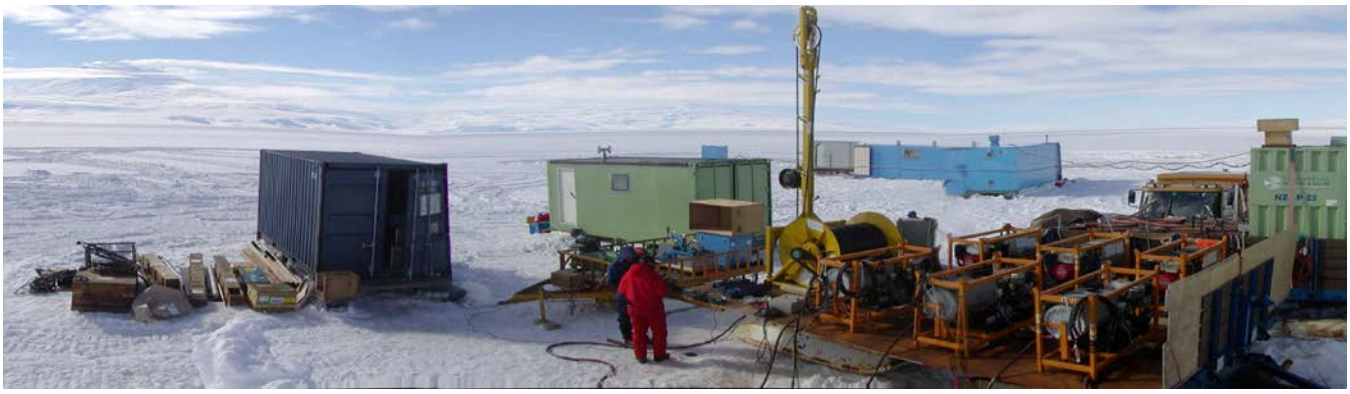
LOGISTICS REPORT

K042: Oceanography and Sedimentation beneath the McMurdo/Ross Ice Shelf in Windless Bight
ANTARCTICA NEW ZEALAND 2002/03



Event Personnel:

Prof. Peter Barrett	Antarctic Research Centre VUW
Dr Lionel Carter	NIWA
Dr Gavin Dunbar	Antarctic Research Centre VUW
Mr. Eric Dunker	AWI Bremerhaven
Ms Giovanna Giorgetti	University of Siena
Mr Johno Leitch	Ant.NZ/Scott Base staff
Mr Doug Mason	Antarctic Research Centre VUW
Dr Frank Niessen	AWI Bremerhaven
Dr Uwe Nixdorf	AWI Bremerhaven
Mr Alex Pyne	Antarctic Research Centre VUW
Ms Christina Riesselman	Stanford University
Ms Natalie Robinson	Antarctic Research Centre VUW

Name of compiler: Alex R. Pyne Signature of compiler:______________________

*AIMS

This project was designed both to investigate the little explored sub-ice shelf environment and to provide essential site data for coring 1000 m into the sea floor by ANDRILL for a history of the McMurdo-Ross Ice Shelf (MRIS). Ross Island has been depressing the crust under its own weight for at least the last million years, and at the same time has been acting as the western pinning point for the MRIS. As a result sediment has been accumulating in a sea floor depression over 900 m deep to the south of Ross Island in Windless Bight (Fig. 2). These sediments record the presence and possible past absence of the MRIS, and the movement of Ross Sea Shelf Water behind Ross Island between McMurdo Sound and the central Ross Sea

Proposed field activity

We proposed to occupy up to 4 sites on the McMurdo Ice shelf (Windless Bight area), first melting a 50-cm-wide hole through the ice shelf (70 to 150 m thick). We then proposed to measure water depth (expected to be over 800 m) and water column properties through a tidal cycle (conductivity, temperature, current speed, current direction) before sampling the sea floor by grab and gravity corer. At one or more sites a mooring to measure currents over several tidal cycles would be deployed and recovered. The access hole was to be melted by a Hot Water Drilling system provided by the Alfred Wegener Institute for Polar and Marine Research, which had been delivered by ship the previous summer.

Achieved activity

The project ran extremely well with access holes drilled and kept open through the ice shelf for up to 9 days (for a full account see the Logistics Report). This was critical for the success of the project. All instruments and sampling devices deployed through the access holes functioned and were recovered. The two most central of the 4 proposed sites were occupied, and a third site at the edge of the ice shelf monitored over a period of three weeks for currents in the upper 2/3 of the water column. The field operation to deploy the camp, drill and ream the access holes took longer than expected for the first site especially. In addition the techniques that we would trial to re-drill a hole and recover the frozen-in mooring were evaluated and it was decided that these required further development before this procedure would likely be successful. We decided to concentrate on two ice shelf holes setting short-term current moorings in both and a sea ice site where a mooring was deployed for 22 days.

*PERSONNEL

Name	Designation	Organisation	Departed Chch	Returned Chch
Prof. Peter Barrett	PI	ARC VUW	07 Jan 03	5 Feb 03
Dr Lionel Carter	Scientist	NIWA	07 Jan 03	28 Jan 03
Dr Gavin Dunbar	Scientist	ARC VUW	04 Jan 03	10 Feb 03
Mr Eric Dunker	Engineer	AWI Bremerhaven	30 Dec 02	10 Feb 03
Ms Giovanna Giorgetti	Scientist	Uni. Siena	07 Jan 03	10 Feb 03
Mr Johno Leitch	Engineer-Driller	Ant.NZ SB	Scott Base	10 Feb 03
Mr Doug Mason	MSc student	ARC VUW	04 Jan 03	10 Feb 03
Dr Frank Niessen	Scientist	AWI Bremerhaven	07 Jan 03	9 Feb 03
Dr Uwe Nixdorf	Scientist-Driller	AWI Bremerhaven	30 Dec 02	10 Feb 03
Mr Alex Pyne	Field leader	ARC VUW	30 Dec 02	9 Feb 03
Ms Christina Riesselman	PhD student	Stanford Uni.	07 Jan 03	10 Feb 03
Ms Natalie Robinson	MSc student	ARC VUW	07 Jan 03	10 Feb 03

*PLANNING

- *Application process*

At the time of submission of this program for review by Antarctica New Zealand AWI and VUW had committed to sending the AWI hot water drilling equipment to Antarctica by ship in January 2002 and was also awaiting the outcome of PGSF funding. This was a significant risk and a commitment of funds primarily by AWI before the result of the proposal submission was known. The timing of Antarctic logistics, the timing of season proposal system due October 2002 for one season (2002/03) programs did not allow any alternative and would require a one year delay. In future the earlier timing of proposal submission and the longer term (3 year) proposals will hopefully reduce this problem. PGSF funding was approved March-April 2003, the hot water drilling equipment wintered at Scott Base so the program could proceed.

Communications with Antarctica New Zealand staff

This program was one of the larger programs supported by Antarctica NZ in 2002-03 and it was clear that it would require a significant large part of the available surface vehicle resources. These resources and in particular their timing when they were available were a constraint to the field program. Field events such as the Divers working on the sea ice in October-November and the seismic operation (K114) working in the WOLZ before Williams Field opened (October 21) required the same resources. We also considered it to be prudent to under take NZ's first hot water drilling operation during the warmer part of the season to minimise freezing problems based on past experience with other drilling projects. The AWI HWD system is also operated outside without protection from wind and temperature. We proposed to operate in the January – February period when temperatures were still relatively warm but were also conscious of the limited time frame available especially the expectation of minimal aircraft cargo capacity for equipment return to NZ and therefore relying on ship cargo which had to be available early February. Antarctica NZ was aware and understood these constraints and accommodated our program within their resource capability.

A significant planning step was to confirm the position of the proposed HWD sites with the US Airfield authorities. This was done by several emails and a meeting with NYANG and ANT.NZ representatives in Christchurch in mid 2002. Several different groups approved the proposed 2002/2003 seismic lines and HWD sites in the US system. One site was too close to the Williams field cross wind runway but this was only apparent when we had setup our considerable camp. We and Antarctic NZ followed appropriate procedure, got US approval but it is now clear that the system at McMurdo is extremely complex and that the system and process is will have to be clarified for future work such as ANDRILL.

We did have some miscommunication and changes regarding the start timing of our field operation and our flexibility to change this was limited because of international flight travel by our German, Italian and US collaborators. There is a difficulty in planning around the Christmas – New Year period when few flights are planned but more a usually scheduled as the season progresses. Antarctica NZ's effort to get three of us on a NYANG flight was very helpful.

In future this HWD operation probably would be better planned for the warm and settled weather period from mid November to ensure a longer field period is possible without the cargo on timing constraints associated with the end of the season.

- *Provision of maps and aerial photographs*

Aerial Photographs or maps were not sourced from Antarctica NZ. During our negotiation with NYANG and McMurdo authorities regarding the seismic and HWD operation in the WOLZ it became apparent that a map data base of the McMurdo Station area with the airfields, roads etc. is available and updated by USGS/Raytheon. It would be extremely helpful if Antarctica NZ investigated this and made it available to NZ researchers and also the operating group at Scott Base.

- *Pre-season information*

We were well informed by the Operations Manager and Cargo Operations during most of the planning stages. Our operation was complex and we accept that it is important to able to initiate dialogue and requests with the personnel who are directly providing the service.

- *Medicals, documentation and flights to Antarctica*

International collaborators add an extra dimension to this process. It is important that this is considered and the process this year as in the past of accepting other national programs medicals should continue. This season German and Italian members used their own medial process and hand-carried their medical records to Scott Base to be held by the Operations Manager. Our US member was not supported by the US program and completed NZ requirements. Some of the documentation could be available earlier in the year. The cost of medicals is an increasing concern especially for people visiting Antarctica on a regular basis. At the moment all Laboratory tests must be done again and these seem to be increasing in Number (SARS next?).

