by clasts) formation prob as below (2.05 - 2.55)					

Pg 2

Site

DATE CORED 12 Dec 97

CORE # TM-8B cont

TIME CORED 10-12 AM

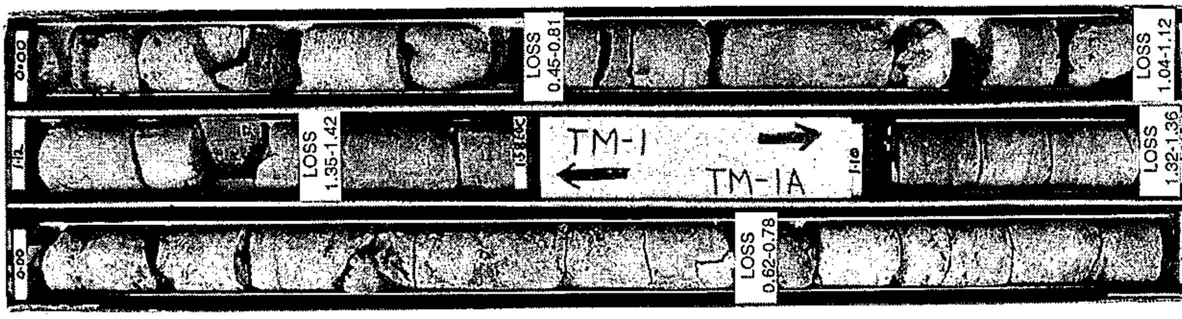
Box No.	CORE	DEPTH (m)	MEDIAN GRAIN SIZE (GRAVEL, SAND, SILT, CLAY; g c c m f f)	LITHOLOGY	COLOUR	Stratification	Clasts	OTHER DESCRIPTION
Box 15		2.00	LOST But prob as below		X	X	X	
	④	2.05	alt grey-tan bedding (1-5mm) deformed; possible wtr-escape structures; poss rip-up clasts of grey-tan material @ 2.17; pbls of shale & alt dolerite			2.22		Split run
		2.55	AA					
Box 16		2.65	0.40 loss (grinding)			X		
	⑤	3.05	recovered cuttings & chips					
		3.10	0.22 loss					
		3.32	faint grey/tan bedding, clasts (1-3cm) matrix supported; appears wtr deposited; sm isolated clasts; Iff & clay filled frax @ 3.68					Sandy ↑ change in lithology
	⑥	3.73		Diamict, clast-poor, variable clast content; some stratification & banding; oblique fracture w/ clay coating				↓
		4.00						

Site Barrett Depth area DATE CORED 12 Dec 96

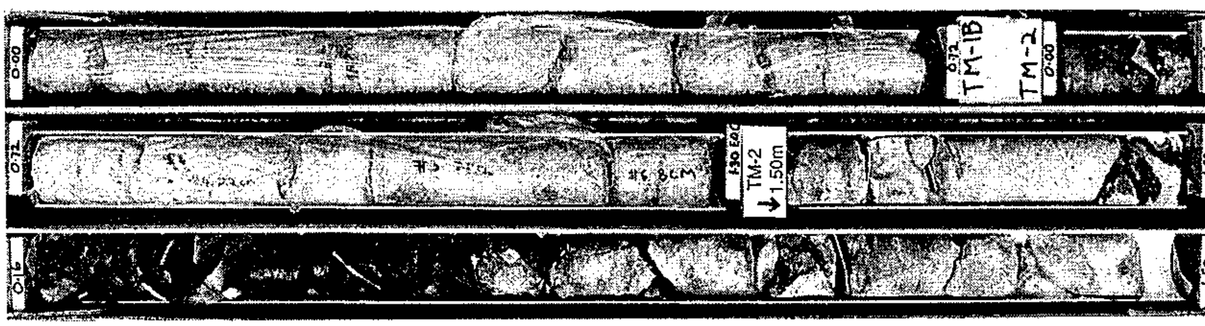
CORE # TM-8B cont' TIME CORED 12-2 pm

NQ

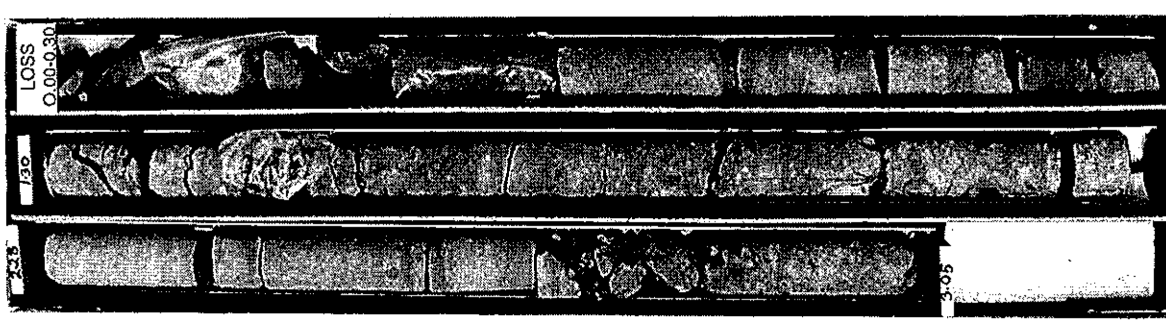
Box No.	CORE	DEPTH (m)	MEDIAN GRAIN SIZE (GRAVEL / SAND g c c m f f / SILT / CLAY)	LITHOLOGY	COLOUR	Stratification	Clasts	OTHER DESCRIPTION
BOX 16	6	4.00	AA					
		4.16 – 4.23	lost 0.07	X	X	X	X	
		4.23 – 4.72 (.50)	AA	4.50 clay filled fracture inclined @ 45°				
	7	4.72 – 5.07 (5.00)	AA w/ lg clasts			Sand stringers & stratification most promenant @ 4.8 - 5.0		
		5.07 – 5.15	lost 0.07	X	X	X	X	
	8	5.15 – 5.47	AA	5.25 sub-vert fracture				
		5.46	x x x x x ← LOST 0.01					
	9	5.47 – 5.73	AA	5.60 prominant sand stringer and structure				
	10	5.73 – 5.9	AA					
		5.9	EOC	cored ~2-3cm into either lg dol clast or dol basement				
			P & A	v. slow drilling & decided to P&A - clast grabbed core catcher & Pat hit drill rod & core snapped & broke off - bent.				



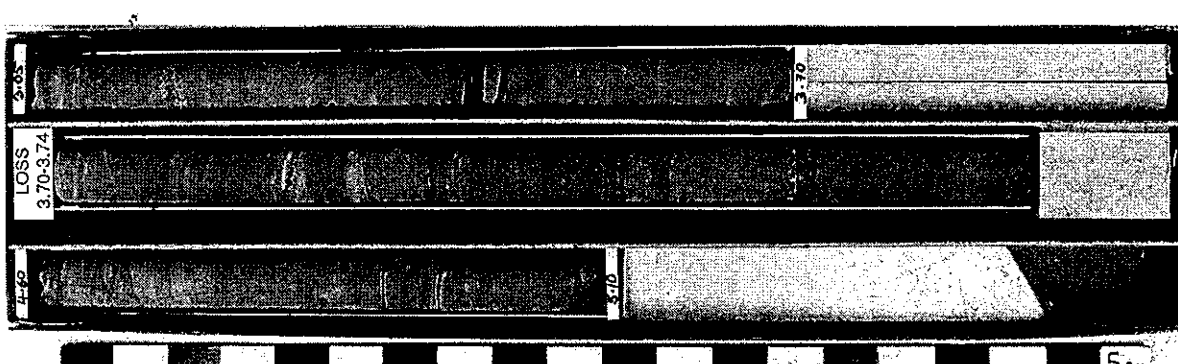
BOX 1: TM-1, 0 - 1.58m; TM-1A, 0 - 1.36m



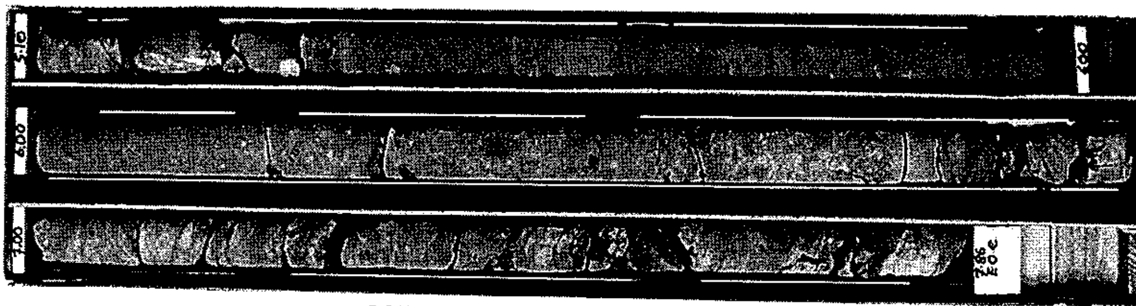
BOX 2: TM-1B, 0 - 1.30m; TM-2, 0 - 1.92m



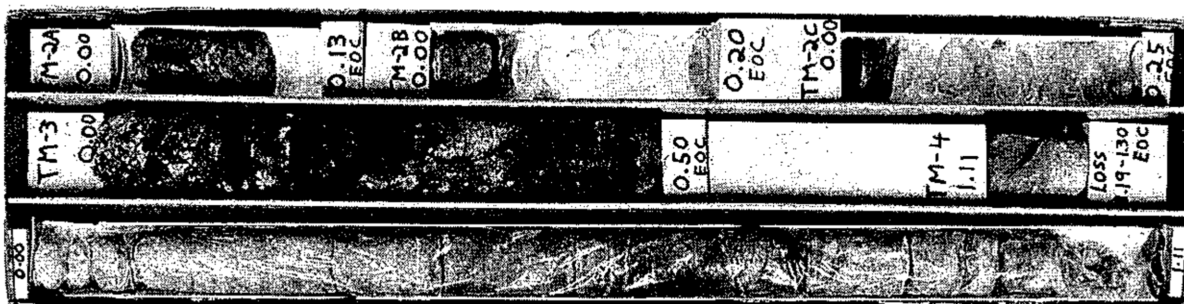
BOX 3: TM-1C, 0 - 3.05m



BOX 4: TM-1C, 3.05 - 5.10



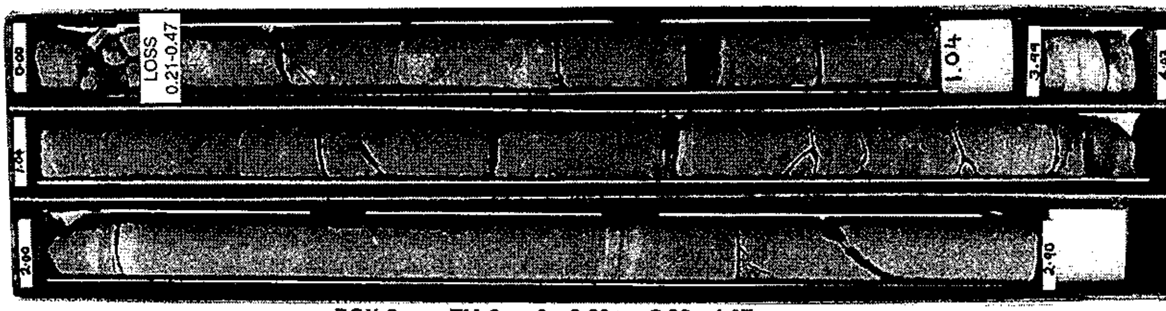
BOX 5: TM-1C, 5.10 - 7.86



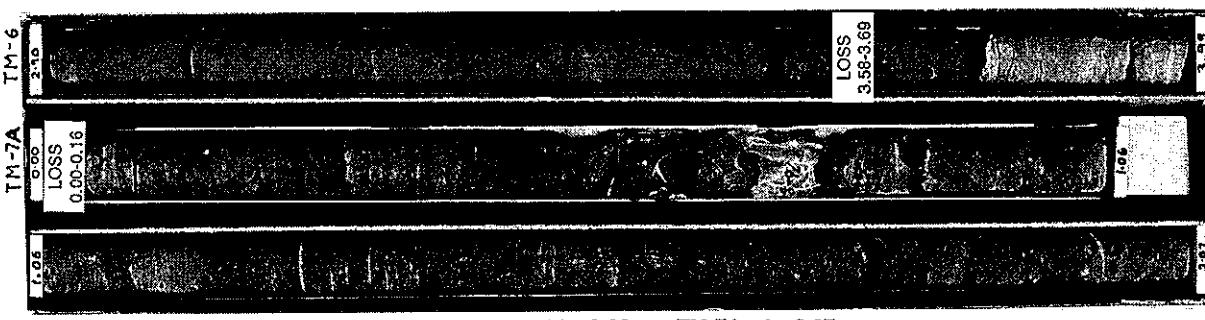
BOX 6: TM-2A, 0 - 0.13m; TM-2B, 0 - 0.20m; TM-2C, 0 - 0.25m
TM-3, 0 - 0.5m; TM-4A, 0 - 1.30m