*PREPARATIONS FOR THE FIELD

- *Reception and planning for your event*

This process was complicated due to the size and complexity of the program. We hired Johno Leitch as camp and program engineer and he was involved in planning and the set up of equipment from mid December for this event prior to the other event members starting on the program and arriving in Antarctica. This position required extensive knowledge of Scott Base, trade skills and field experience. In addition to an engineer salaried to the project the Scott base engineering group provided support including building core processing and sea ice mooring equipment, set up and minor modification to a Cape Roberts project drill site lab container for physical properties measurements on the core. A refuelling operation at the Willies field Road transition was co-ordinated by Scott Base Engineers. The plant operators were available to assist with the movement of the equipment and their contribution was a vital part of the operation.

- *Field training*

Members of our event new to Antarctic with “old” members doing appropriate refresher courses undertook field training. We appreciated the flexibility that Antarctica NZ makes available to “adjust” a course to the event’s activity that takes into account existing experience within the event. There is probably still some scope in refining this process to include area specific familiarisation where appropriate i.e. a local McMurdo Area road, routes and procedures.

- *Field party equipment 'shakedown' journey*

This was not undertake primarily because the area of activity was primarily close to Williams field and a semi permanent camp was set up for the field operation. A significant part of the science activity was undertaken at Scott Base in tandem with the field operation.

- *Delays at Scott Base, whatever the cause*

No significant delays occurred except for a storm on 20-21 January when personnel were at both the camp and Scott Base.

- *Safety and Risk Management processes*

I believe that we operated in a safe way, identified risks, which are increased in any large-scale operation that uses heavy equipment and vehicles. Drilling operations also have specific risks including hot water as well as operation of winches and movement near the ice shelf hole where personnel were in safety harness. Travel procedures for our operation were negotiated and agreed to that were more in line with field procedures than Scott Base procedures. The revised procedures made our operation work and we would have required more resources and personnel on Call from Scott Base if we followed Scott base rules. It was clear that with a field activity operating so close to Scott Base that some differences would be apparent to Scott Base personnel. Perhaps further training should be undertaken by Base personnel to allow more flexible procedures to field activities.

Other comments

FIELD TRANSPORT

- *Vehicle*

Generally all vehicles were in good condition.

Final drive noise in the D6 that developed during the early was an initial concern because without this vehicle this program could not be deployed into the field. This was monitored by the mechanic but was probably getting progressively worse.

The Hagglund and Kassbohrer PB100 allocated K042 were operated without incident. Of concern in the H2 was the lack of a functioning engine pressure gauge and odometer when the vehicles were allocated to the event.

The Kassbohrer PB170 was vital for our operation and was not in good condition. It was serviced back at Scott Base by expert engineers during the field period but returned no better that before. Both the Hiab crane hydraulic hoses and the vehicle hydraulic transmission controllers had problems. The stub axel on the front right was also damages when the wheel fell off driving back to Scott Base. This was temporarily repaired but need further maintenance.

Two Alpine (model 2) and a new Skandic skidoo were allocated to the event. The new skidoo performed faultlessly but it is unstable on rough ground and potentially dangerous if rough ground is encountered at speed. The engine of one of the old Alpine 2 skidoos failed and the vehicle was towed back to Scott Base.

- *Aircraft Operations*

Helicopters was used on two occasions:

1. Gonville and Caius Range.
2. New Harbour and Black Island ANDRILL site familiarisation. At New Harbour the Rig Point site used for storing MSSTS drill equipment was located. A small amount of equipment and rubbish still remains and this could be cleaned up within a few hours during the snow free period of the year.

- *Ship Operations*

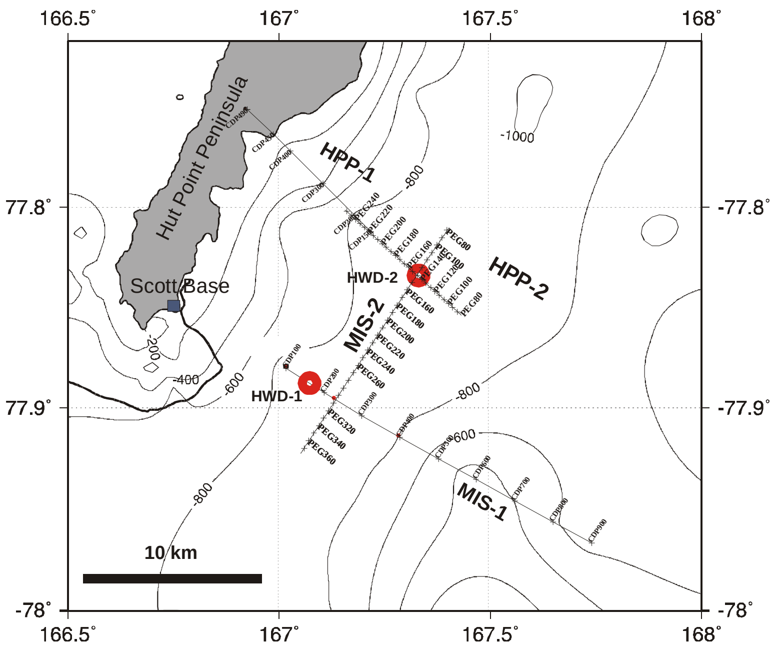
Science cargo was prepared for ship cargo return to NZ on 5 February.

*EVENT DIARY

Date	Main Activities and Location	Other Comments
16-30 Dec.	Preparing Aalener sledge for Hot Water Drill at Scott Base	Johno Leitch
	Preparing Camp Containers, CRP DS Lab and equipment at Scott Base	Johno Leitch, Scott Base staff.
30 Dec.	E. Dunker, U. Nixdorf, A. Pyne; Chch to Scott Base	
31Dec.- 4 Jan.	Assembly and testing equipment at Scott Base –Willy Rd. transition. Preparing traverse loads	Assisted by SB plant ops. (Kim and Gus)
4 Jan.	G. Dunbar, D. Mason; Chch to Scott Base	
3-5 Jan.	Traverse equipment to MISHWD-1 site. Start camp setup.	
5 Jan.	Move site west along seismic line to HWD-1 site.	
6 – 7 Jan.	Camp setup, Vehicle licences, started making water with HWD	
7 Jan.	P. Barrett, L. Carter, G. Giorgetti, F. Niessen, C. Riesselman, N. Robinson; Chch to Scott Base. Melting snow at HWD site 1 for drilling.	
8 -12 Jan.	Drilled HWD-1 hole. Down hole reamer fitting lost and new hole drilled 3 m away	
8 Jan.	Preparing equipment and laboratory operation at Scott Base.	
10 Jan.	Sea ice site for Broadband Deployment, site BB2, Kassbohrer drilled hole.	
11 Jan.	BB2 site, recovered instrument for checking and set up snow box (box brownie) around hole.	
14 Jan.	HWD-1. Started current meter (S4) and water bottle sampling. Winch motor problems, used skidoo. Multiple water bottle array stuck under ice, recovered at slack water.	
15-16 Jan.	Winch operating with SB electric motor. 24 hour current profiling and water sampling.	
16-17 Jan.	Completed current profiling and water sampling. Calliper log of hole and coring and grab of sea floor. Reamed hole for ADCP mooring.	
18 Jan.	Deployed ADCP mooring. Some personnel return to Scott Base.	
19 Jan.	Fuelling and camp maintenance.	Johno camp caretaking
20-21 Jan.	Storm, condition 1-2 on Willy Rd. Some personnel return to HWD-1 camp on 21 Jan. during short weather break.	
22 Jan.	Dig out and recover ADCP mooring (86 hour duration). Personnel to HWD-1 camp for instrument download.	
23 Jan.	Start camp pack up and move. HWD-2 site located and camp moved for overnight occupation. Some personnel to Scott Base.	Johno and Gus
24 Jan.	Set up Hwd-2 campsite. Move remaining equipment form HWD-1 to HWD-2 site.	
25 Jan.	Preparing HWD equipment, make start-up water and complete camp setup. Personnel to site	
26 Jan.	Drill HWD-2. Ice thickness approx 144 m.	
27 Jan.	Reaming hole	Visitors from SB
28 Jan.	Started 24 current profiling and water sampling	
28 Jan.	L. Carter return Chch.	
29 Jan.	Completed water column profiling. Coring and grab sampling of the sea floor	Visitors from Crary Lab & McMurdo.

30 Jan.	Calliper log and reaming hole. Prepare and deploy ADCP mooring.	
31 Jan.	Caretaking at site, some personnel return to SB and return to site.	
1 Feb.	Personnel to site for mooring recovery, recover mooring started at 2300 hrs.	
2 Feb.	3.5Khz and further coring of the sea floor. Preparing instruments for return to NZ and transport to Scott Base.	
3 Feb.	Set up mini HWD on Hagglund sledge for sea ice mooring recovery. Recover sea ice BB ADCP.	
4 Feb.	Break camp and start return of equipment to the SB transition.	
5 Feb	Packing for Ship Cargo, returning camp/equipment to SB	
5 Feb.	P Barrett return Chch.	
6 Feb	Helicopter recon. To New Harbour and Black Island, proposed ANDRILL sites. (Dunker, Nixdorf & Pyne)	
7-9 Feb.	Packing up equipment and laboratories at Scott Base.	
9 Feb.	F. Niessen & A. Pyne return to Chch.	
10 Feb.	G. Dunbar, E. Dunker, G. Giorgetti, J. Leitch, D. Mason, U. Nixdorf, C. Riesselman & N. Robinson return Chch.	

EVENT MAP



HUT POINT PENINSULA AND THE MCMURDO ICE SHELF TO THE SE, SHOWING THE BATHYMETRY OF THE BROAD CHANNEL CONNECTING THE WATERS OF MCMURDO SOUND TO THE NW WITH THOSE BENEATH THE ROSS ICE SHELF TO THE EAST. THE INTERSECTING LINES MARK SEISMIC SURVEYS RUN BY THE INSTITUTE OF GEOLOGICAL & NUCLEAR SCIENCES (MELHUISH ET AL., 1995; BANNISTER AND NAISH, 2002; HORGAN ET AL., 2003) SITES 1 AND 2 ARE MARKED WITH CIRCLES AND THE CURRENT MONITORING SITE AT THE SHELF EDGE WITH A SQUARE.

*WEATHER

The weather conditions during the field operation were generally unsettled with intermittent light snow, light winds and overcast conditions for most of the time with only a few clear calm days. These conditions did not affect the drilling operation significantly although some minor overnight glycol mix freezing problems resulted when air temperatures fell below about –15°C as temperatures began cooling at site 2. Poor visibility on occasion did affect and delay transport between Scott base and camp. A storm event on 20-21 Jan. with winds up to 35 knots, heavy snow fall and poor visibility caused some problems which prevented members of the event returning to HWD site 1 camp from Scott Base and delayed the recovery of the mooring. This storm was relatively benign at the McMurdo Ice Shelf site.

*ACCIDENTS, INCIDENTS OR HAZARDS

A minor amount of equipment was lost during the drilling operations, see environmental section but no other accidents or incidents were reportable during the drilling and field operation. The storm event on 20-21 Jan. was unpredicted and did result in one experienced person remaining at camp caretaking over night and this was longer than anticipated. Event personnel prior to returning to Scott Base had carried out camp maintenance and fuelling operations.

FIELD EQUIPMENT

- The hot water drilling operation can be wet especially operating in the warm part of the summer season on the ice shelf. Waterproof (but breathable) clothing gloves and footwear are required. The black diamond boots are not completely waterproof (leather-rubber seams) when it is warm and may be too hot. Keeping the liners dry is a constant problem. Our German colleagues used insulated waterproof "cordura" one-piece suits and fur lined calf length leather boots.
- The field camp primarily consisted of ISO container wannigans.

  CRP Kitchen container on CRP sea ice sledge.

  CRP Drill Site Lab Container connected to the kitchen and used as a mess on CRP sea ice sledge.

  CRP accommodation container on CRP sea ice sledge.

  NZ10 accommodation.

  Camp Haskell Generator and fuel on CRP Aalener sledge.

  Scott Base Dive hut container used as a field laboratory.

  AWI HWD drilling equipment container on CRP sea ice sledge.

  AWI HWD on Aalener sledge.

  CRP sea ice bridge sledge.

  Two – three polar tents were also used for sleeping.
- FOOD supplies. This event was required to support up to 12 people intermittently at camp. The camp included the Cape Roberts Project kitchen container with a new large semi professional/domestic gas stove fitted. Bulk food was drawn from the field store system in addition to a smaller quantity of food from the Scott Base kitchen supply. Food boxes were only used for emergency backup.

  The current field food allocation system does not cater for medium to large field parties (over 5 people) very well especially when operating from wannigans and semi permanent field camps. The type of bulk food supplies required is much closer to that used at Scott Base especially if bulk food is continued to be purchased in forms that are smaller packages or can be readily separated into smaller quantities e.g. free flow frozen portions.

RADIO COMMUNICATIONS

- VHF communications were only required during this program and the local Scott base repeater was used. Both hand held and vehicle VHF radios were used. Some of the vehicle VHF radios were older models and we found that the channel availability and numbering was not consistent with current Ant.NZ allocations as noted in the field manual. This was particularly frustrating when trying to call Williams airfield tower in H2 and PB 170 to obtain permission to cross the approach to runways. The radios were reprogrammed at Scott Base when we realised the problem but this does highlight that a process should be in place to check all vehicle radios early in the season to make them consistent.
- Scott Base radio communications .was generally very good and we received good service and support. We had some difficulty maintaining our radio schedule timing because of the drilling and science operations that could not be stopped. We tried to maintain a listing watch with a personnel hand held while drilling but sometimes the noise of the operations affected our ability

to pick up calls. At times we had some confusion understanding if we were communicating with Scott Base or an individual (comms. operator).

We were required to note how many personnel were over-nighting at camp every evening radio schedule. The timing for this (2000 hrs) was often difficult because our workday was still uncompleted at this time. This was improved when the night comms. Operator took responsibility for this.

SCOTT BASE AND ARRIVAL HEIGHTS FACILITIES

Facility	Use
Hatherton Geoscience Laboratory	Offices, email,
Q-Hut Laboratory benches	
Scott Base Wet Laboratory	
Scott Base Summer Laboratory	Equipment preparation, oceanographic instrument programming, microscope work
CRP Drill Site Lab	Core physical properties measurements. (Frank Niessen AWI)
TAE Hut	
Library	

- Microscope (Petrographic polarising and stereoscopic), oceanographic equipment and core physical properties measurement equipment were specifically sent to Scott Base for this programs.
- *Other comments*

COMPUTER FACILITIES

- *Suitability and effectiveness of computer network*
- *Quality, suitability and performance of public computers*

*ENVIRONMENTAL IMPACT

*Sites Visited

Site name	McMurdo Ice Shelf HWD-1
Site location (coordinates/description)	77° 53.308'S 167° 05.067'E
Dates occupied	3 – 23 Jan. 2003
Total days (or hours) at site	20 Days
Maximum number of people at site	15
Total person-days (or person-hours) at site	(see SB Ops report for person nights)
Main activity undertaken	Hot Water drilling, sub ice oceanography and sea floor sampling

*Sites Visited

Site name	McMurdo Ice Shelf HWD-1
Site location (coordinates/description)	77° 5.111'S 167° 20.209'E
Dates occupied	23 Jan. – 5 Feb. 2003
Total days (or hours) at site	13 days
Maximum number of people at site	15
Total person-days (or person-hours) at site	(see SB Ops report for person nights)

Main activity undertaken	Hot Water drilling, sub ice oceanography and sea floor sampling

*Sites Visited

Site name	Sea ice BB site
Site location (coordinates/description)	77° 5.111'S 167° 20.209'E (approx 4.5 km south of Scott Base)
Dates occupied	Instrument: 10 Jan. –3 Feb. 2003
Total days (or hours) at site	Instrument deployment: 23 days
Maximum number of people at site	6
Total person-days (or person-hours) at site	Approx. 300 hours
Main activity undertaken	Hot Water drilling, sub ice oceanography and sea floor sampling

*Sites Visited

Site name	Gonville and Caius Range
Site location (coordinates/description)	
Dates occupied	
Total days (or hours) at site	
Maximum number of people at site	
Total person-days (or person-hours) at site	
Main activity undertaken	Geological sampling

*Sites Visited

Site name	New Harbour (Rig Point)
Site location (coordinates/description)	77°32.686'S 163° 42.241'E
Dates occupied	
Total days (or hours) at site	1 hour
Maximum number of people at site	4
Total person-days (or person-hours) at site	
Main activity undertaken	Locate for possible ANDRILL land storage site.

Geological Material

Location	77° 53.308'S 167° 05.067'E
Specimen type	Sea floor sediments
Quantity (kg)	30 kg max.

Geological Material

Location	77° 5.111'S 167° 20.209'E
Specimen type	Sea floor sediments
Quantity (kg)	30 kg max.

Geological Material

Location	Gonville and Caius Range
Specimen type	Beacon rock samples
Quantity (kg)	?

Chemicals

Chemical form	Propylene Glycol (food grade)
Quantity used	Approx 300 litres, mixed with fresh water.
Location of use	Two Hot Water drill sites
Storage/release details of unused chemicals	Used antifreeze mix was returned to Scott Base for ultimate return and disposal in NZ. Minor quantity of mix was lost down hole.

Chemicals

Chemical form	Glutaraldehyde.
Quantity used	50 mg
Location of use	Camp Lab
Storage/release details of unused chemicals	All contaminated sea water filtration liquids (20 litres) were returned to Scott Base and returned to NZ

Chemicals

Chemical form	Mercuric Chloride solution. (HgCl)
Quantity used	10 ml
Location of use	Camp Lab
Storage/release details of unused chemicals	No release of chemical. Unused solution returned to Scott base and NZ for disposal.

Equipment installed/left in field

Type of equipment	Drilling equipment lost down hole or buried in 2 m deep snow pit.
Location of installation left in field	77° 53.308'S 167° 05.067'E in moving McMurdo ice Shelf.
Size of items left in field	Plywood sheet 1.2 m x 1.2 m, Plastic deflector 0.45 m diameter
Number of items left in field	2
Date of intended retrieval	Not retrievable

*Other environmental impacts

Minor loss of food grade glycol fresh water mixture

*Differences from original Preliminary Environmental Evaluation (PEE)

Approval for use of food grade glycol and burying of human wastes as part of revised PEE process.

IMMEDIATE SCIENCE REPORT

K-042 - Oceanography and Sedimentation beneath the McMurdo/Ross Ice Shelf in Windless Bight ANTARCTICA NEW ZEALAND 2002/03

Event Personnel :

Prof Peter Barrett	Victoria University of Wellington
Mr Alex Pyne	Victoria University of Wellington
Dr Gavin Dunbar	Victoria University of Wellington
Mr Dougal Mason	Victoria University of Wellington
Ms Natalie Robinson	Victoria University of Wellington
Dr Frank Niessen	Alfred Wegener Institute for Marine and Polar Research
Dr Uwe Nixdorf	Alfred Wegener Institute for Marine and Polar Research
Mr Erich Dunker	Alfred Wegener Institute for Marine and Polar Research
Dr Lionel Carter	National Institute for Water and Atmospheric Research
Dr Giovanna Giorgetti	University of Siena, Italy
Mr Jonathan Leitch	Antarctica New Zealand
Ms Christina Riesselman	Stanford University, USA

Hot water drilling system in operation on the McMurdo Ice Shelf 12 km east of Scott Base, with the Royal Society Range in the background.