BOX 7: TM-4, 0 - 3.00m

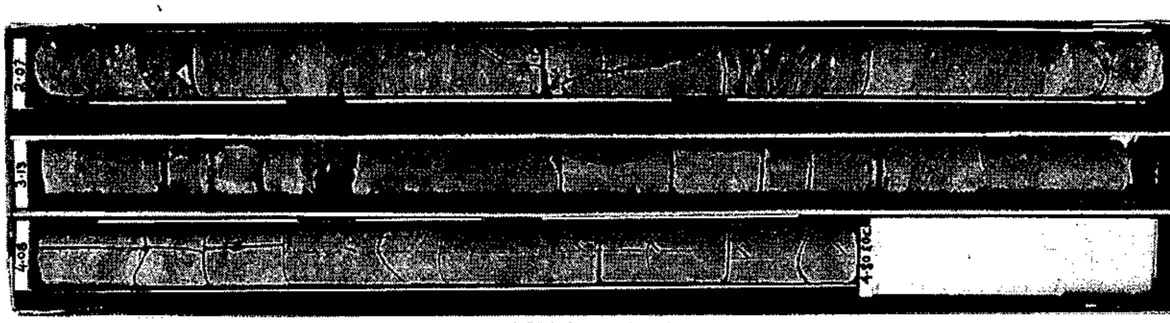
BOX 8: TM-5, 0 - 2.15m



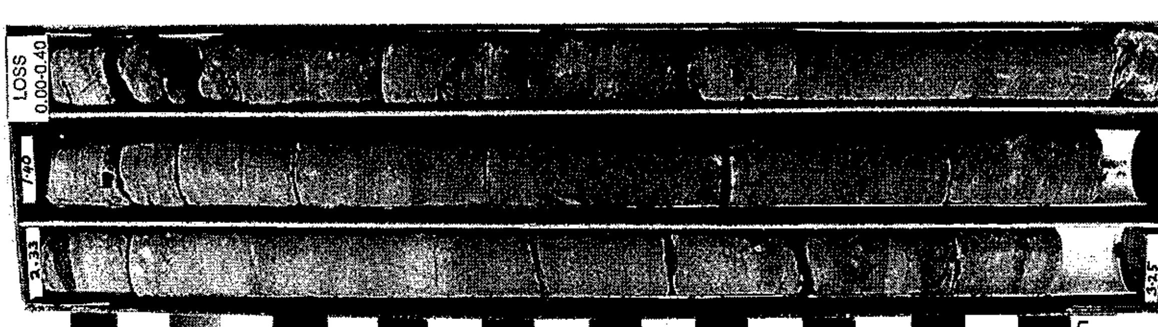
BOX 9: TM-6, 0 - 2.90m; 3.99 - 4.07m



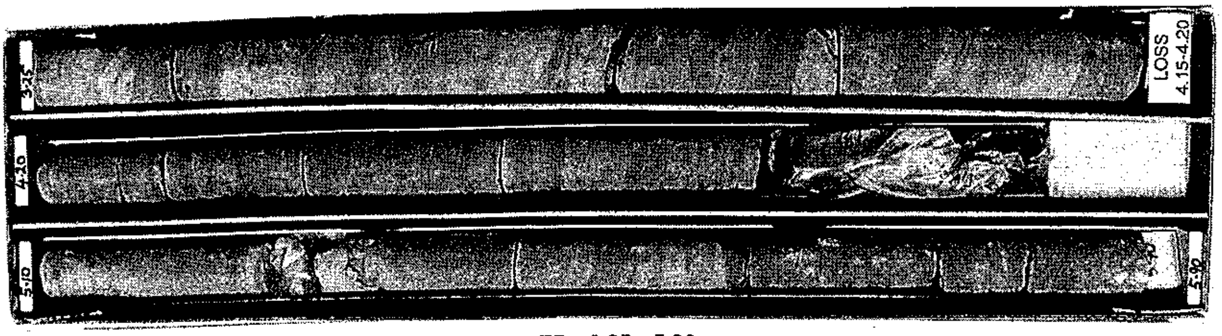
BOX 10: TM-6, 2.90 - 3.99m; TM-7A, 0 - 2.07m



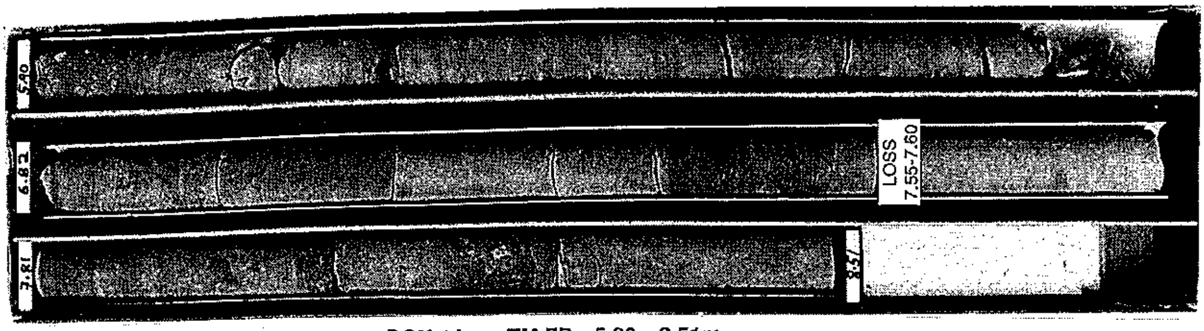
BOX 11: TM-7A, 2.07 - 4.80m



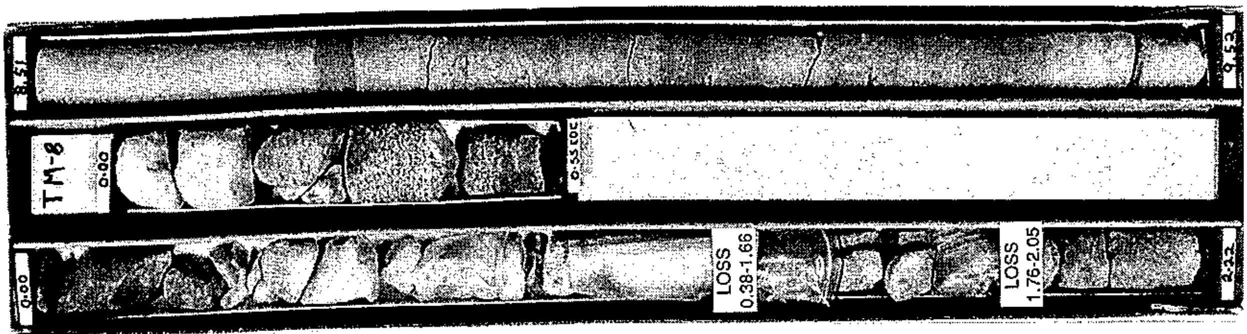
BOX 12: TM-7B, 0 - 3.25m



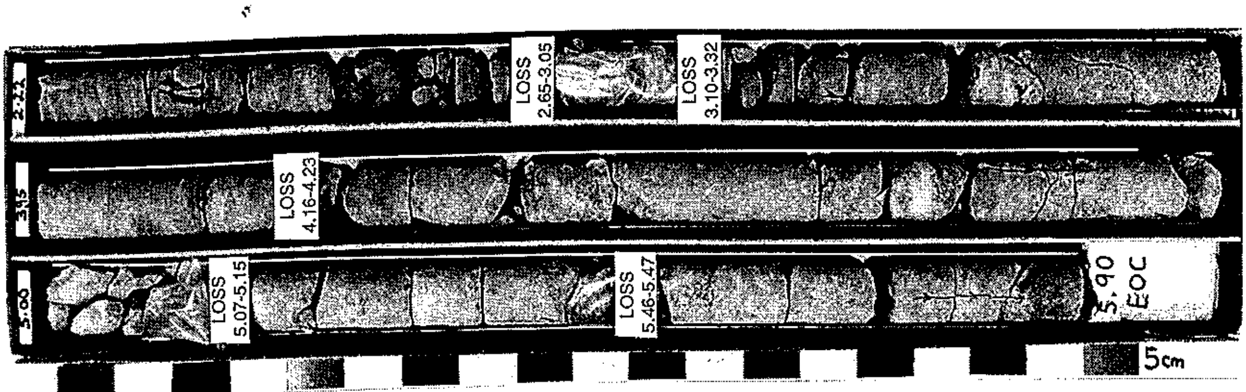
BOX 13: TM-7B, 3.25 - 5.90m



BOX 14: TM-7B, 5.90 - 8.51m



BOX 15: TM-7B, 8.51 - 9.52m; TM-8, 0 - 0.55m; TM-8B, 0 - 2.22m



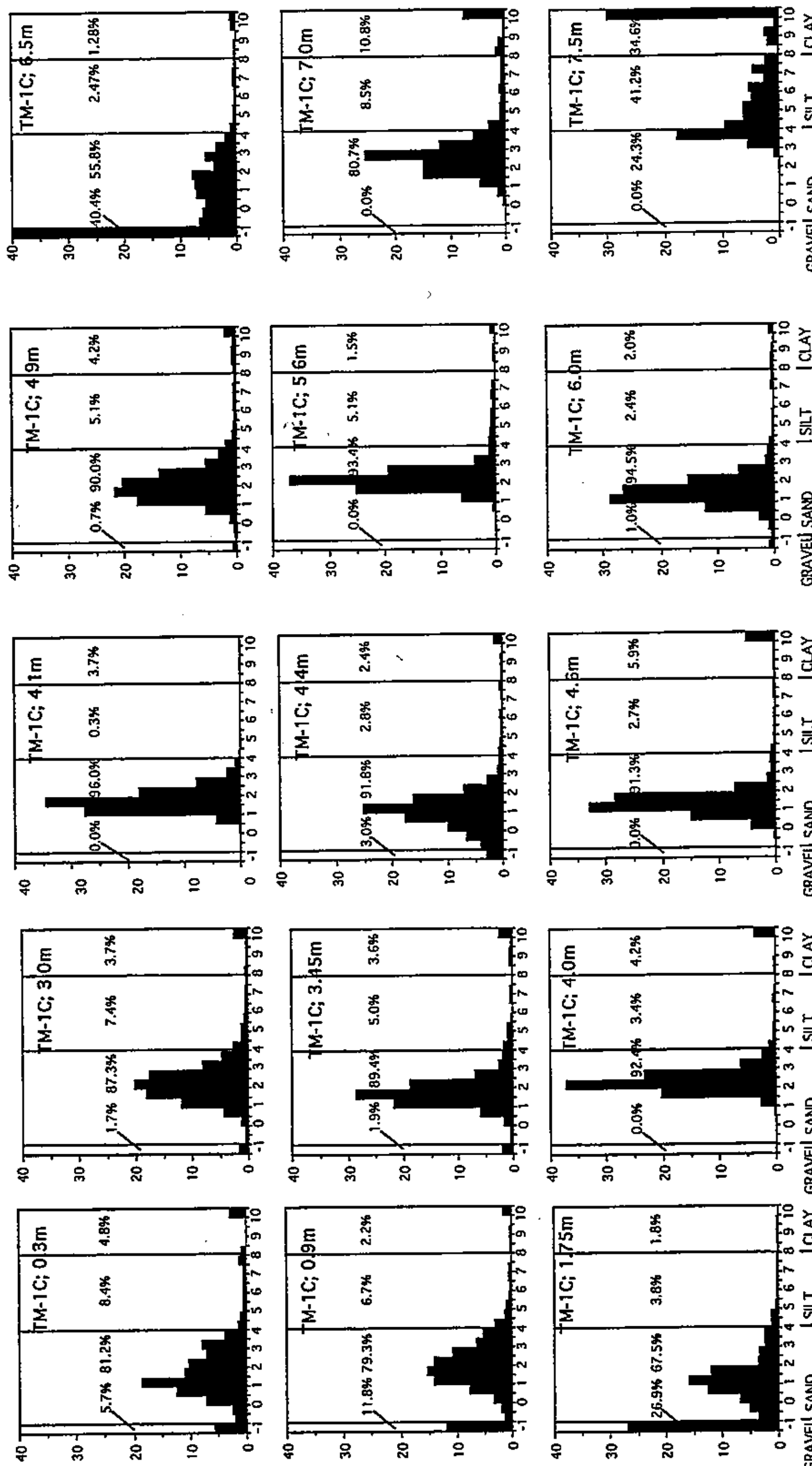
BOX 16: TM-8B, 2.22 - 5.90m

GRAIN SIZE DATA AND MOISTURE CONTENT OF CORES AND OUTCROPS															
			A					B				FOLK			
DEPTH	GRAVEL	SAND	SILT	CLAY	MUD	GRAVEL	SAND	SILT	CLAY	MUD	MEAN S	STD.D	SKEW	KURT	WATER
TM-1C															
0.3	5.7	81.2	8.4	4.8	16.8	20	69	7	4	11	2.17	2.12	0.24	1.83	3.6
0.9	11.8	79.3	6.7	2.2	8.9	20	72	6	2	8	1.76	2.24	-0.21	2.12	8.6
1.75	26.9	67.5	3.8	1.8	5.6	40	55	3	1	4	0.24	2.39	-0.29	1.18	6.7
3	1.7	87.3	7.4	3.7	11.1						2.38	1.39	0.27	1.77	9.3
3.45	1.9	89.4	5	3.6	8.6						1.92	1.15	0.34	2.01	10.5
4	0	92.4	3.4	4.2	7.6						2.42	1.02	0.42	2.67	12.8
4.1	0	96	0.3	3.7	4						1.83	0.67	0.29	1.28	12.9
4.4	3	91.8	2.8	2.4	5.2						1.11	1.21	0.07	1.65	11.7
4.6	0	91.3	2.7	5.9	8.6						1.52	1.75	0.47	4.95	14.4
4.9	0.7	90	5.1	4.2	9.3						2.16	1.4	0.38	2.01	9.5
5.6	0	93.4	5.1	1.5	6.6						2.28	0.77	0.3	1.81	11.7
6	1	94.5	2.4	2	4.4						1.65	0.84	0.23	1.43	11.2
6.5	40.4	55.8	2.5	1.3	3.8	70	28	1	1	2	-0.77	3.16	-0.21	0.76	7.8
7	0	80.7	8.5	10.8	19.3						3.1	3.54	0.61	5.43	10.1
7.5	0	24.3	41.2	34.6	75.8						10.9	10.51	0.82	1.55	13.1
TM-6															
0.58	1.3	82.1	7.4	9.2	16.6	10	75	7	8	15	2.39	2.58	0.57	2.85	8.9
0.94	0.7	88	5.4	5.9	11.3	10	80	5	5	10	2.12	1.86	0.5	2.59	9.7
1.72	0	89	6.9	4.1	11	5	85	7	4	11	2.22	1.47	0.45	1.86	9.9
2.59	0	94.3	3.7	2	5.7	5	90	4	2	6	1.75	0.9	0.36	1.75	15.2
3.94	0.2	78.5	12.1	9.2	21.3	10	71	11	8	19	3.22	2.27	0.56	2.1	7.5
TM-7B															
1.08	0	62.9	30.5	6.6	37.1						3.64	2.16	0.17	1.7	17.7
2.03	0.5	92.1	3.2	4.3	7.5						1.9	1.14	0.52	3.01	11.8
2.53	0	84.4	12.6	3	15.6						2.57	1.15	0.33	1.34	12.6
4.64	0.1	89.9	7.5	2.5	10						2.49	1.15	0.23	1.47	11.2
5.87	3.7	90.5	3.2	2.6	5.8	25	70	2	2	4	1.3	1.26	0.15	1.99	12
7.5	0.5	94	2.6	2.9	5.5						2.15	0.87	0.33	1.22	12.6
8.27	0.9	77.8	15.6	5.6	21.2						2.99	2.05	0.18	1.89	12.7
8.85	0	97.9	2.1	0	2.1						1.88	0.65	0.19	1.15	16.7
OUTCROPS															
TM-1	32.9	59.2	4.2	3.7	7.6						-0.53	4.4	-0.43	1.37	
J2	18.1	75.5	3.8	2.6	6.4						2.25	2.22	0.22	2.14	
TM-6	5.1	85.9	6.6	2.4	9						2.13	1.82	0.08	1.86	
TM-7	28.1	57.7	8.6	5.6	14.2						3.77	1.31	0.21	1.21	
SITE 11	0.2	96	3.8	0	3.8						2.53	1.51	0.11	1.97	
SITE 5.	60	38.1	1.4	0.5	2.1						-3.11	4.83	-0.23	0.83	
Column "A" is measured data. Column "B" is recalculated using a visually estimated proportion of gravel.															

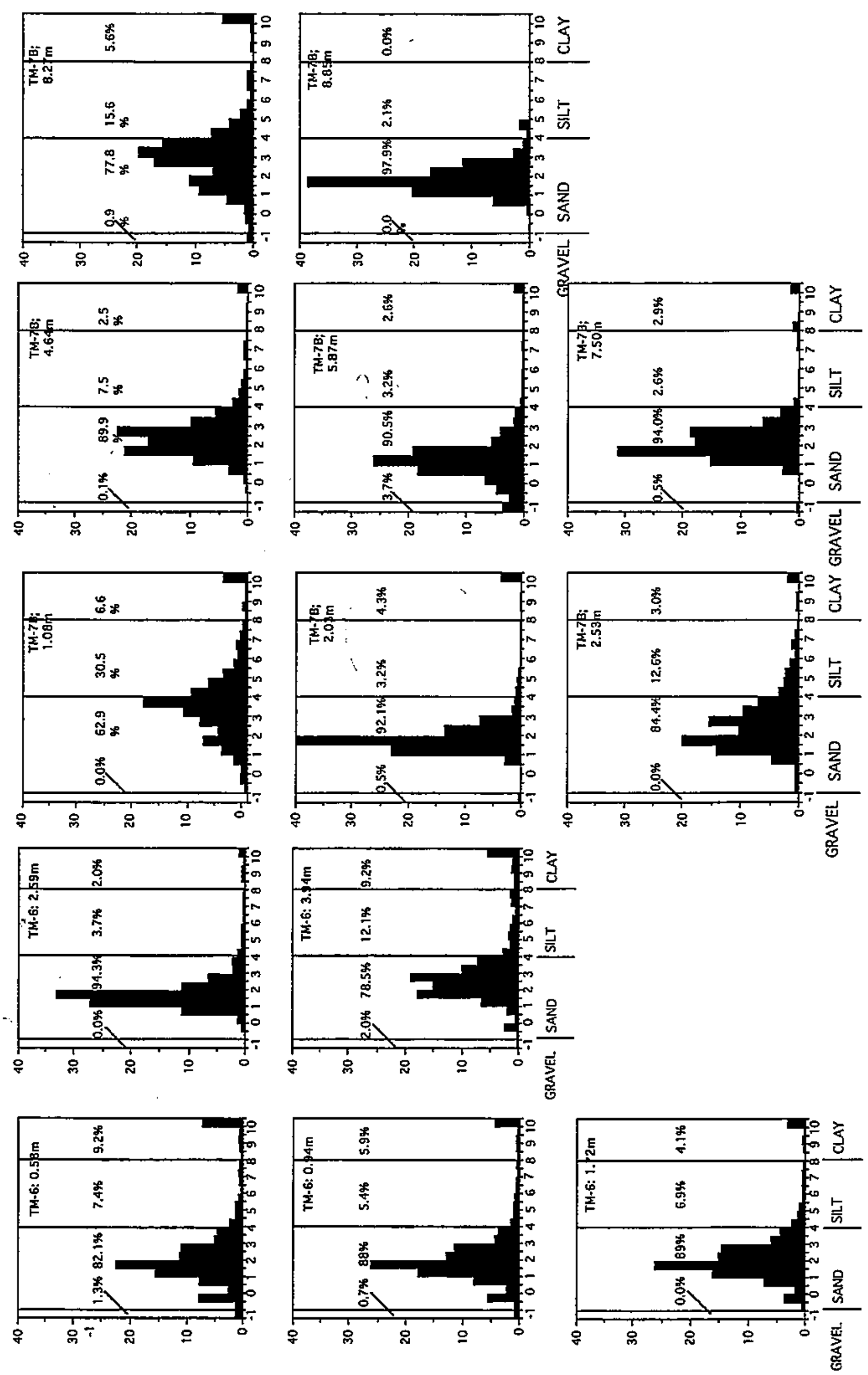
MOISTURE CONTENT, GRAIN SIZE DATA AND FREQUENCY PLOTS (continued)

	GRAIN SIZE DATA-FREQENCY %																							
CLASS LIMITS	-1.00	-0.50	0.00	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	REST
DEPTH																								
TM-1C																								
0.3m	5.70	1.90	2.30	7.10	12.40	18.40	10.90	10.10	7.10	7.90	3.80	1.40	1.00	0.40	0.50	0.50	0.40	0.40	1.10	0.70	0.00	0.00	0.00	2.90
0.9m	11.80	1.30	2.00	3.30	7.60	13.90	15.10	13.90	10.70	6.30	5.20	3.00	1.10	0.90	0.50	0.30	0.50	0.40	0.00	0.20	0.30	0.20	0.10	1.40
1.75m	26.90	3.50	5.00	6.70	12.50	16.00	11.90	3.60	3.40	2.40	2.50	1.30	1.10	0.50	0.30	0.20	0.30	0.30	0.30	0.10	0.20	0.30	0.30	0.10
3.0m	1.70	0.50	0.50	1.20	4.30	11.90	18.00	20.30	17.70	8.10	4.80	2.60	1.10	1.20	0.70	0.50	0.50	0.40	0.20	0.50	0.30	0.20	0.30	2.30
3.45m	1.90	0.50	0.60	1.60	6.00	21.70	28.50	18.80	6.90	2.60	2.00	1.80	1.00	0.90	0.30	0.10	0.40	0.40	0.00	0.10	0.40	0.40	0.20	2.30
4.0m	0.00	0.00	0.00	0.10	0.20	2.60	20.30	37.20	23.40	6.20	2.40	1.20	0.50	0.40	0.20	0.30	0.50	0.30	0.10	0.20	0.30	0.10	0.10	3.50
4.1m	0.00	0.00	0.00	0.30	4.40	27.60	34.60	18.10	7.90	2.30	0.90	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.4m	3.00	4.10	6.70	10.10	17.70	25.10	16.40	7.20	2.80	0.90	0.70	0.70	0.40	0.20	0.20	0.40	0.10	0.20	0.40	0.20	0.30	0.20	0.10	1.50
4.6m	0.00	0.10	0.30	4.20	15.10	32.80	28.40	7.10	1.40	0.80	0.90	0.80	0.30	0.30	0.30	0.20	0.10	0.30	0.20	0.10	0.30	0.30	0.30	5.00
4.9m	0.70	0.20	0.50	1.10	5.60	17.80	21.90	20.30	13.90	5.40	3.20	1.90	0.60	0.50	0.30	0.50	0.50	0.50	0.30	0.50	0.60	0.80	0.40	1.90
5.6m	0.00	0.00	0.00	0.00	0.40	6.20	25.20	37.00	19.50	3.80	1.30	1.30	1.00	0.80	0.60	0.50	0.60	0.40	0.00	0.10	0.20	0.30	0.00	0.80
6.0m	1.00	0.40	0.90	2.50	12.00	28.60	26.60	15.10	6.10	1.40	1.10	0.70	0.30	0.30	0.30	0.10	0.10	0.40	0.20	0.50	0.40	0.20	0.10	0.70
6.5m	40.40	6.70	5.90	5.40	7.30	7.50	8.00	4.00	5.40	3.60	2.00	0.90	0.50	0.50	0.30	0.30	0.40	0.40	0.20	0.20	0.20	0.10	0.80	1.00
7.0m	0.00	0.00	0.00	0.50	1.40	4.90	15.10	15.00	25.70	12.20	5.90	3.00	0.90	1.00	0.70	0.90	0.80	0.60	0.60	1.70	1.10	0.20	0.20	7.60
7.5m	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.10	0.90	5.40	17.80	9.50	6.10	6.20	4.60	5.20	2.70	4.40	2.40	0.00	1.80	2.40	0.60	29.80
TM-6																								
0.58m	1.3	1.3	7.70	2.50	7.70	15.50	22.30	11.10	11	5	4.4	2.3	1.2	1.2	0.7	0.3	0.5	0.7	0.5	0.3	0.5	0.7	0.6	7.1
0.94m	0.7	0.7	5.40	2.30	7.90	17.70	26.20	12.90	11.4	4.2	3.7	1.4	0.9	0.9	0.7	0.4	0.5	0.3	0.4	0.2	0.5	0.5	0.3	4.2
1.72m	0	0.4	3.50	1.70	6.80	15.50	25.30	14.50	14.1	5.8	4.3	2.3	1.3	0.9	0.6	0.4	0.6	0.5	0.2	0.1	0.3	0.4	0.3	3
2.59m	0	0	0.60	1.30	11.10	27.10	33.00	11.00	6.4	1.9	2.3	1.2	0.6	0.6	0.4	0.3	0.2	0.3	0.2	0.1	0.4	0.5	0.2	0.9
3.94m	0.2	0.3	2.50	0.50	1.90	6.50	17.70	15.00	19	10	7.1	2.7	1.6	1.8	1.6	1	0.6	1.3	1.4	0.7	0.8	1.2	0.9	5.5
TM-7B																								
1.08m	0	0.5	1.1	1.2	2.5	4.7	8.2	5.4	8.8	11.7	18.8	10.4	7.1	4.5	2.5	1.7	2	1.4	0.9	0.5	0.8	0.4	0.4	4.5
2.03m	0.5	0.1	0.1	0.1	2.9	23.7	41.2	13.9	7.5	1.6	1.1	0.9	0.6	0.5	0.2	0.2	0.3	0.2	0.2	0.1	0.2	0.2	0.1	3.6
2.53m	0	0.7	0.7	0.7	4.8	14.3	20.3	10.5	15.7	9.6	7	3.5	2.6	2.3	1.4	0.6	1.2	0.7	0.3	0.1	0.5	0.4	0.1	1.9
4.64m	0.1	0	0.2	0.7	3.3	9.4	21.2	17.2	22.4	9.8	5.6	2.6	1.5	1	0.6	0.3	0.7	0.6	0.2	0.2	0.3	0.2	0.1	1.8
5.87m	3.7	2.5	4.7	6.7	18.5	26	19.3	5.5	4.1	1.8	1.5	0.7	0.5	0.5	0.4	0.2	0.3	0.4	0.2	0.2	0.2	0.3	0.2	1.8
7.50m	0.5	0	0.1	0.1	2.8	15	30.5	17.6	18.4	6.2	3.3	0.9	0.3	0.3	0.2	0	0.1	0.5	0.4	1	0.3	0	0	1.6
8.27m	0.9	0.6	1	1.3	4	8.3	9.8	6.3	15.1	17.6	13.8	6.5	3.7	2	0.9	0.4	0.9	0.8	0.4	0	0.4	0.2	0.4	4.6
8.87m	0	0	0.1	0.5	6.1	20.3	38.5	17.1	11.5	2.7	1.1	0.4	1.7	0	0	0	0	0	0	0	0	0	0	0
OUTCROPS																								
TM-1	32.9	2.4	3.7	5.5	8.7	11.3	9.5	7.1	5.3	2.7	2.8	1.1	0.7	0.6	0.5	0.3	0.4	0.3	0.3	0.4	0.3	0.2	0.2	2.6
J2	18.1	2.5	4	5.8	10.6	16.2	14	10.2	6.6	3	2.7	1.4	0.7	0.4	0.4	0.3	0.1	0.2	0.2	0.1	0.3	0.3	0.1	1.9
TM-6	5.1	0.9	1.5	2.8	6.7	14.7	19.2	13.5	14.3	7.3	4.9	2.1	1.4	0.8	0.5	0.5	0.6	0.4	0.3	0.3	0.4	0.4	0.3	0.9
TM-7	28.1	0.9	1.7	2.1	5.4	8.4	13.1	7.8	9.6	5.1	3.7	1.8	1.7	1.3	0.8	0.8	0.9	0.7	0.6	0.5	0.5	0.5	0.4	3.7
SITE 11.1	0.2	0.2	0.1	0.4	4.1	18.7	40.6	17.8	9.5	2.4	2.1	1	0.3	2.6	0	0	0	0	0	0	0	0	0	0
SITE 5.4	60	3.2	3.5	3.4	5.2	6.6	7.3	3.3	3	1.5	1.2	0.3	0.4	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0	0	0.3

MOISTURE CONTENT, GRAIN SIZE DATA AND FREQUENCY PLOTS (continued)



MOISTURE CONTENT, GRAIN SIZE DATA AND FREQUENCY PLOTS (continued)



CORE HOLE TEMPERATURES

Warren Dickinson

Introduction

Closely spaced (10-30 cm) measurements of ground temperatures from the surface to four metres deep have not been made at high elevations in the Dry Valleys area. Previously, temperature measurements have only been made in soil profiles to about 0.5 metres depth (Claridge, pers. comm, 1996; Nichols and Ball, 1964) and in a granite intrusion to a depth of about three metres adjacent to Lake Vanda (Thompson et al, 1971a). The lack of ground temperature measurements reflects the lack of shallow surface holes that have been drilled into Antarctic sediments and rocks.