1 Popular Summary of Scientific Work Achieved

SUMMARY

This project investigated water flow and sedimentation beneath the McMurdo Ice Shelf south of Ross Island. Its purpose is to help understand the past (and future) behaviour of the huge Ross Ice Shelf, which lies immediately to the south. Team members from the Alfred Wegener Institute used a hot water drilling system to melt 0.6-m-wide access holes through the ice shelf in two locations 5 and 12 km east of Scott Base, thus allowing measurements and samples to be taken from the water column and sea floor beneath. The sites are relatively remote, being covered by ice 70 and 143 m thick and with sea floor 926 and 923 m below sea level respectively.

Water column measurements from the two locations show that the main current direction is to the east from McMurdo Sound through to the Ross Ice Shelf, with speeds averaging 5 to 7 cm/sec but at times reaching 17 cm/sec. Flows at a third and shallower location at the ice shelf edge off Scott Base were much stronger – up to 60 cm/sec. Water column profiles of salinity and temperature are similar to those found 25 years ago at the first ever hole drilled through the Ross Ice Shelf 400 km south at J9. These waters are the coldest and densest in the world, helping drive deep ocean circulation as they flow north into the Pacific Ocean.

The sea floor at both sites is soft mud with siliceous algae and calcareous microfossils. The former are well known in open Ross Sea surface waters, being swept in by currents. The latter live in mud and were not expected because of the cold corrosive waters. One of the cores passed down into a stony glacial deposit believed to represent sediment released from basal ice grounded nearby more than 10,000 years ago when ice filled most of the Ross Sea after the last glaciation. However penetration of low energy (3.5 kHz) seismic waves 300 m into the sea floor shows that the sites were too deep to have been compacted or eroded by grounded ice. This observation, together with the fine-grained nature of the sediment confirms the basin's suitability for the planned 1000-m-deep ANDRILL hole for recovering a long and sensitive record of Ross Ice Shelf history.   Current speeds in the water column also indicate its technical feasibility.

Fig.1 Hut Point Peninsula and the McMurdo Ice Shelf to the SE, showing the bathymetry of the broad channel connecting the waters of McMurdo Sound to the NW with those beneath the Ross Ice Shelf to the east. The intersecting lines mark seismic surveys run by the Institute of Geological & Nuclear Sciences (Melhuish et al., 1995; Bannister and Naish, 2002; Horgan et al., 2003) for imaging the geometry of the strata filling the basin (see fig. 2). Sites 1 and 2 are marked with circles and the current monitoring site at the shelf edge with a

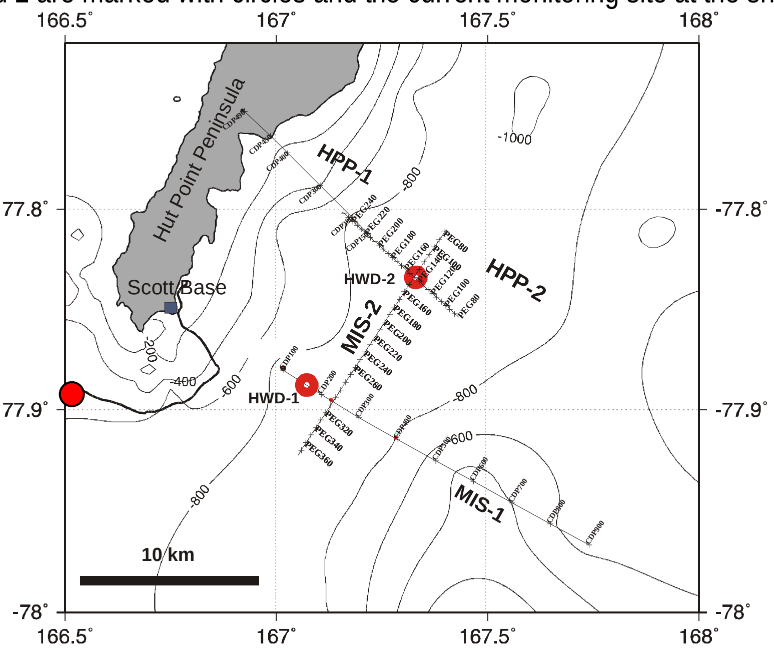


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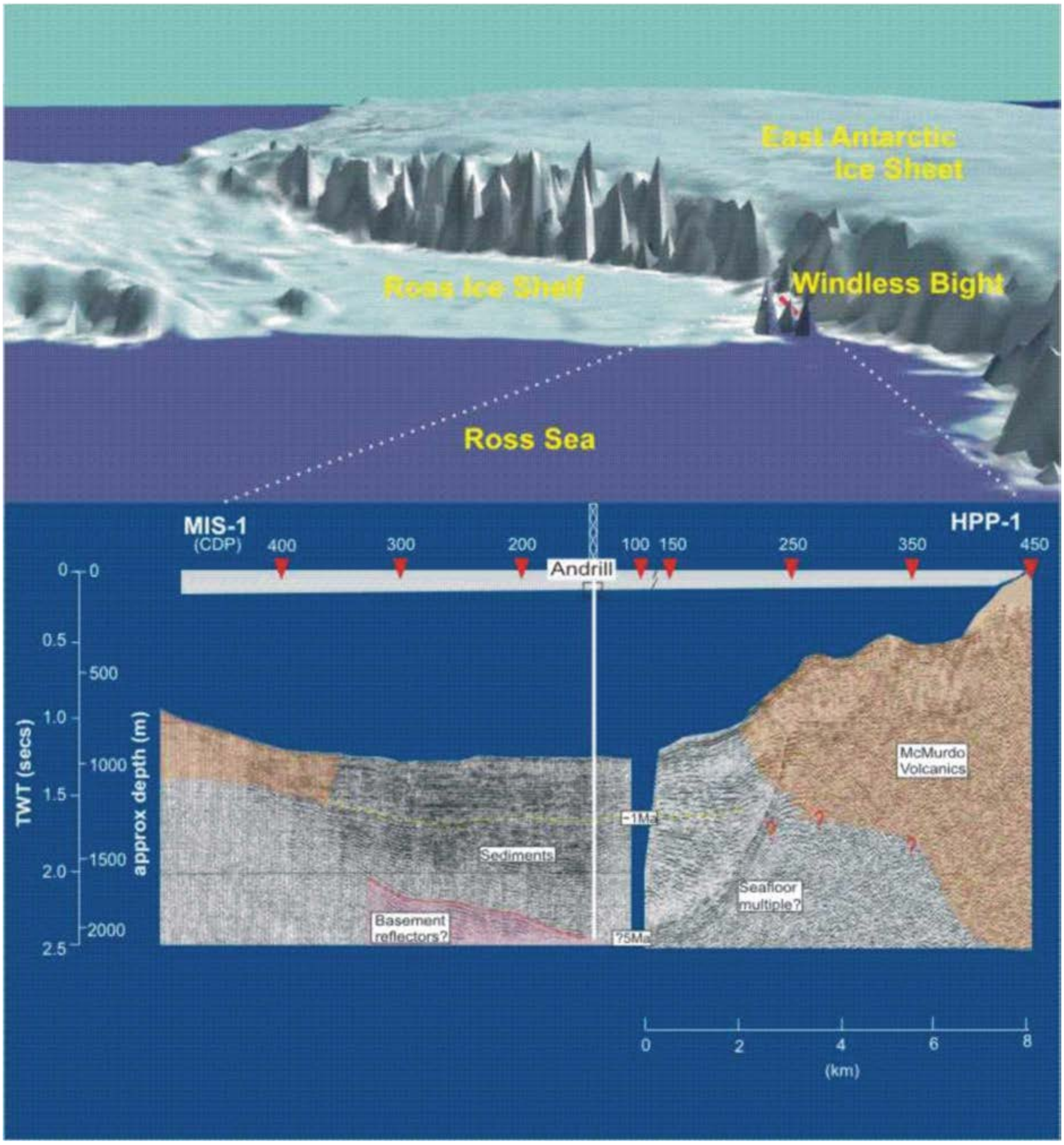
Fig. 2 The Ross Embayment and a seismic section beneath the ice shelf south of Ross Island, showing the setting for the K-042 operation.



2 Proposed Programme

This project was designed both to investigate the little explored sub-ice shelf environment and to provide essential site data for coring 1000 m into the sea floor by ANDRILL for a history of the McMurdo-Ross Ice Shelf (MRIS). Ross Island has been depressing the crust under its own weight for at least the last million years, and at the same time has been acting as the western pinning point for the MRIS. As a result sediment has been accumulating in a sea floor depression over 900 m deep to the south of Ross Island in Windless Bight (Fig. 2). These sediments record the presence and possible past absence of the MRIS, and the movement of Ross Sea Shelf Water behind Ross Island between McMurdo Sound and the central Ross Sea

We proposed to occupy 4 sites, first melting a 50-cm-wide hole through the ice shelf (70 to 150 m thick). We then proposed to measure water depth (expected to be over 800 m) and water column properties through a tidal cycle (conductivity, temperature, current speed, current direction) before sampling the sea floor by grab and gravity corer. The access hole was to be melted by a Hot Water Drilling system provided by the Alfred Wegener Institute for Polar and Marine Research, which had been delivered by ship the previous summer.

The project ran extremely well with access holes drilled and kept open through the ice shelf for up to 9 days (for a full account see the Logistics Report). This was critical for the success of the project. All instruments and sampling devices deployed through the access holes functioned and were recovered. The two most central of the 4 proposed sites were occupied, and a third site at the edge of the ice shelf monitored over a period of three weeks for currents in the upper 2/3 of the water column.