Although not a part of the initial proposal, closely spaced measurements of ground temperatures were taken for several reasons. 1) The core holes provided an excellent opportunity that otherwise would not have been available. 2) Temperatures are needed to calibrate, correlate and compare with oxygen isotope temperatures obtained from ice in fractures and pores of the tillite. 3) Near surface temperatures are needed to determine the potential for periglacial or active movement that might produce patterned ground.

Methods

The equipment and methods used for measuring the temperatures were designed to be simple and economic. They also had to be able to accommodate a range of unknown conditions. At the outset of the project, the depth and number of core holes was uncertain as well as the ability to actually measure the core hole temperatures.

The measuring system consisted of a digital thermometer calibrated for K-type thermocouples and 15 thermocouple wires from 0.5m to 4.5m in length. One metre lengths of threaded plastic tubing of various diameters (90, 80, & 50mm OD) were used to hold the thermocouples and connecting wires in the holes. Total cost, not including the plastic tubing, was $770 ($353 for digital thermometer, $417 for thermocouple wires and fittings).

A thermocouple consists of two wires of different metal alloys that are joined together at each end. If the two junctions are at different temperatures, a voltage proportional to the difference in temperatures is induced in the wires. The wires at the measuring junction are welded while the wires at the reference junction are connected to a voltage measuring device. When the temperature of the reference junction is known, the temperature of the measuring junction can be determined by measuring the thermocouple voltage and adding the corresponding temperature difference to the reference temperature.

Based on their depth and location, five core holes were selected for temperature measurements (see drill-site map elsewhere in report; Table 1). The core holes varied in diameter between 70 and 90mm and for this particular range the 50mm OD pressure pipe worked best for holding the wires down the hole (Fig. 1). The relatively loose fit ensured that the plastic pipe would not get stuck in the hole. Thermocouple wires were strung down the centre of the pipe and out through holes at 0.25m intervals. The wires were taped to the outside of the pipe and bent to form whiskers protruding about 10mm outwards from the pipe. In this way, the wire whisker, with the thermocouple junction on the end of it, contacted the side of the core hole. Foam insulation was placed at approximately 0.5m intervals to hold the thermocouple wires in the pipes and prevent air convection. Foam insulation and dirt were also placed around the pipe at the top of the hole to prevent air convection from the surface (Fig. 1).

Results and Discussion

Surface temperatures are subject to high variations (Table 1; Fig. 2) which may be caused by three main factors: insolation, air temperature, and wind speed (Thompson et al, 1971b). However, because the thermocouple used to measure the surface temperature was buried several cm below the ground, the effects of wind and air temperature are probably minimized when compared to the degree of sunlight hitting the ground. Temperatures of +19°C were recorded in the dirt cover at TM-1C and TM-7A on bright sunny days (Table 1).

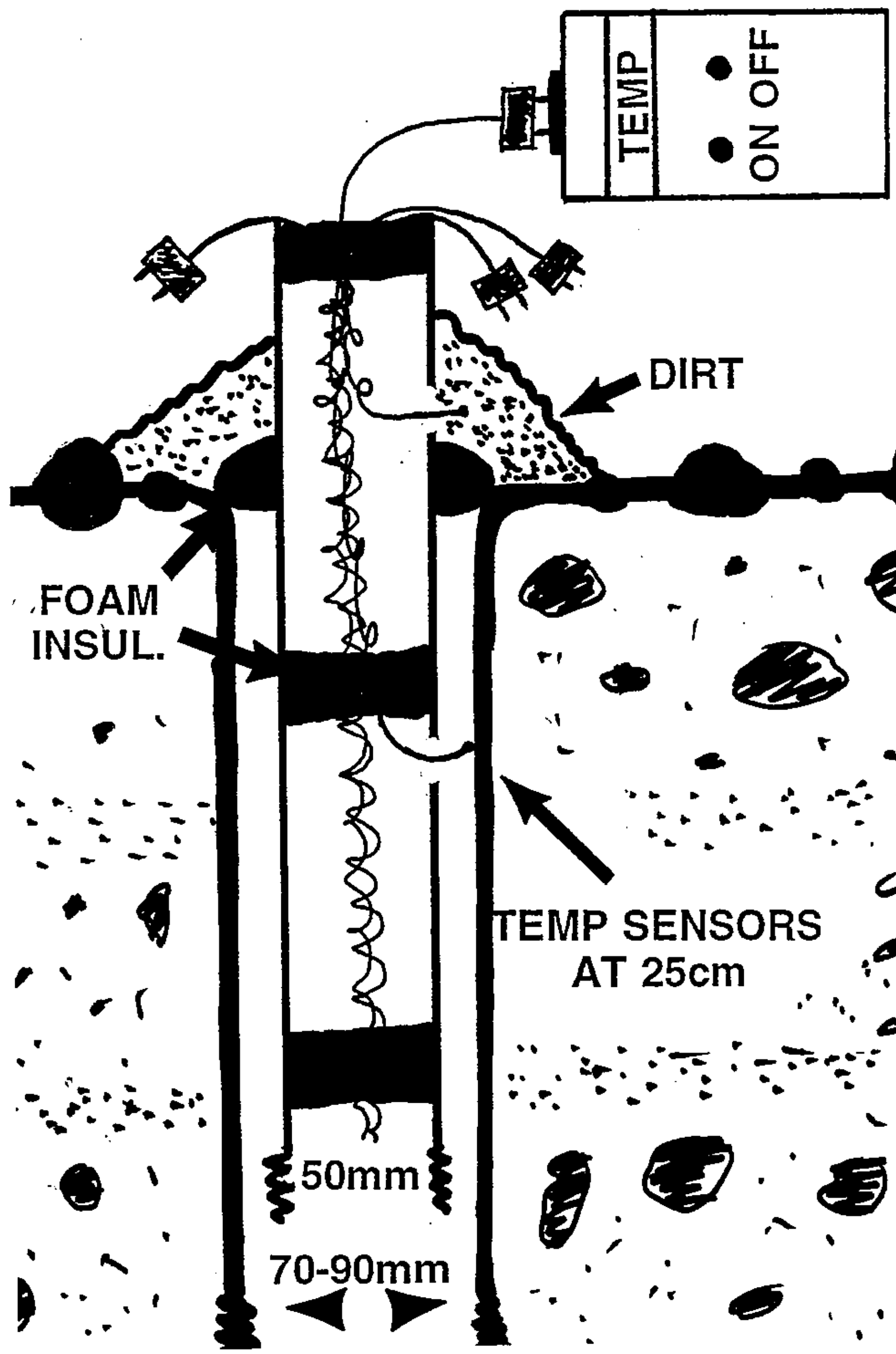


Figure 1. Diagrammatic sketch of core hole temperature measurements.

Table 1. Temperatures (°C) at core hole depths.

Core Hole, Start Date and Time	Hours from Start	Surface Weather and T °C	DEPTH (m) +0.5	-0.2	-0.45	-0.68	-0.93	-1.17	-1.43	-1.68	-1.94	-2.19	-2.70	-2.93	-3.19	-3.70
TM-1C 9 Dec 22:00	0.0	PC,L,-15	19.0	-7.7	-11.3	-14.0	-15.1	-16.0	-17.6	-18.1	-18.9	-19.7	-21.6	-22.1	-21.6	-22.6
	8.0	---	5.1	-7.4	-11.2	-14.0	-15.5	-17.1	-17.7	-18.7	-19.1	-20.5	-21.2	-21.3	-22.2	-23.0
	24.0	PC,L,-15	-1.5	-9.9	-12.1	-13.9	-14.8	-16.0	-16.9	-17.8	-18.7	-19.2	-20.8	-21.5	-21.6	-22.5
		Avg T °C	**7.5**	**-8.3**	**-11.5**	**-14.0**	**-15.1**	**-16.4**	**-17.4**	**-18.2**	**-18.9**	**-19.8**	**-21.2**	**-21.6**	**-21.8**	**-22.7**
		SD	**10.4**	**1.4**	**0.5**	**0.1**	**0.4**	**0.6**	**0.4**	**0.5**	**0.2**	**0.6**	**0.4**	**0.4**	**0.3**	**0.3**
TM-2 3 Dec 16:45	0.0	SC,-10	-4.6	-7.9	-11.5	-13.5	-14.8	-16.2	-17.4	-18.7	---	---	---	---	---	---
	2.0	---	-3.0	-6.8	-11.0	-13.7	-15.1	-16.2	-17.5	-19.0	---	---	---	---	---	---
	4.0	---	-3.1	-6.2	-10.9	-13.5	-15.1	-16.2	-17.5	-18.5	---	---	---	---	---	---
	5.0	---	-4.8	-6.7	-11.7	-13.6	-15.2	-16.4	-17.5	-19.2	---	---	---	---	---	---
	17.0	PC,-13	-1.2	-8.3	-9.1	-10.7	-13.1	-14.6	-16.5	-18.3	---	---	---	---	---	---
	26.5	---	-1.6	-6.8	-10.1	-12.6	-13.7	-15.0	-16.4	-17.5	---	---	---	---	---	---
	28.0	---	-0.9	-6.2	-9.9	-12.5	-13.5	-14.7	-15.6	-16.7	---	---	---	---	---	---
	41.5	SC,L,-8.5	-1.4	-8.5	-11.0	-12.3	-14.2	-14.7	-17.7	-18.4	---	---	---	---	---	---
	51.5	---	6.6	-4.2	-8.7	-12.3	-12.9	-14.2	-15.7	-17.9	---	---	---	---	---	---
	73.5	C,L,-13	1.1	-8.1	-9.8	-11.5	-13.7	-15.0	-16.2	-17.7	---	---	---	---	---	---
	90.0	C,M,-12	-6.8	-8.4	-10.5	-12.5	-14.0	-15.1	-17.4	-18.8	---	---	---	---	---	---
	95.0	---	0.8	-8.8	-11.0	-12.7	-13.9	-14.7	-16.9	-18.1	---	---	---	---	---	---
	114.0	C,L,-13	-5.1	-8.8	-10.7	-12.5	-14.5	-16.1	-16.9	-18.1	---	---	---	---	---	---
	119.0	---	3.1	-8.2	-10.2	-12.0	-14.2	-15.3	-16.6	-18.1	---	---	---	---	---	---
		Avg T °C	**-1.5**	**-7.4**	**-10.4**	**-12.6**	**-14.1**	**-15.3**	**-16.8**	**-18.2**	**---**	**---**	**---**	**---**	**---**	**---**
		SD	**3.6**	**1.3**	**0.9**	**0.8**	**0.7**	**0.7**	**0.7**	**0.6**	**---**	**---**	**---**	**---**	**---**	**---**
TM-6 13 Dec 12:00	0.0	S,L,-14	-3.4	-10.1	-12.3	-13.1	-14.1	-15.0	-15.6	-16.5	-17.4	-17.8	-18.8	-19.6	-20.0	-20.9
	19.0	SC,L,-12	3.1	-9.7	-11.7	-12.8	-13.9	-14.6	-15.4	-16.4	-17.0	-17.9	-18.7	-19.4	-19.9	-20.8
		Avg T °C	**-0.2**	**-9.9**	**-12.0**	**-13.0**	**-14.0**	**-14.8**	**-15.5**	**-16.5**	**-17.2**	**-17.8**	**-18.8**	**-19.5**	**-20.0**	**-20.8**
		SD	**4.6**	**0.3**	**0.4**	**0.2**	**0.1**	**0.3**	**0.1**	**0.1**	**0.3**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**
TM-7A 15 Dec 0:15	0.0	SC,L,-11	19.0	-6.1	-11.6	-12.6	-13.7	-14.6	-15.8	-16.0	-17.7	-18.9	-19.0	-19.4	-20.4	-21.7
	31.0	SC,L,-10	3.2	-3.6	-10.6	-11.9	-12.9	-14.2	-14.8	-15.7	-16.2	-17.3	-19.0	-19.8	-20.8	-21.5
		Avg T °C	**11.1**	**-4.9**	**-11.1**	**-12.3**	**-13.3**	**-14.4**	**-15.3**	**-15.9**	**-17.0**	**-18.1**	**-19.0**	**-19.6**	**-20.6**	**-21.6**
		SD	**11.7**	**1.8**	**0.7**	**0.5**	**0.6**	**0.3**	**0.7**	**0.2**	**1.1**	**1.1**	**0.0**	**0.3**	**0.3**	**0.1**
TM-8B 14 Dec 18:00	0.0	C,L,-12	-7.0	-6.1	-8.0	-9.9	-11.5	-12.8	-13.9	-15.2	-16.4	-17.5	-19.1	-20.0	-21.2	-22.1
	15.0	PC,L,-11	1.0	-8.7	-10.0	-11.5	-12.7	-14.0	-14.8	-15.8	-17.1	-18.0	-20.0	-20.7	-22.3	-22.7
	28.0	S,L,-12	7.0	-6.1	-8.3	-10.8	-12.5	-13.9	-15.0	-16.2	-17.4	-18.4	-20.4	-21.1	-21.7	-22.7
		Avg T °C	**0.3**	**-7.0**	**-8.8**	**-10.7**	**-12.2**	**-13.6**	**-14.6**	**-15.7**	**-17.0**	**-18.0**	**-19.8**	**-20.6**	**-21.7**	**-22.5**
		SD	**7.0**	**1.5**	**1.1**	**0.8**	**0.6**	**0.7**	**0.6**	**0.5**	**0.5**	**0.5**	**0.7**	**0.6**	**0.6**	**0.3**

SC Sunny and Clear   C Cloudy   L Light winds (0-5 knots)   S Strong winds (10-20 knots)
PC Partly Cloudy   S Snowing   M Moderate winds (5-10 knots)   --- Data not available

Measurements over a period of five days at TM-2 show a clear relationship between surface temperature and variations down the hole (Fig. 2). These variations decrease with increasing depth. This is shown by the decrease in standard deviation of temperatures at each depth (Table 1). It is not clear if this temperature variation results from conductance down the copper thermocouple wire or from conductance in the frozen ground. However, calculations of conductance along the copper wire is possible.