System specifications
Hot water capacity: 90 l/min from 6 JP8 fueled burners
Water temperature: 95°C
Working pressure: 80 bar (1200 psi)
Drilling rate:
Pilot hole (~150 mm diameter) 30 m/hr
Reamer hole (>600 mm diameter) 20 m/hr
Bottom reamer (>600 mm diameter) 5 m/hr

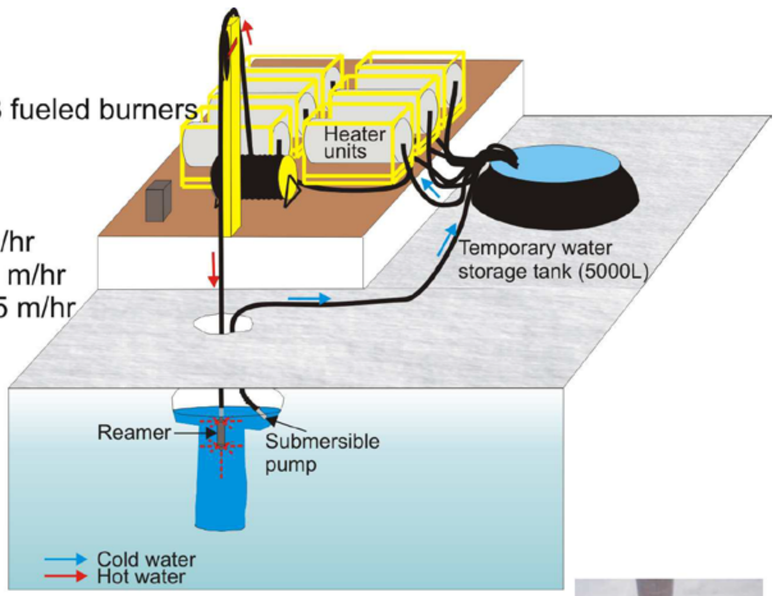


Fig 3. The system uses a combination of melted snow and re-circulated melt-water to produce a jet of hot (95°C) water to melt through the ice shelf. Firstly a vertical pilot hole (~15 cm) is made through the ice shelf. This is then widened to >600 mm using a reamer. Additional reaming is needed at the bottom of the hole as hot water is lost to the ocean beneath the ice shelf.

3 Scientific Endeavours and Achievements

The data and sample gathering phase of the Windless Bight project has now been successfully completed. Some results are immediately apparent and are summarised below. Others require further data reduction and analysis. Roles and responsibilities for the field phase just completed are shown in Table 1.

Table 1. The K-042 team for the Windless Bight survey

PERSON	ROLE	RESPONSIBILITIES
Peter Barrett, VUW	Scientific Leader	Overall programme & scientific report.
Alex Pyne, VUW	Field Leader	Field programme and logistics report. Setting and retrieving oceanographic instruments and bottom sampling equipment. Analysis of current measurements for sea riser modeling.
Gavin Dunbar, VUW	Scientist	Assistance with setting and retrieving oceanographic instruments. Visual core description. Sampling of bottom sediments. Subsequent textural analysis and organisation of supporting analyses
Lionel Carter, NIWA	Scientist	Assistance with setting and retrieving oceanographic instruments. Analysis of water column CTD data
Natalie Robinson, VUW	Scientist	Analysis of water column current data.
Christina Riesselman, Stanford U	Scientist	Analysis of water and particulate chemistry from the water column. Microfossil analysis of water column particles and sea floor sediment.
Giovanna Giorgetti, Siena	Scientist	Petrographic analysis of bottom sediments
Frank Niessen, AWI	Scientist	Acoustic sounding, gravity coring. Sediment physical properties (including shear strength)
Uwe Nixdorf, AWI	Engineer HW drilling	Drilling and maintaining access holes. Ice shelf observations.
Erich Dunker AWI	Asst Eng HW drilling	Drilling and maintaining access holes
Jonathan Leitch, VUW	Eng plant & camp	Maintaining plant and camp operations
Dougal Mason,VUW	Field assistant	Assisting drilling access holes

Camp was set up on the first site at the intersection of seismic lines MIS-1 and MIS-2 on January 3. However, because the site was too close to one of the approaches to a runway on Williams Field it had to be moved 1.75 northward along the seismic line to 77º 53 308’ S; 167º 17.753’ E and was designated HWD03-1 or Site 1 (Fig. 1). At the same time a Broadband ADCP current meter was installed in sea ice at the edge of the ice shelf south of Scott Base to record currents to 400 m depth continuously over the following 4 weeks. The hole at Site 1 was drilled on 10 Jan and after 4 attempts successfully reamed to a diameter of > 0.56 m throughout. Measurements and sampling through the hole took place from January 13 to 22. On January 23 and 24 the camp was shifted 7 km northeast to the second site to be occupied (HWD03-2 or Site 2). The access hole was completed on January 26 and kept open until February 2 for measurements and sampling. Camp and equipment were returned to Scott Base and the field operation completed by February 4.

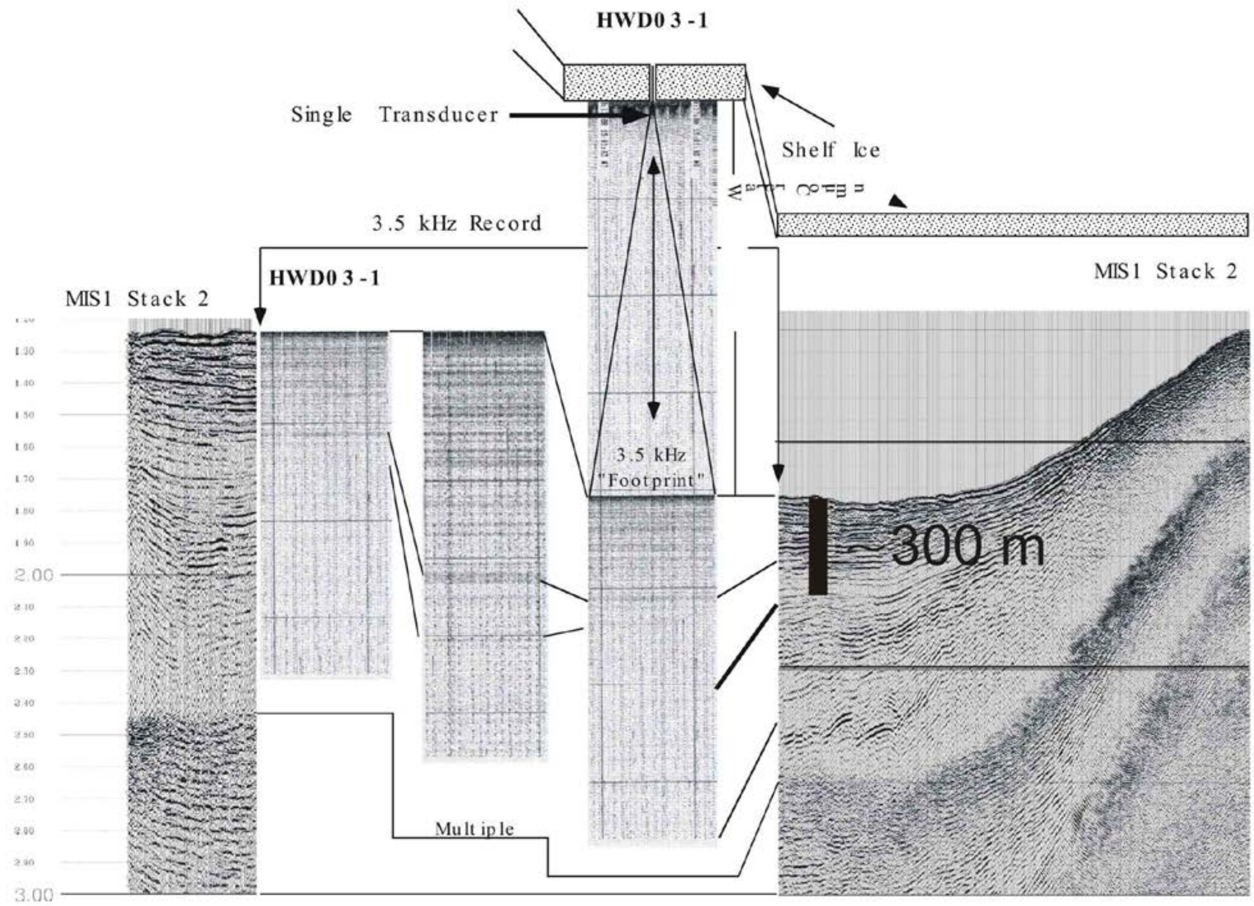
Table 2 Basic data for the two sites occupied by K-042 on the McMurdo Ross Ice Shelf

HWD-1 - 5 km from edge of shelf		
Position:	77º 53.308'S	167º 05.067'E
Ice Shelf thickness	70.5+-0.1 m	
Datum - Ice Shelf surface	0 m	
Firn-ice transition	27.0+-0.5 m	
Sea level depth	17.3+-0.2 m	
Sea floor depth by wire line	938 m (920 m bsl)	
HWD-2 - 12 km from edge of shelf		
Position:	77º 50.111'S	167º 20.209'E
Ice Shelf thickness	143.7+-0.1 m	
Datum - Ice Shelf Surface	0 m	
Firn-Ice Transition	27.2 +-0.2 m	
Sea level depth	27.6 m	
Sea Floor Depth by wire line	950.7 m (923 m bsl)	

OCEANOGRAPHIC AND SEA FLOOR MEASUREMENTS

The first measurements at Site 1 were to establish water depth and nature of the sea floor. A 3.5 kHz transducer was lowered and set 2 m below the base of the ice shelf to obtain a high quality acoustic record of the sea floor and subsurface sediment. Water depth was determined to be 855 m below the base of the ice shelf (908 m bsl, 926 m below the ice shelf surface, a convenient reference point for all subsequent oceanographic measurements). The sea floor reflector was sharp and stratification recognized down to a depth of over 300 m. This indicates that the sediment for this interval is largely fine-grained and unconsolidated. The water depth was determined by weighted line to be 938 m, 12 m deeper than the acoustic estimation. This depth was used for operational purposes on oceanographic casts.

Fig. 4. Seismic record through Site 1 (MIS-1 line, Bannister et al., 2002), with image from 3.5 kHz profiler inserted. Reflectors can be seen down to ~300 m below the sea floor.



A similar procedure was followed for site 2, and an outline of the scientific data gathered for both sites is shown in table 3.

Table 3. Measurements and samples taken by K-042 through the two access holes in Windless Bight.

SAMPLING DEVICE	Samples taken	HWD03-1	HWD03-2
3.5 kHz sounder	Water depth and sub-seafloor stratigraphy	Penetration to ~300 m	Ice shelf too thick for cable
S4	Current speed and direction profiles through the water column	Casts 1 to 13 from 1400 Jan 14 to 1700 Jan 16	Casts 1 to 10 from 1110 Jan 28 to 1240 Jan 29.
CTD	Conductivity and temperature profiles through the water column		
1 litre NIO bottles	Water samples for chemistry and suspended particulate matter	~20 samples taken at 6 levels	~20 samples taken at 6 levels
ADCP array	Current speed and direction measured simultaneously through the water column for at least 48 hours	Deployed for 87 hours on Jan 18-22. See Fig. 3	Deployed for 47 hours on Jan 31 to Feb 1
Gravity cores	48 mm diameter sediment cores – at least 3 from each site more than 50 cm long	Cores 7, 11, 13, 50, 60 and 61 cm	Cotes 29, 42, 61 and 63 cm
Grab	Top 3-5 cm from sea floor.	Grabs 1 and 2 empty. Grab 3 30% full.	Grabs 1 & 2 empty. Grab 3 full

Cast procedure and water/particulate chemistry samples: After a trial cast with the S4 1 m above the weighted bottom and the CTD 5 m above that, a second cast was run with 1 litre NIO bottles at depths at 6 levels through the water column for water sampling. Several bottles proved difficult to bring up through the hole because currents in the water column deflected the rope, and were damaged. It was then decided to attach only two bottles 5 m apart and 5 m above the CTD on each cast but to trip them each cast at successively higher levels to cover the 6 planned sampling levels. This worked well, and the 14 casts were completed late on January 16. Filtration was done on samples from each level for 3 casts with a fourth close to the sea floor, and 3 further samples from water in the gravity corer just above the sediment water interface. Material could be seen on all filters, with those close to the sea floor showing an obvious brown coating. Samples were also taken for water chemistry.

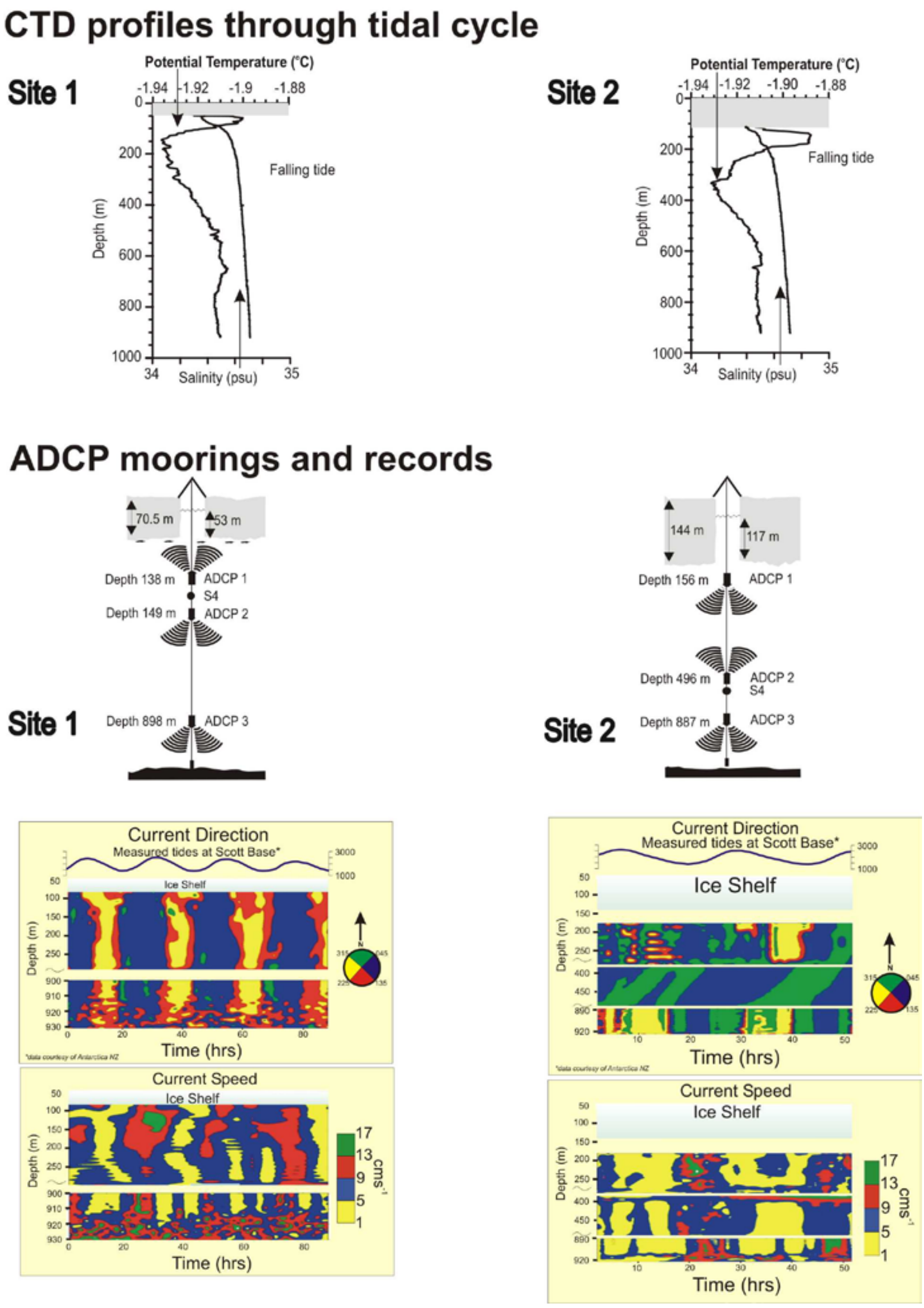
CTD measurements: Oceanographic data were collected at both sites primarily with a Conductivity-Temperature-Depth profiler during water sampling casts, and later by a moored array of Acoustic Doppler Current Profilers (ADCPs). The setup and some results are shown in figure 5.

Temperature and salinity profiles from the CTD casts identify 4 water zones in Windless Bight.

Zone	Depth range [m]	Salinity [psu]	Temperature [°C]
A	53 - 150	34.38 to 34.46	-1.915 to -1.90
B	111- 275	34.59 to 34.63	- 1.93 to -1.936
C	260 - 660	34.65 to 34.67	-1.918 to -1.914
D	660 - 922	34.70 to 34.71	- 1.911

Zones B, C and D resemble High Salinity Shelf Water (HSSW) and Deep Ice Shelf Water (DISW) of Jacobs et al. (1985), whereas Zone A resembles Shallow Ice Shelf Water (SISW). Site J9, 450 km south of the Ross Ice shelf, has a similar Temperature/Salinity structure suggesting continuity of water masses with Windless Bight. However, the shallowest zones are much colder at J9 and lack the relatively warm intrusion (Zone A) seen in the Bight.

Fig 5. Oceanography beneath the McMurdo-Ross Ice Shelf.
Site locations are shown in figure 1.



Current velocity measurements: Current measurements from the ADCP arrays are heavily influenced by the diurnal tides (Fig 5). Currents are relatively slow in the floor of the basin at both sub-ice shelf sites (averaging around 7 cm/s with a maximum of 17 cms), but are considerably faster (up to 60 cm/s) at the ice shelf edge off Hut Point Peninsula where the water is shallower (~600 m). Flood tides enter from the E and swing N below the McMurdo Ice shelf. This is also the direction of the mean flow, suggesting that, like the western and central Ross Ice Shelf edge, McMurdo Sound may also be a point of sub-ice shelf inflow.

Sea floor sediments: Initial gravity coring attempts yielded cores only a few cm long but by applying grease to the inside of the core liner cores in excess of 50 cm were consistently recovered from both sites. Grab samples of the top 2-3 cm were also recovered from both sites, and showed that the sea floor sediment at each comprises a thin (5 mm) layer of sandy mud with scattered basaltic pebbles up to 15 mm across. The sediments beneath are diatomaceous sandy mud with diverse diatoms, occasional foraminifera and rare shells. The mud gives way at 31 cm at Site 1 and 60 cm at Site 2 to a pebbly sandy mud or diamicton beneath (Fig. 6). Cores from Site 1 have from 23 to 30 cm an unusual laminated well sorted sand with a sharp base and top, tentatively interpreted as a sediment gravity flow. The diamicton in the lower part of each core was firm but not over-consolidated, indicating that the basal ice that deposited the sediment did not load or erode the sea floor.

The sand mineralogy is basaltic glass and rock fragments throughout both cores, but they also have a significant proportion of quartz, some of it rounded like grains in the Beacon sandstone from the Transantarctic Mountains 100 km to the west. Smear slides also show a trend of increasing biogenic silica up the core. While further work is needed these results are support the view that the cores represent a period of glacial retreat from a time of more extensive grounded ice, effectively recording ice retreat perhaps since the Last Glacial Maximum, a pattern consistent with cores elsewhere in the Ross Sea.

SUMMARY

Two key results of the survey include:

- water column data that show the prevailing tidal nature of the sub-ice shelf flow, but with a net inflow from McMurdo Sound into Windless Bight. The temperature/salinity structure is very similar to site J9, suggesting continuity of water masses beneath the entire ice shelf, with McMurdo Sound being another possible point of inflow.
- Cores penetrated a Holocene mud blanket, which is underlain by soft diamicton.

The lack of sediment compaction indicated by 3.5 kHz penetration to 300 m bsf shows that water was deep enough not to have grounded ice during the Last Glacial Maximum (or for previous such events for perhaps as much as a million years or more). These data indicate that the basin contains a long and continuous record of the presence, absence and (near) grounding of the Ross Ice Shelf over the last million years or more. One of ANDRILL's goals is to core this record.