Average temperatures show a decrease in the gradient with increasing depth (Fig 3). Average bottom hole temperatures at 3.67 m vary by about 2°C. Variation at the bottom of the holes do not correspond to variation at the top of the holes. For example, TM-7A has the highest average surface temperature but not the highest average bottom hole temperature. These variations in the temperature profiles may have numerous causes such as conductance variations in the rock, differences in the micro climate at the surface, and mechanical differences in temperature measurements. More measurements are necessary to determine the reason.

Problems and Future Recommendations

Part of the variation in measurements is due to drift of the initial temperature read out. The drift in temperature was usually between 0.5 and 1.0°C less than the initial reading. After 5 to 10 minutes the temperature reading would stabilize and hold constant. This problem of drift may be caused by the way the reference junction temperature is maintained interacts with the low air temperatures in Antarctica. This drift problem increased the time necessary to take the measurements to about 1 hr.

Another problem is the uncertainty of the contact between the thermocouple measuring junction and the rock. The pressure at which the junction presses against the rock or even if the junction is in contact with the side of the hole would be useful to know if small variation in temperature are to be understood. However, the degree to which the uncertainty of this contact effects the measurement versus the cost of getting a specific contact pressure must be weighed.

If the problem of drift in the initial temperature reading can be understood or corrected, then using a hand held digital thermometer to measure down hole temperatures is for short periods of time (less than one week) is simple and efficient. For longer periods of time, a data logger which can record several temperatures per day will probably be necessary.

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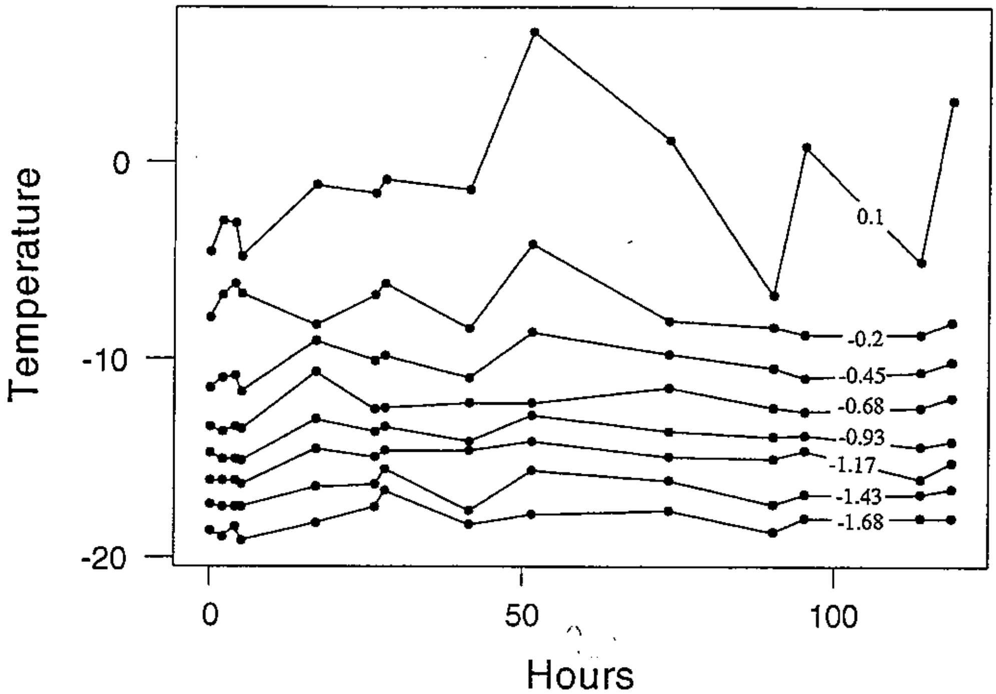

Figure 2. Temperature (°C) plotted against time (hours) from start of measurements at core hole TM-2.

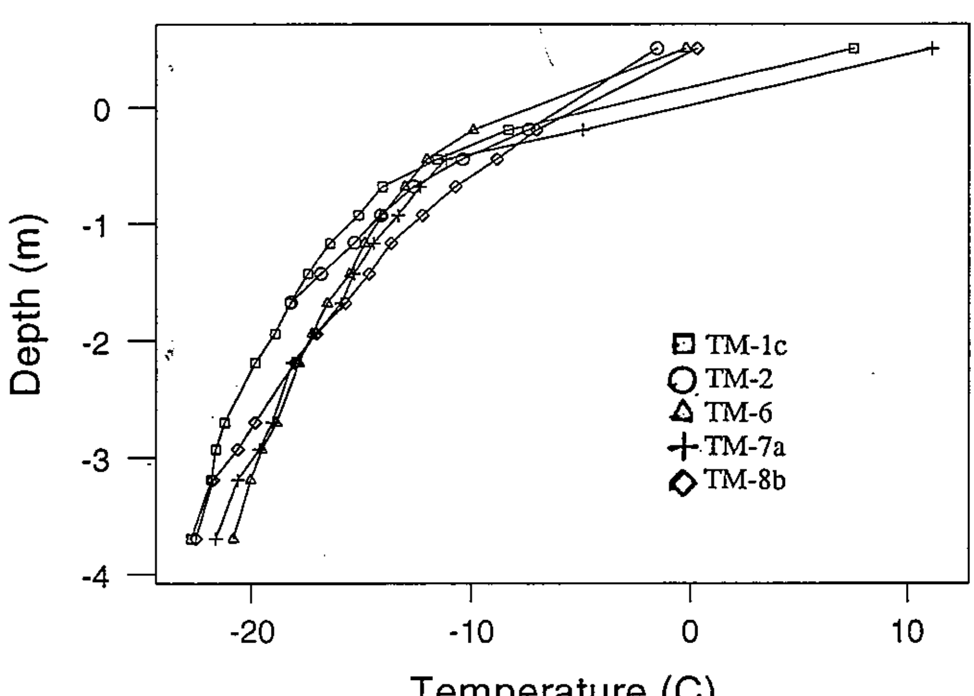

Figure 3. Average temperature profiles for five core holes.

SITE RE-LOCATION AND RESTORATION

Warren Dickinson and Ian Jennings

RE-LOCATION OF CORE HOLES

For future monitoring of ground temperatures five holes (TM-1C, TM-2, TM-6, TM-7B, and TM-8B) were left open and not filled in. Eventually, it may also be feasible to deepen hole at TM-7B and penetrate through the Sirius to the underlying bedrock contact.

To protect the open holes, a plastic pipe, 20 to 40 cm long, was driven into the top of each hole so that 5-10 cm was left above the ground surface. The pipe was cemented in the hole with a slurry of mud, and its top was sealed with ductape. Small cairns of one to two cobbles high were then placed over the top of the pipes to protect and hide them from view.

Distances and bearings in Table 1 may be used to locate the general area of the core holes. However, the photos, distances, and bearings in figures 1 - 6 may be used to find the exact locations of the open holes.

SITE RESTORATION

The main impact at the Table Mt sites consisted of tramping over the fragile desert pavement. While this is unavoidable if field work is to be conducted in the area, such an impact is visible for at least 5 to 10 years after the event. The length of time this impact persists relates to the slow the process by which the pavement forms.

The desert pavement is the uppermost soil horizon on unconsolidated and unlithified deposits, but it is not present on lithified, bedrock surfaces. The pavement is a lag or armour of gravel that results from deflation by wind. Gravel size may be from granule to boulder, and in most places, light tan sands and silts lie directly underneath this armour. If the gravel pavement is removed or altered, the exposed sands and silts are blown away until new clasts, which are buried within the sands and silts, are brought to the surface. The resulting surface is an armour of gravels, which cannot be blown away by the average winds and protects the underlying sands and silts from being blown away.

When working around a drill site, event personnel attempted to follow the same track. Despite this most of the pavement was generally destroyed around the sites (Fig. 6). However, when the drill sites were vacated, pavement stones were swept and raked over the tracks in an effort to reclaim the surface (Fig. 5). In most cases this mitigation significantly reduced the visual impact and should allow the pavement to reform naturally in roughly half the time had the area not been swept and raked.

Table 1. Bearings, distances, and elevation differences from sites

FROM	TO	BEARING °TN	DISTANCE	ELEVATION
Station 1	TM-1	226	9.2 metres	-1.3 metres
	TM-2	347	19.7	-3.6
	TM-3	002	23.3	-3.3
	TM-4	181	32.1	-3.1
	TM-5	199	29.8	-6.0
	TM-6	349	247	-41.9
	Ian's Rock	326	426	-86.7
Ian's Rock	TM-6	122	237	+44.8
	TM-7	320	74.4	+1.8
	TM-8	225	9.1	+0.5

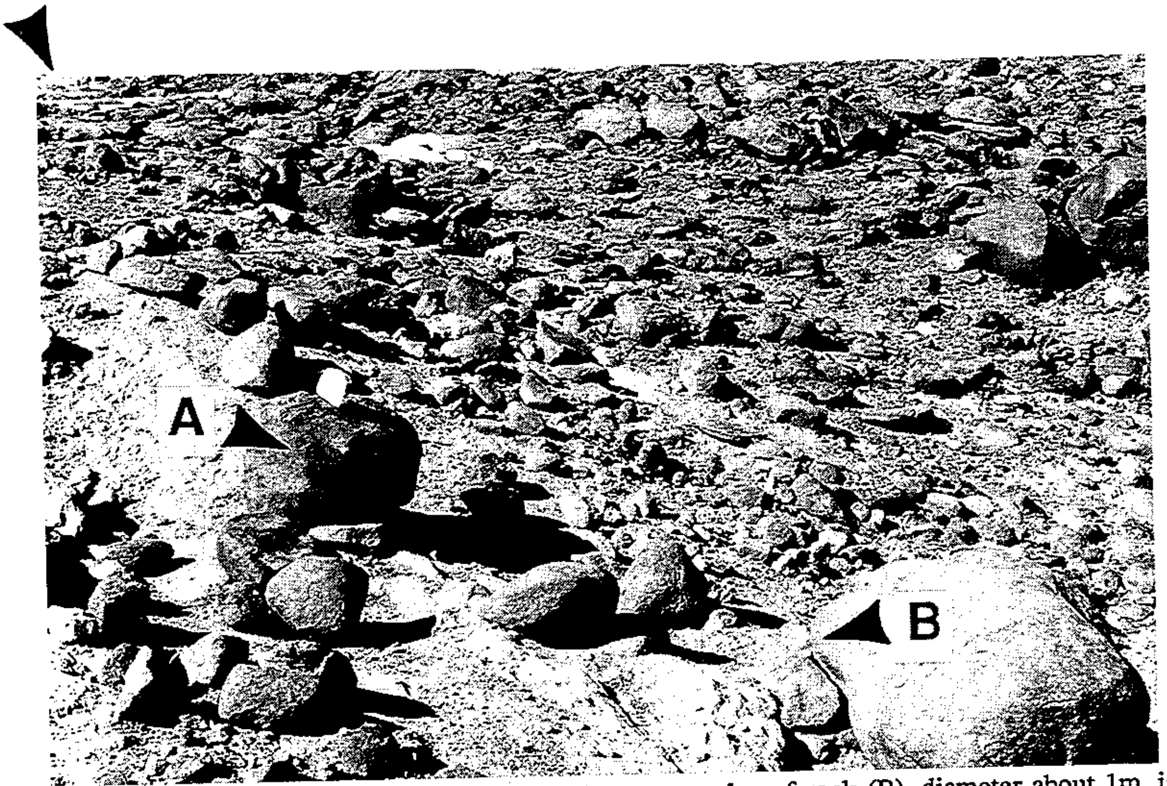

Figure 1. Hole TM-1C is under rock (A). The nearest edge of rock (B), diameter about 1m, is 1.3m bearing 236°TN from rock (A). Photo looking toward GPS station 1 (arrow) bearing 40°TN.

Figure 2. Hole TM-2 is under rock (A). The nearest edge of rock (B), diameter about 4m, is 5.6m bearing 85°TN from rock (A). Photo looking toward Table Mt bearing 180°TN.

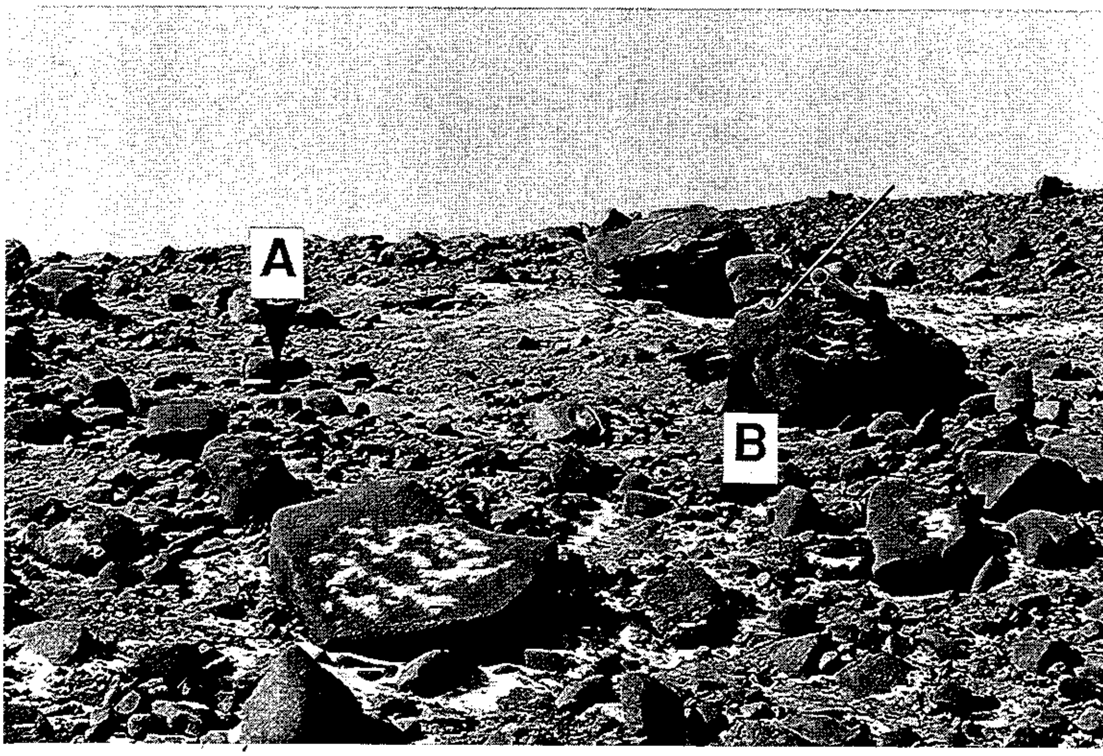

Figure 3. Hole TM-6 is under rock (A). The nearest edge of rock (B), diameter about 1.5m, is 2.5m bearing 8°TN from rock (A). Photo looking up ridge bearing 100°TN.

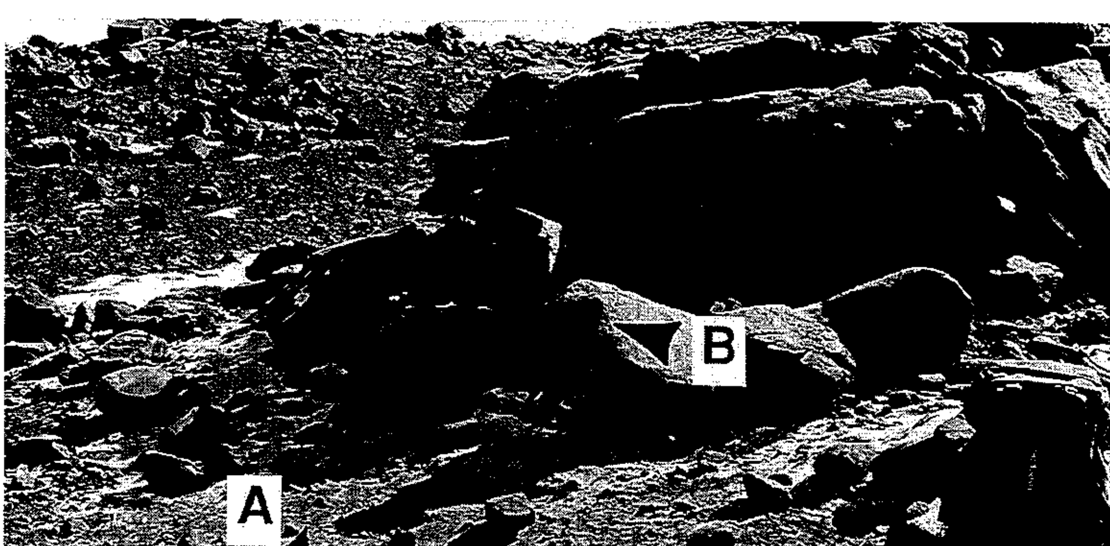

Figure 4. Hole TM-8B is under rock (A). The nearest edge of rock (B), which is on the SW end of Ian's Rock (IR), is 1.7m bearing 200°TN from rock (A). Photo looking due north.

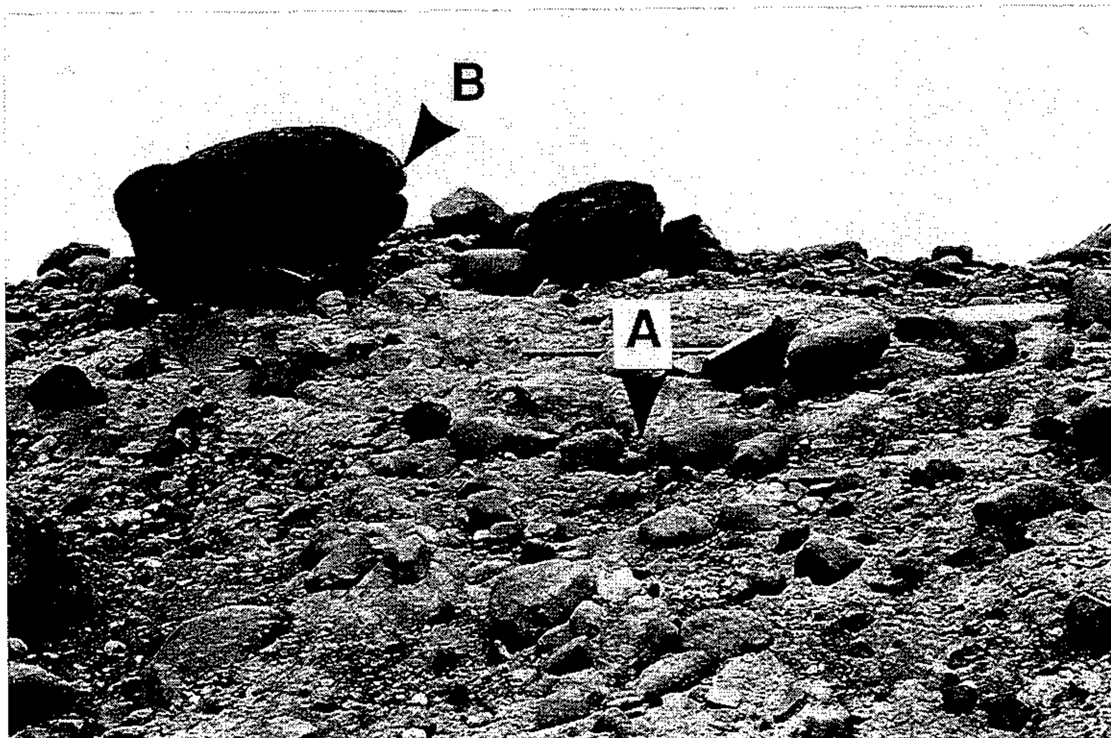

Figure 5. Hole TM-7B is under rock (A). The nearest edge of rock (B), diameter about 2m, is 5m bearing 110°TN from rock (A). Photo looking up ridge bearing 320°TN.

Figure 6. Site at TM-7 prior to restoration by sweeping gravels over the area. Compare with above figure 5 taken from same position after site restoration. Arrow shows hole TM-7B uncovered.

RECONNAISSANCE

Warren Dickinson and James Goff

Mt Feather

On December 3rd a group decision was made to cancel the scheduled move to Mt Feather on December 10th. Based on five days of drilling experience at Table Mt, there were several good reasons for this decision:

1) Although drilling was going well at Table Mt, it was much slower and more labour intensive than originally planned. In addition, because the Sirius deposit at Table was thicker and more extensive than previously thought, it made sense to do as much coring as possible at Table Mt.

2) As seen from Table Mt, the weather at Mt Feather was constantly windy and cloudy. Based on this observation, it was probable that little drilling could be accomplished during the seven days scheduled on Mt Feather. In fact, the possibility existed we would not be able to drill at all.

3) Although the drilling equipment was operational it required constant maintenance. Severe weather and the 2800 m elevation at Mt Feather would make repairs slow and difficult and further reduce the power output of the motors.

In summary, the success and outlook of the results at Table Mt outweighed the risk of failure at Mt Feather. In addition, the Sirius at Mt Feather had been cored in December 1995, and although of poor quality, the core was already undergoing extensive analytical investigation.

In lieu of a full camp move to Mt Feather, a light drilling reconnaissance was proposed with a helicopter standing by on site for two hours. Our plan was to test core two sites without the air compressor, tripod, and extra drill rod.

Due to mechanical problems our re-supply helicopter did not arrive until 20:30 on December 10. Clear and calm conditions appeared to remain on Mt Feather as they had for the last 12 hours. After unloading supplies at Table Mt camp, Dickinson, DeVries, and Cooper departed at 21:30 for Mt Feather. Drilling equipment consisted of the following:

1) Sthil motor mounted on holding frame with the attached torque bar,
2) Two 1m lengths of NQ drill rod for single tube coring,
3) One tungsten 3-wing bit, and one surface set diamond bit,
4) Petrol, tongs, and small tool kit.

After circling the small Sirius outcrop on Mt Feather, the pilot found a suitable landing site. At landing, the weather was clear, wind calm, and temperature of -20°C. After a brief search within several hundred metres of the helicopter, previous drill sites by Wilson (1996) and Bleakley (1996) were not located, we attempted our first test drilling site about 10m from the helicopter (Fig. 1).

We quickly realized that without a flushing fluid, such as compressed air, the drill cuttings could not be removed from the hole. The result of this was that the outer surface of the core pulverized into sand near ground level, where the Sirius was not cemented by ice (Fig. 2). Therefore, any whole pieces of core, which survived intact, could not be pulled out of the ground because there was nothing solid for core catcher in the bit to grab. Consequently, the hole had to be cleaned out repeatedly with split plastic tubes used as makeshift scoops or grabbers.

Once into the ice-cemented zone, which was encountered at about 20 cm depth, friction melted the ice and turned the drill cuttings into a muddy paste. This paste would freeze solid within 15-30 seconds after the bit stopped turning. However, the muddy paste prevented core from falling out of the barrel when it was pulled out of the hole. Core was then extracted by pounding on the barrel with a hammer (Fig 3). This had to be done quickly to prevent the core pieces, which were surrounded by the muddy paste, from freezing in the barrel. In most cases, the core pieces were dumped directly into plastic bags. On several occasions the hot bit melted the plastic bag. Due to the muddy paste freezing to the sides of the core barrel as well as the sides of the

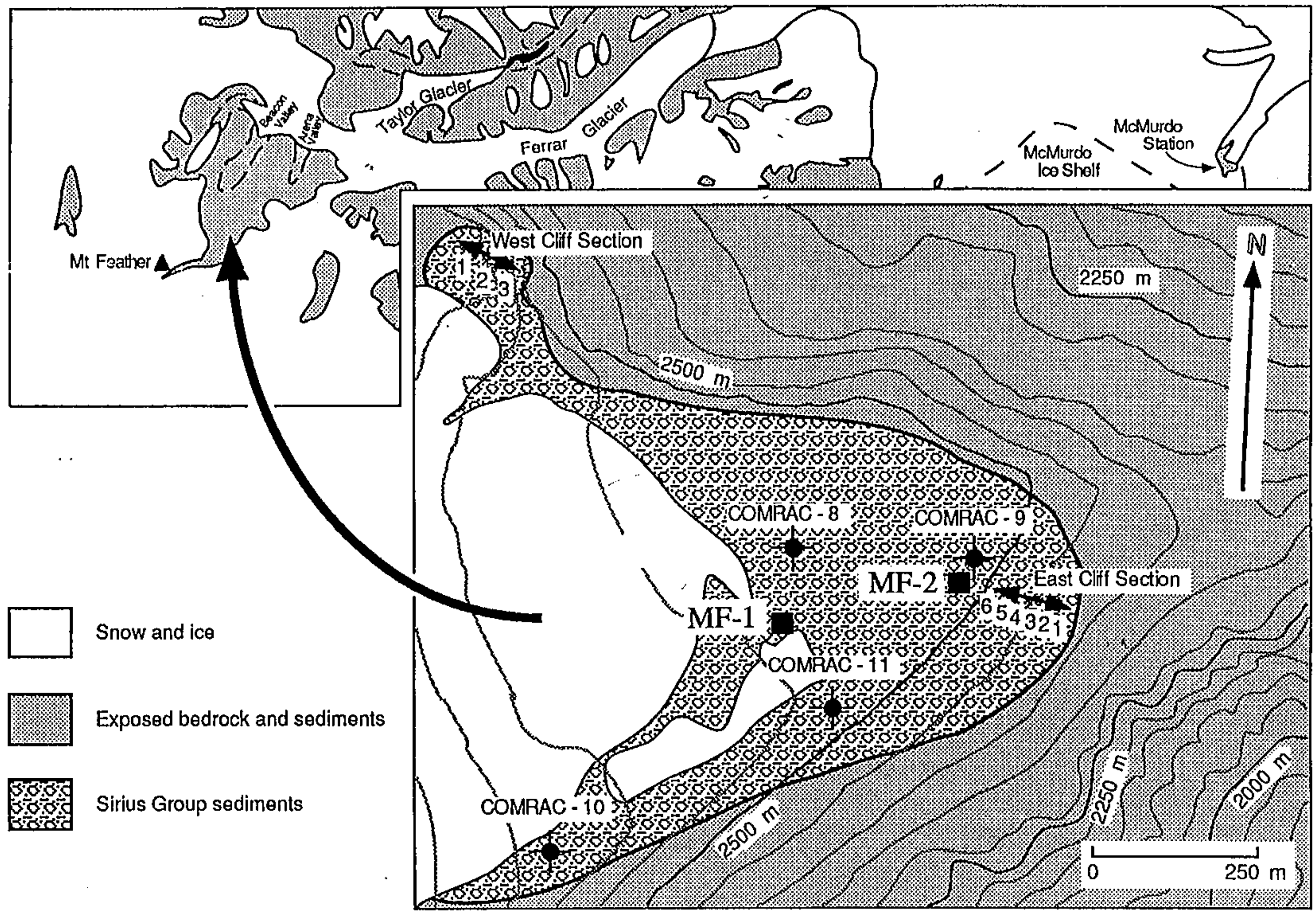

Figure 1 Map shows core site locations of Friedman, Wilson, and Gillichinsky (Dec 1995) and pilot holes MF-1 and MF-2 cored in Dec 1996 (modified map after Wilson, 1996).