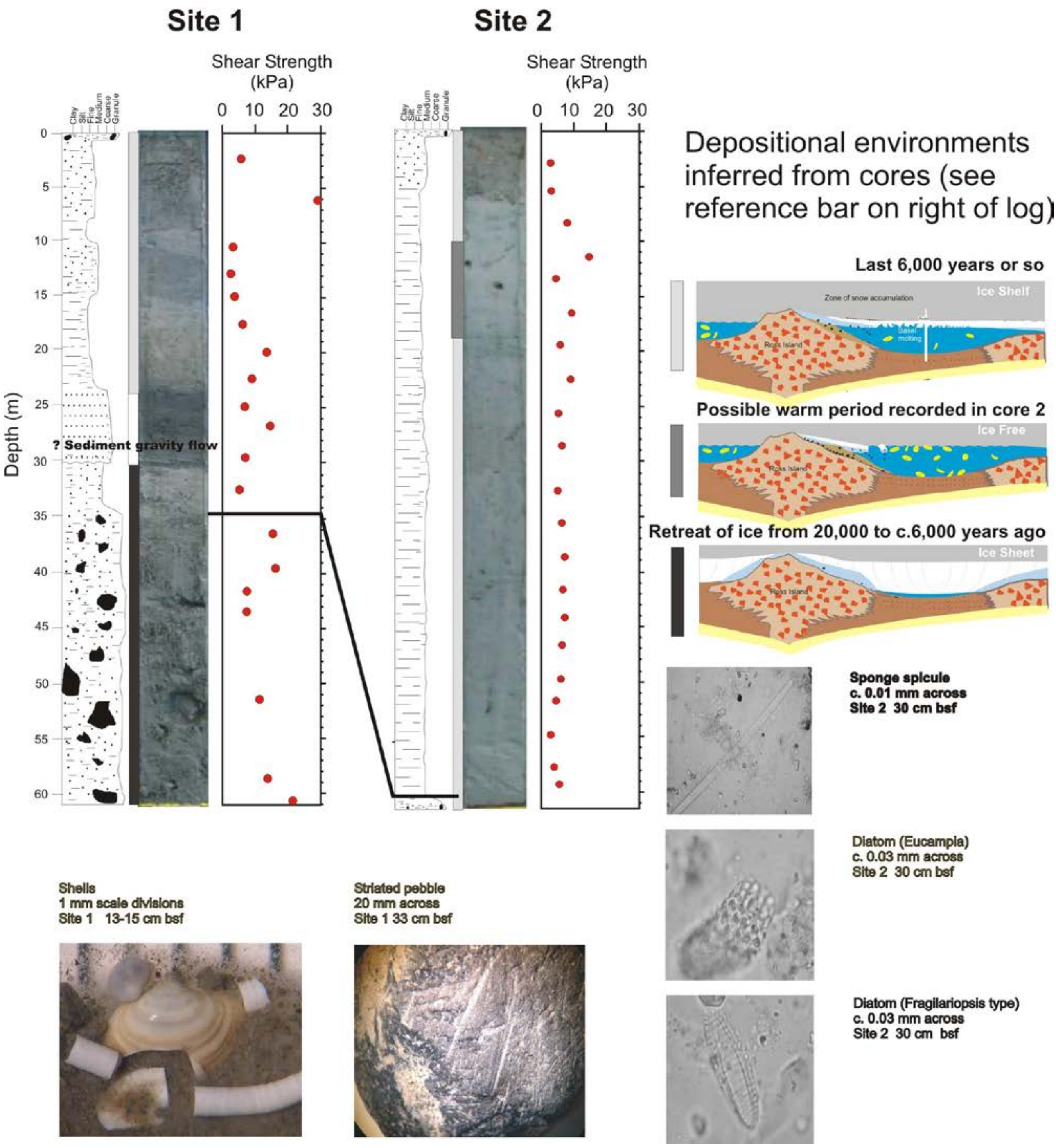
Further work on the oceanographic data will help understand the origins and maintenance of oceanic circulation under the present global climate regime. It will also help in designing ANDRILL's deep coring system, with deployment planned for 2005-06.

REFERENCES

H. Horgan, T. Naish, S. Bannister, N. Balfour, G. Wilson, M. Finnemore and Pyne A. 2002 Seismic stratigraphy of the Ross Island Flexural moat under the McMurdo Ross Ice Shelf, Antarctica. AntarcticaNZ Event Report for the 2002-03 field season.

Bannister, S. and Naish, T.R. 2002. ANDRILL Site Investigations, New Harbour and McMurdo Ice Shelf, Southern McMurdo Sound, Antarctica. Institute of Geological and Nuclear Sciences Report 2002/01,24 p.

Fig 5. Recent sedimentary record beneath the McMurdo-Ross Ice Shelf



4 Publications

Work planned on data and samples collected by K-042 is outlined in Tables 4a and b below.

Table 4. Proposed reports and papers based on data and sea floor samples.
a) On site scientists

Lead authors	Institution	Nature/content of report/paper
P Barrett	VUW	Scientific Report to AntarcticaNZ. Poster for AGU/EGA/EUG, Nice (with help from G. Dunbar & others).
P Barrett	VUW	Scientific Report on McMurdo Ross Ice Shelf study VUW publication with contributions from whole party
A Pyne	VUW	Logistics Report to AntarcticaNZ. Authorship A Pyne Report to ANDRILL on current measurements for design of sea riser.
G Dunbar	VUW	Sedimentation beneath the McMurdo/Ross Ice Shelf. For submission to leading international journal. Input from Barrett, Carter, Giorgetti, Neissen, Pyne, Riesselman.
G Dunbar	VUW	History of the MRIS since the LGM (input from all) for *Science* or similar
L Carter	NIWA	Oceanographic measurements and implications for sediment transport (input from G. Dunbar, R.Dunbar, A Pyne, C Riesselman, N Robinson and M. Williams)
N Robinson	VUW	Thesis and paper on description and modelling of current behaviour between Ross island and White Island. (input from Barrett, L.Carter, G. Dunbar, M.McGuinness, A. Pyne, M.Williams).
G. Giorgetti	U Siena	Provenance of bottom sediment beneath MRIS (input from Barrett, Carter, G. Dunbar), including petrography, chemical analysis of seds by XRF (input from Giorgetti, GDunbar, C Reisselman
F Neissen	AWI	Nature of the sedimentary sequence beneath MRIS based on site seismic data and physical properties. (with input from Alex Pyne and Tim Naish)
U Nixdorf	AWI	Platelet ice beneath MRIS
U Nixdorf	AWI	Hot water drilling through MRIS (with input from Erich Dunker).

b) Other proposed collaborators

Lead authors	Institution	Nature/content of report/paper
W Ehrmann	AWI	Clay species and their proportions from core samples
H von Eynatten	U Jena	Paleoclimate from chemical alteration of volcanic granules from core samples
H Helmer	AWI	Regional ocean currents incorporating MRIS data
(FN to arrange)	AWI	Secular variation from depositional remnant magnetization measured in whole core
(LC to arrange)	NIWA	Trace element characterization of sponge spicules
D Damiani	U Siena	Morphoscopic and textural study of quartz grains by SEM
D Damiani	U Siena	Structural and chemical compositional analyses of clay minerals by XRD and TEM-AEM
F Talarico	U Siena	Petrography of clasts by microscope and SEM

5 Acknowledgments

We are grateful to Antarctica New Zealand for its support before, during and after the field operation, and for the support during the field phase from the Scott Base staff. The operation was large and complex and its success depended on timely arrival of equipment and personnel. We also acknowledge the support of a number of funding agencies, including the NZ Foundation for Research Science and Technology for its support for the VUW component of the project, as well as support from the home institutions of all participants.

The diagrams in this report were created largely by Gavin Dunbar for a poster for the joint AGU-EAG-EGU meeting in Nice, France in April 2003. The poster can be downloaded from:
ftp://ftp.geo.vuw.ac.nz/CAPE/outgoing/AGUNicePoster.pdf .

*EVENT DIARY (FROM DRAFT LOGISTICS REPORT)