Figure 2 Drilling into the uncemented surface horizon without compressed air at Mt Feather shows the core being pulverized.

Figure 3 Extracting muddy core from the ice-cemented zone by hammering on the core barrel before the paste can freeze.

drill hole, the outer surface of core pieces are highly contaminated with cuttings from other parts of the hole.

After 45 minutes of drilling and removing the core from each 10 to 20 cm of penetration, we reached a depth of 80 cm in pilot hole MF-1. This depth was near the limit of our capabilities with this technique even though with more time we could have drilled another 50-70 cm. To go deeper than 80 cm we needed to add another metre of drill rod. This extra length would have greatly increased the risk of freezing the drill bit in the hole because of the time needed in to pull the drill string out of the ground. It was also likely that during this extended time, the muddy paste in the core barrel would freeze and make it very difficult and time consuming to extract any core.

Pilot hole MF-2 was about 325 m bearing 080° (true north) of MF-1. Previous drill sites were still not spotted. By the time we had set up at this site, we only had 20 minutes to drill before the helicopter was scheduled to depart. Drilling was carried out by the same procedure as at MF-1. At the end of 20 minutes we had penetrated just over 40 cm. The wind had remained calm during our drilling and we lifted off Mt Feather at 0:45 to return to Table Mt.

KNOBHEAD

A site on the north side of Knobhead was investigated for possible exposures of Sirius Group deposits (Fig. 4). The ledge at about 1500 m elevation consisted primarily of patterned ground which appears to have reworked a thin veneer of glacigenic material. However, the lithologies and general site characteristics were unlike those seen on Table Mountain. On approach to the site by helicopter, some exposures of pinkish material, possible Sirius Group, were visible at about 1800 m on the northwest side of Knobhead, however we were unable to access these sites during the time available. In comparison with the elevation and characteristics of the Sirius deposits on Table Mountain, it is probable that the Knobhead exposures may well be Sirius Group. They would be unsuitable for drilling because they are on a steep valley side, but it is suggested that further investigation of the Knobhead site be carried out on the western side on a higher ledge at approximately 2000 m elevation. A combination of analysis of aerial photographs, and observations from the inbound helicopter have been used to identify this as the most favourable location on Knobhead for further research. Surface samples were taken from the patterned ground material and grain size measurements are included in the enclosed documentation. There is still ample material available for any additional analyses.

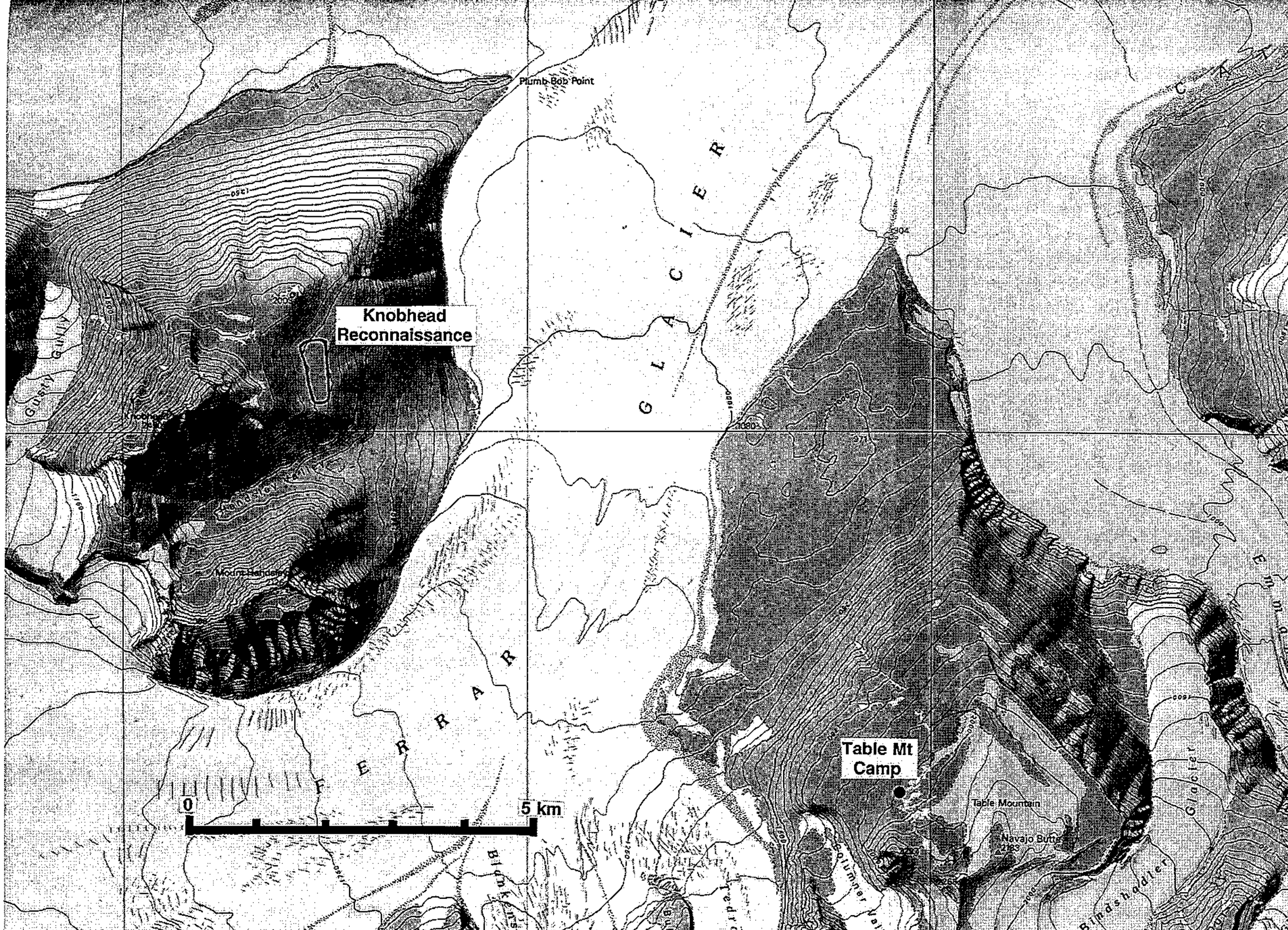

Figure 4   Map shows location of reconnaissance on Knobhead.

APPENDICES

A Event Personnel

Warren Dickinson 101 Beauchamp St Karori, Wellington	Event leader/coordinator, responsible for overseeing and assisting with all of the duties performed by event personnel
Jon DeVries 62 Buckley Rd Melrose, Wellington	Field leader, mountaineer, safety officer, loadmaster, mechanic
James Goff School of Earth Science Victoria University PO Box 600 Wellington	Site geologist, geologic/geomorphic mapping, assisting with coring, core analysis; provide compiled base maps for field mapping
Ian Jennings School of Earth Science Victoria University PO Box 600 Wellington	Mapping and measuring of field data, logging/packing/processing of core, core analysis
Pat Cooper Cooper Drilling Services Rapid Creek Waimangaroa, Westport	Driller and mechanic
Bain Webster Webster Drilling PO Box 50-354 Porirua	Drilling contractor and designer of drilling equipment

B Event Diary (Nov - Dec 1996) (Warren Dickinson)

Nov 14	Dickinson, Goff, Jennings, and Webster depart (13:00) Wellington for Christchurch; fitting of field clothing; night at Windsor
Nov 15	Christchurch to Scott Base (Dickinson, Goff, DeVries, Webster, Jennings)
Nov 16-18	Antarctic Field Training (Dickinson, Goff, Jennings, DeVries-assistant instructor); Webster unpacking and setting up drilling equipment
Nov 19-21	Tested drill equipment on permafrosted ground at Scott Base and on sea ice; Dickinson and Webster packing and testing drill equipment for field; DeVries, Jennings and Goff packing food, and field equipment. Webster returns to Wellington Thur, 21 Nov.
Nov 22-24	All equipment staged into four loads on helio pad. Dickinson, Goff, Jennings, DeVries, R & R Scott Base
Nov 25	Goff and DeVries depart for Table Mt 10:00 from McMurdo; Dickinson and Jennings depart for Table Mt 14:30 from McMurdo arrive at Table 15:30.

Nov 26-27	Set-up and establish camp; reconnaissance of area, drill site selection; start geologic and geomorphic mapping
Nov 28	Cooper arrives with load #2 at Table Mt; final load #4 arrives at 16:30. Sent back rock for Thornley memorial and Nerida Bleakley's samples from Dec 1994. Set-up kero heater in Pol-haven tent. Set up drill rig after dinner.
Nov 29	Set-up and drilling by 12:30 and first metre is very slow. Become stuck in hole at 17:30p, break for dinner to make plans.
Nov 30	Whole day spent trying to recover frozen bit; recovered core barrel drill rod but unsuccessful with bit and reamer and decided to continue with productive drilling.
Dec 1	Recovered 6.05m (nearly 100%) at site TM-1C.
Dec 2	Requested 9m of NQ drill rod from Cape Roberts Project so we can reach bedrock contact. Did not have more pipe because did not expect to be able to drill this deep.
Dec 3	Decision made to not take camp to Mt Feather. Equipment is stressed and time would be better spent doing complete job at Table. However, a reconnaissance with light drilling equipment should be made to Mt Feather.
Dec 4	Helio arrives 13:30 with additional pipe and Terralink crew (Belgrave, Cairns, and Simonsen) run GPS survey and photograph NW Table Mt area.
Dec 5	TD hole TM-1C at 7.29m in bedrock. Sledge compressor down hill to site TM-6.
Dec 6	Site move to TM-7 using helio to carry compressor.
Dec 7-9	Drilling slow due to many repairs and complications in drilling unfrozen clast-rich material near the surface.
Dec 10	Resupply helio due to arrive at 14:00 but delayed by mechanical problems. The NSF, Bell 212 arrives 20:30, and Dickinson, DeVries, & Cooper travel to Mt Feather for reconnaissance and test coring; Return Table Mt at 01:00 (Dec 11) to pick up Terralink GPS; Goff returns (01:30) to Scott Base for treatment of eye injury.
Dec 11	Late start! Move core box to upper helio pad. Start drilling of TM-8B. Early dinner as three of us are still quite tired.
Dec 12	BBC (Kate O'Sullivan) arrives unannounced 09:00 to film. TD hole TM-8B at 5.9m in hard dolerite clast; much core loss in this hole due to gravels.
Dec 13	Reach 9.52m in TM-7B without penetrating bedrock contact, but equipment won't allow deeper drilling.
Dec 14	Goff arrives back at Table Mt; Jennings and Goff reconnaissance of Knobhead; Cooper and load #1 of drilling equipment return to Scott Base
Dec 15	Continue temperature measurements, Goff and Jennings recon south end of Table Mt and in the afternoon recon they recon to the north. We all fill in Prentice trench dug in 1993 to look at Sirius. Light snow in late afternoon.

Dec 16	Continued temperature measurements, clean up of drill sites and reclamation of tracks with rake and broom. Finest weather day of the trip.
Dec 17	Scheduled field departure and return to Scott Base delayed because of light snow and cloud.
Dec 18	Dickinson, Goff, DeVries and Jennings depart (10:45) Table Mt arrive Scott Base; field gear unpacked and returned by 17:00.
Dec 19-20	R & R Scott Base while waiting for flight to Christchurch
Dec 21	Flight to Christchurch (clear skies, light wind) 11:30-18:30; night at Windsor Hotel
Dec 22	Dickinson, Goff, DeVries and Jennings depart Christchurch 08:30 for Wellington.

C **Drilling Diary** (Pat Cooper and Warren Dickinson)

Thur, 28 Nov:

Cooper arrives 13:30; set-up drill rig and used water to freeze in surface layer where spud in will be. Bed at 02:30.

Fri, 29 Nov:

Overcast -16°C. Drilling at 10:30 with HQ triple tube core barrel; some melt out at bit face; ice and clasts in formation; became locked in hole when drill bit froze to formation at 1.58m while attempting to re-fuel. Pulled out core barrel and could not move drill string with tongs or jack. Left for night to plan strategy. Because we observed melting on the core we suspect that surface area and radial speed of the bit cause too much heat for the amount of air being delivered at bit face.

Sat, 30 Nov:

Overcast -15°C. Moved compressor close to hole to shorten hose and run warm air from compressor down hole in attempt to melt bit; air entry into compressor is +10° and air entry into hole is +8°; after 1 hr we could turn drill pipe but had no way to lift it while turning. Then decided to use NQ drill rod with Cooper-made tungsten shoe-bit to drill parallel relief holes. No melting observed on core and believe that less surface area and slower rotary speed are reason. Drilled two relief holes to 1.36m and 1.30m deep. Attempted to break out bit and reamer failed. Then tried oxy-acetylene bomb down drill pipe in attempt to blast it loose. Three charges set off, but failed to loosen the bit and reamer. Back rotated drill rod and left HQ diamond bit and reamer in hole so we could continue productive coring.

Sun, 1 Dec:

Set-up over hole TM-1C and drilled with NQ tungsten shoe-bit. A slight melting of core was observed but generally cored well with minor grinding. Air temperatures measured:

air into compressor =-10°
air into drill hole =-5°
air out of hole =-8°

Cored to 6.04m and had no more NQ drill rod so will call Cape Roberts Project (CRP) in morning and ask for some pipe. Big celebration night after coring success.

Mon, 2 Dec:

Foggy and -15°. Called Scott Base and requested 3x3m NQ from CRP. Moved drill rig and equipment 30m NW to drill Sirius patterned ground area; did not move compressor but in future could use longer air hose to access drill sites farther away without moving the compressor. Drilled mostly ice with NQ shoe-bit. Clasts break loose and cause grinding of core. Drilled three holes. Snowing heavily in late afternoon

Tue, 3 Dec:

Discussion on whether to go to Feather or stay and get good core recovery at Table. Equipment is stressed at Table and men finding it hard work. Feather would probably be a mission in itself and, due to weather, would require at least 8 days to drill 1 or 2 holes. Called Bain Webster and he will send the following: NMLC core barrel, 1.5m (needs testing in these conditions); NQ diamond impreg bit, NQ surface set bit; blank bits; sub to NQ drill rod. Moved rig to site TM-4 to drill whole sequence lateral to TM-1. Made up HQ tungsten shoe-bit by cutting off old HQ diamond bit. Drilled with good penetration, but core dropped out and lost 0.16m. Drilled back down over it and continued to 3m but dry blocked this time and got total recovery. Bit worked well. Drilled TM-4A to 1.3m. Compressor problems - clutch spring on motors and drive chain breaking (need duplex chain).

Wed, 4 Dec:

Stripped compressor motor - clutch mechanism seized probably because it was installed without a spacer between motor housing and clutch. Drilling by 11:30. Moved to TM-5 which was located 2m down slope from TM-4A; Drilled TM-5 to 2.15m with HQ tungsten. Vince Belgrave arrives at about 14:00 with 9m of NQ drill rod from CRP. We set-up over TM-1C to continue drilling from 6.04m. Drilled to 7.29m and ended shift at 21:30.

Thur, 5 Dec:

Beautiful day. Continued drilling TM-1C and reached total depth at 7.93m when we were certain of being close to contact. All of TM-1C drilled with NQ diamond shoe-bit. Called for chopper support to move compressor but decided not to wait and moved it down hill using drill pipes as rails. Set up on TM-6. Top metre is very fractured and losing air down hole. No core recovery so abandoned and set up on TM-6A. Drilled to 2m using NQ diamond. Good penetration rate but problem with core dropping out. Cored back over and dry-blocked with no air to retain core. End of shift 9:30p.

Fri, 6 Dec:

Overcast. Continued drilling TM-6. Removed reamer and this improved hole clearing. Removed and repaired winch drive and Cooper fabricated a new bushing. Encountered shale ice contact at 3.69m. Removed diamond bit and drilled to TD at 4.10m. Helio arrived with Vince Belgrave who delivered steaks and paper with Rat headlines. Helio moved compressor to Barrett's Dropstone area and remainder of gear was manhauled. End of shift at 18:00. Schemed on possible bit systems:

1) Auger system, dry system with flights on outside of pipe to remove cuttings
2) Single tube, thin kerf diamond or tungsten bits; Strata-pack bits also possible
3) Dual tube NMLC core barrel with large kerf may work if more air can be delivered to bit.
4) HQ single tube appears to work well for uncemented (no ice) surface materials
5) HQ triple tube, wireline will probably not work unless a large air compressor is used

Sat, 7 Dec:

Continued setting up on TM-7 and drilled to 0.54m and abandoned in fracture zone. Set-up on TM-7A. Manifold on compressor fractured and was removed and welded. Then chain drive on compressor broke twice. Drill motor played-up so shut down and replaced clutch. Drilled to 4.8m before end of shift at 20:00.

Sun, 8 Dec:

Fine weather with 2-5 knots at -15°. Set up over TM-7B and drilled with HQ single tube, thin kerf shoe-bit (70mm core). Compressor motor clutch went out and exchanged motor clutches with spare motor. Fly wheel came loose on drilling motor and damaged starter assembly. This HQ bit worked well with good core recovery, but had problems with core falling out. To recover the core it was again necessary to core over and dry block. Weight of core tends to push dry block out, but eventually recovered all of core minus top section which consisted of uncemented conglomerate. Drilled 4.2m of core for the day.

Mon, 9 Dec:

Continue drilling TM-7B. Ran NQ Tungsten shoe-bit into HQ and core from 4.20m to 5.10m. Geos uncertain if cored formation is Windy Gully or Sirius so decided to move to site TM-8. Moved compressor down slope on drill pipe and manhauled rig and equipment 100m to site. Used HQ Tungsten shoe-bit to spud encountered clasts at 0.1m. Very slow so pulled out and tried NQ diamond impregnated bit from 0.1 to 0.4m. Still very slow so try NQ surface set bit from 0.4 to 0.55m. Still in large clasts so abandon hole at 0.55m after drilling for two hours. Repair starter cable in rig motor. Air temperatures while drilling 0.1 to 0.4m:

Ambient air =-15°C
Air into compressor =-8°
Air into drill pipe =+2°
Air out of drill hole =-8°

Ian and James doing field work so only 3 at rig all day.

Tue, 10 Dec:

Weather is fine and calm. Waiting on helio for reconnaissance to Mt Feather. Testing dry-block barrels. Equipment taken to Feather:

Drill motor, frame and torque bar,
Two 1m NQ drill rods,
One Tungsten shoe-bit, and one diamond (surface-set) shoe bit.

Helio finally arrives at 21:30 and we leave for Feather 22:30 p and arrive 23:00p. Weather on Feather is clear, -20°C and < 5 knots wind. View down Ferrar Glacier towards Erebus is awesome. Dry drilled first hole to 0.8m. Bagged samples after each run of about 0.1m. Helio to pick us up at 0:30 at second site. Moved about 300m in direction of Erebus and dry drilled second hole to 0.5m. Experienced severe melt of core with dry drilling. Bit becomes extremely hot (one to two hundred degrees) due to the friction generated by not having the cuttings cleared and removed. Dry plugged core and bagged samples at site. Returned to Table Mt camp about 01:30 after picking up Terralink's receiver on Table Mt ridge. James returned to Scott Base with 212 pilots. In bed at about 04:00.

Wed, 11 Dec:

Late start! Moved core box to upper helio pad and buried it in snow to keep at constant temperature. Set-up rig on TM-8B. From surface to 0.38m deep we cored with NQ tungsten bit, encountered many clasts in uncemented matrix, and these were impossible to recover. Clasts fall into hole and, as they are ground up, they prevent the recovery of core. At 0.79m switched to NQ diamond bit but recovery remains poor due to clast grinding. Recommended to use a large diameter (PQ or HQ) stratapack bit for uncemented gravels and a grabbing tool to clean clasts out of the bottom of the hole.

Thur, 12 Dec:

Light snow. BBC arrives unannounced on site about 09:15. We acted as film stars doing retake of this and that. Continued drilling TM-8B from 2.55m to 5.90m. Obtained good recovery as no gravels were encountered. However, after drilling for a half hour on a hard dolerite clast encountered at 5.8m we abandoned the hole at 5.90m. Moved compressor up hill and set-up over pervious hole TM-7B. Tried NMLC core barrel from 5.10 to 5.70m and finished shift early at 19:30. Measured air temperatures from TM-7B as follows:.

Ambient air =-14°
Air into compressor =-4°
Air into drill pipe =-4°
Air out of hole =-10°

Fri, 13 Dec:

Light snow during night and morning, -14°. Black Friday. After discussion with Peter Barrett geos decided that we were still in Sirius and should attempt to drill to bedrock contact at hole TM-7B. Continued drilling TM-7B with NMLC. Appears that cuttings, which have come from the inside gauge on bit, are adhering to the core. However, internal airways on the bit would solve this problem. HQ bit we have been using has such airways. NMLC barrel is also prone to jamming in the hole after drill run is complete even though core recovery is 100% and fracturing of core is minimal. This may be caused by the small tolerance this core barrel and bit have to irregularities in the hole which are due to uneven weight on the bit, numerous trips in and out of hole using tripod, and friability of formation. At 6.20m NMLC barrel became stuck in hole. Reamed HQ barrel over it, but forgot about the HQ landing ring on backend of NMLC barrel. As result the HQ became locked on the NMLC. Laboured for 3 hours to free the NMLC. When finally loose, both drill strings had become locked together and were pulled out of hole this way. Black Friday hole now clear of junk. Continued drilling with single tube NQ using diamond shoe-bit. Slight jamming of drill rod at 9.52m and weight of string plus core was at limits of aluminium tripod and hand winch so the decision was made to terminate hole. Although the bedrock contact was not penetrated, we beat the reaper on Black Friday.

Sat, 14 Dec:

Cooper leaves Table Mt 11:30 for Scott Base. General recommendation is to use double walled drilling tubes to prevent erosion or contamination effect of air stream. Russian drilling data on permafrost using chilled air:

RPM = 102-182
Axial load =2.5-3 KN
Air flow = 4.5-10 m^3/min
Air pressure =0.22-0.8 MPa
Air temp = -7 to -10
Drilling rate m/hr =sand 9-11; granite clasts 4.5; mixture 5-8;
Use drill bits with cutters projecting 3mm on inside and outside.

"In dry drilling, the quality of core sharply deteriorates and its original cryogenic structure becomes completely destroyed"

D Expenditures (June 1996 - June 1997)

Antarctic Training (Christchurch)		
Air NZ	4 x Wgtn-Chch-Wgtn tickets	808.00
		808.00
Antarctic Transport, Accommodation, Food (Christchurch)		
Air NZ	4 x Wgtn-Chch-Wgtn tickets	1264.70
Windsor	(5 people) 9 nights @ $26.67	240.00
Food	5 people, 2 nights	224.60
		1729.30
Antarctica NZ Charges		
Medical Assessments	5 @ $25	125.00
Chch Services	5 @ $60	300.00
Clothing Hire	W. Dickinson 37 da	780.00
	J. DeVries 37 da	234.60
	J. Goff 37 da	861.30
	I. Jennings 37 da	829.00
	B. Webster 7 da	176.70
Food at Scott Base	26 x $86.50	2249.00
Freight	Shipping core boxes Chch-Wgtn	313.10
		5868.70
Drilling Equipment (consumables)		
AEI	Air freight from Port Moresby	97.50
Alpha Plastics	200mm wide plastic layflat	51.60
Ansett Courier	Bit delivery Wgtn to Chch	105.00
Australasian Tools	Diamond core bits and reamers	5085.50
Douglass and Unwin	Stihl parts	782.50
Eutectic	Welding rods	170.40
Gerrard	Strapping materials	31.50
James Walker	Compressor gaskets	86.90
Mainfreight	Freight to Chch	434.50
Mana Bearings	Compressor parts	595.00
Metal Sales	Steel, tubing, welding rods	629.00
Mobil	Rarus compressor oil	202.00
Projex	Stihl motor hire for trials	343.50
Stainless Engineering	Repairs to gearbox housings	264.00
Sthil	Stihl parts	515.00
Telecom	Scott Base calls	218.00
Unifast	Nuts and bolts	79.90
		9691.80
Drilling Equipment (capital)		
Australasian Tools	1.5m second hand core barrel	196.00
Compair	Compressor	2365.00
Fenner	Chain guide and tensioner	122.00
JO Downs	Stihl motor	1189.90
Projex	Two x 056 AV Stihl motors	600.00
Repco	Tool kit	152.50
Ullrich Aluminium	Compressor bell housing	96.40
VM Diesels	Transfer box	600.00
		5321.80

Personnel Services		
Pat Cooper	Drilling supervision 22 days @ $300	6600.00
Jon DeVries	Event safety, mechanic, loadmaster	7500.00
Peter Moroney	Engineer 110 hrs @ $35	3850.00
Bain Webster	Drilling consultant	--
		17950.00
Photographic Supplies, Services and Maps		
Kmart	9 rolls b&w, 10 rolls colour slides	222.50
Agfa	2 bulk rolls Agfa 100 slide	--
USGS	Aerial photographs	214.00
Terralink	Aerial photographs	415.00
VUW	Photographic services	276.70
Antarctica NZ	Ross Island and Dry Valleys maps	61.00
		1189.20
Scientific Support Equipment		
SoPac Marine	Sigmar Kerosene Heater + pan	1264.70
VUW	6 insulated core boxes	530.00
LL Wright	Thermocouple array + thermometer	771.30
Ramset Fasteners	Rock drill 20mm + rod	253.90
Dwights Canvas	Nylon windscreen (for drilling tripod)	350.00
Benchmark	Duc Tape, markers, tools	398.10
Pharmacy Wholesalers	Sample jars for ice	85.00
MicroWakefeild	PVC split plastic tube	341.80
Charta Packaging	20 core storage boxes @ $19	380.00
		4374.80
Scientific Analysis		
IGNS	Stable isotopes 30 samples @ $100	3000.00
Overseas visitors	NZ accommodation and transportation	967.00
		3967.00
	Sub total	**50900.00**
	GST	**6363.00**
	Total	**57623.00**