Date	Main Activities and Location	Other Comments
16-30 Dec.	Preparing Aalener sledge for Hot Water Drill at Scott Base	Johno Leitch
	Preparing Camp Containers, CRP DS Lab and equipment at Scott Base	Johno Leitch, SB staff.
30 Dec.	E. Dunker, U. Nixdorf, A. Pyne; Chch to Scott Base	
31Dec.-4 Jan.	Assembly and testing equipment at SB –Willy Rd. transition. Preparing traverse loads	Assisted by SB plant ops. (Kim and Gus)
4 Jan.	G. Dunbar, D. Mason; Chch to Scott Base	
3-5 Jan.	Traverse equipment to MISHWD-1 site. Start camp setup.	
5 Jan.	Move site west along seismic line to HWD-1 site.	
6 – 7 Jan.	Camp setup, Vehicle licences, started making water with HWD	
7 Jan.	P. Barrett, L. Carter, G. Giorgetti, F. Niessen, C. Riesselman, N. Robinson; Chch to SB	
7- 14 Jan.	Drilled HWD-1 hole. Down hole reamer fitting lost and new hole drilled 3 m away	
8 Jan.	Preparing equipment and laboratory operation at Scott Base.	
10 Jan.	Sea ice site for Broadband Deployment, site BB2, Kassbohrer drilled hole.	
11 Jan.	BB2 site, recovered instrument for checking and set up snow box (box brownie) around hole.	
14 Jan.	HWD-1. Started current meter (S4) and water bottle sampling. Winch motor problems, used skidoo. Multiple water bottle array stuck under ice, recovered at slack water.	
15-16 Jan.	Winch operating with SB electric motor. 24 hour current profiling and water sampling.	
16-17 Jan.	Completed current profiling and water sampling. Calliper log of hole and coring and grab of sea floor. Reamed hole for ADCP mooring.	
18 Jan.	Deployed ADCP mooring. Some personnel return to Scott Base.	
19 Jan.	Fuelling and camp maintenance.	Johno camp caretaking
20-21 Jan.	Storm, condition 1-2 on Willy Rd. Some personnel return to HWD-1 camp on 21 Jan. during short weather break.	
22 Jan.	Dig out and recover ADCP mooring (86 hour duration). Personnel to HWD-1 camp for instrument download.	
23 Jan.	Start camp pack up and move. HWD-2 site located and camp moved for overnight occupation. Some personnel to Scott Base.	Johno and Gus
24 Jan.	Set up Hwd-2 campsite. Move remaining equipment form HWD-1 to HWD-2 site.	
25 Jan.	Preparing HWD equipment, make start-up water and complete camp setup. Personnel to site	
26 Jan.	Drill HWD-2. Ice thickness approx 144 m.	
27 Jan.	Reaming hole	Visitors from SB
28 Jan.	Started 24 current profiling and water sampling	
28 Jan.	L. Carter return Chch.	
29 Jan.	Completed water column profiling. Coring and grab sampling of the sea floor	Visitors from Crary Lab & McMurdo.
30 Jan.	Calliper log and reaming hole. Prepare and deploy ADCP mooring.	
31 Jan.	Caretaking at site, some personnel return to SB and return to site.	
1 Feb.	Personnel to site for mooring recovery, recover mooring started at 2300 hrs.	
2 Feb.	3.5Khz and further coring of the sea floor. Preparing instruments for return to NZ and transport to Scott Base.	
3 Feb.	Set up mini HWD on Hagglund sledge for sea ice mooring recovery. Recover sea ice BB ADCP.	
4 Feb.	Break camp and start return of equipment to the SB transition.	
5 Feb	Packing for Ship Cargo, returning camp/equipment to SB	
5 Feb.	P Barrett return Chch.	
6 Feb	Helicopter recon. To New Harbour and Black Island, proposed ANDRILL sites. (Dunker, Nixdorf & Pyne)	
7-9 Feb.	Packing up equipment and laboratories at Scott Base.	
9 Feb.	F. Niessen & A. Pyne return to Chch.	
10 Feb.	G. Dunbar, E. Dunker, G. Giorgetti, J. Leitch, D. Mason, U. Nixdorf, C. Riesselman & N. Robinson return Chch.	

Fig 7. The K-042 team at work at Site 2.

K047
2002/03

LOGISTICS REPORT

K047: Climate and Landscape History from shallow drilling in the Dry Valleys
Antarctica New Zealand 2002/03

Event Personnel:

Warren W Dickinson	Victoria University of Wellington
Nicola Wilson	Victoria University of Wellington
Cliff Atkins	Victoria University of Wellington
Camilla Colebatch	Victoria University of Wellington
Hamish McGowan	University of Queensland
David Neil	University of Queensland
Daniel Pringle	Victoria University of Wellington
Joe Trodahl	Victoria University of Wellington

*AIMS

A model to explain the occurrence of ground ice in glacial sediments and bedrock at high altitudes (>1000m) throughout the Dry Valleys where liquid water is rare was developed from work on Table Mtn. (Dickinson, 1997; Dickinson and Rosen, 2002). Although this model may apply at Table Mtn. for the very old glacial sediments of the Sirius Group, it has yet to be tested at other locations in the Dry Valleys. Massive ground ice was discovered for the first time in Pearse Valley during the field season 2001/02.

The sampling programme of the 2002/03 season aims to 1) clarify the nature and origin of massive ground ice in Pearse Valley, 2) gain a better insight into the glaciomorphological history of Columnar, Pearse and Victoria Valleys, and 3) clarify the evolution and occurrence of sand dunes in Pearse and Victoria Valleys.

*PERSONNEL

Name	Designation	Organisation	Departed Chch	Returned Chch
Warren Dickinson	Event Leader	VUW	9 Nov 2002	11 Dec 2002
Nicola Wilson	Honours Student	VUW	9 Nov 2002	13 Dec 2002
Cliff Atkins	PhD student Ex K114	VUW	9 Oct 2002	12 Dec 2002
Camilla Colebatch	PhD Student	VUW	9 Nov 2002	11 Dec 2002
Joe Trodahl	Professor Ex K 131	VUW	3 Nov 2002	18 Nov 2002
Daniel Pringle	PhD Student Ex K 131	VUW	1 Nov 2002	23 Nov 2002
Hamish McGowan	Lecturer	U. Queensland	25 Nov 2002	11 Dec 2002
David Neil	Lecturer	U. Queensland	25 Nov 2002	11 Dec 2002

*PLANNING

i. No suggestions to change the application process
ii. Antarctica NZ staff are excellent
iii. No suggestions on maps and aerial photos
iv. Pre season information is generally good, receiving the field manuals in advance this year was very useful
v. No suggestions on change to the medicals etc.

*PREPARATIONS FOR THE FIELD

i. Reception and planning for your event:

The K047 primary objective supported by Antarctica NZ was to carry out sampling of the sand dunes in the Pearse and Victoria Valleys, and to undertake reconnaissance glaciomorphological mapping and sampling of massive ground ice in Pearse Valley. Because there were only 4 people associated with the event, logistical planning was minimal. Selection of actual campsites in each of the valleys was accomplished largely by relying on previous year's campsites. Scott Base personnel provided excellent support. There was a minor incident during the first fly-out of event personnel when the second load of passengers and equipment was allocated a US helo transport in the last minute. The straight-pole polar tent had to be exchanged to a foldable polar tent due to the restrictions by the US helo programme (transport of polar tents on the skids is not permitted) and there was no time to put the tent up to check it – this particular tent turned out to be very difficult to put up due to a problem in one of the supporting poles.

ii. Availability and condition of equipment received:

The equipment made available to K047 from Scott Base was in good condition and performed well in the field with the exception of two primus stoves (box type). All Scott Base equipment was tested and repacked at Scott Base. However, it was difficult to obtain equipment that was not on the original request list, prepared 3 months in advance. The reason is largely because of the limited resources at Scott Base and the large number of field parties that must be supported. Obtaining equipment (because of an altered situation) at the last minute is always problematic.

iii. Field training:

AFT was undertaken by Nicola Wilson Camilla Colebatch Joe Trodahl and Daniel Pringle; Cliff Atkins and Warren Dickinson had a refresher course.

iv. Delays at Scott Base, whatever the cause:

There was a one day delay (only for Colebatch) for the flight out from Scott Base on 10 December, this was due to the weather conditions.

v. Safety and Risk Management Processes:

These processes were discussed with Jim Cowie, operations manager, prior to departure for the field.

*Event Diary

Date	Main Activities and Location	Other Comments
10 Nov	Arrive in ChCh, kit-up	
11 Mon	Depart for SB at 9:00am, boomerang back to ChCh due to weather at SB	
12 Tue	Depart for SB at 8:30am, arrive at 2:30pm, briefing and AFT briefing	
13 Wed	SB, NW & CC AFT; CA & WD pack field equipment	windy conditions with snow,-
14 Thu	SB, NW & CC complete AFT; CA & WD pack field equipment	beautiful walk on the sea ice
15 Fri	SB, testing and final packing of field equipment,repacking of food boxes	
16 Sat	SB to Table Mt, NW,WD,JT&DP 1st helo; CA&CC 2nd	last minute swap of polar tents
17 Sun	TM, recon walk around the area	wind picking up,very windy night
18 Mon	TM, OSL sampling, recon Columnar Vly and reprogram temp probes	late finish
19 Tue	TM, shallow drilling on polygons in Columnar Vly, finish recon	late finish, need a bigger drill
20 Wed	TM to Pearse Valley, Pringle to SB; short recon walk around Lake House end of PV	Pearse Vly much warmer
21 Thu	PV, NW&CC dig 5 pit; CA&WD recon	late dinner at 10:30pm
22 Fri	PV, NW,WD&CC core one pit,CA recon Lake House area	late dinner at 10:45pm
23 Sat	PV, core and OSL sample another pit, dig 3 more pits	windy and cold evening
24 Sun	PV, recon of dunes, CC to Lake Joyce & Taylor glacier tongue	late dinner at 11pm
25 Mon	PV, NW&WD OSL sampling at dunes; CA&CC dig pits	cold evening –16C
26 Tue	PV, CA,CA&CC core + sample third pit, NW petrography@camp	dinner at 10pm
27 Wed	PV, CA& WD further recon, NW&CC OSL sampling; DV visit @2pm	Helo move confirmed
28 Thu	PV, walk to Lake Joyce Taylor glacier tongue, dig more pits	confusion about helo sched
29 Fri	PV to Vic Vly for CA, NW & WD; DN, HM, DW SB to VV; CC to SB	just made it to SB,weather bad
30 Sat	VV, rec, interviews by DW	early start
1 DEC	VV,recon walk to the dunes, DV visit @3:45pm, sieving of samples	DW retro SB with DV's
2 Mon	VV, surveying, pit digging and drilling at the dunes	
3 Tue	VV, GPS survey of dunes, check and relocation of weather stations	
4 Wed	VV, recon of Victoria glacier tongue, collect samples form sediment traps	
5 Thu	VV, OSL sampling and surveying	
6 Fri	VV, NW completed GPS survey of dunes, weather stations relocated	
7 Sat	VV, rest of the surveys completed, filming at Packard Glacier,visit Lake Vida	Packard Stm flowing
8 Sun	VV, OSL and ice samples from Victoria glacier	
9 Mon	VV to SB NW DN 1st helo & WD, CA, HM on 2end;10a start	Endura tent difficult to pack
10 Tue	SB, cleaning, sorting & packing of field equipment	
11Wed	SB to ChCh-WD,HM,DN & CC	Av Wgtn 8p

12 Thu	SB to ChCh CA	
13 Fri	SB to ChCh NW	

SB=Scott Base; PV=Pearse Valley; VV=Victoria Valley
CA=Cliff Atkins; CC=Camilla Colebatch; DN=David Neil; DP=Daniel Pringle; HM=Hamish McGowan; JT=Joe Trodahl; WD=Warren Dickinson

EVENT MAP

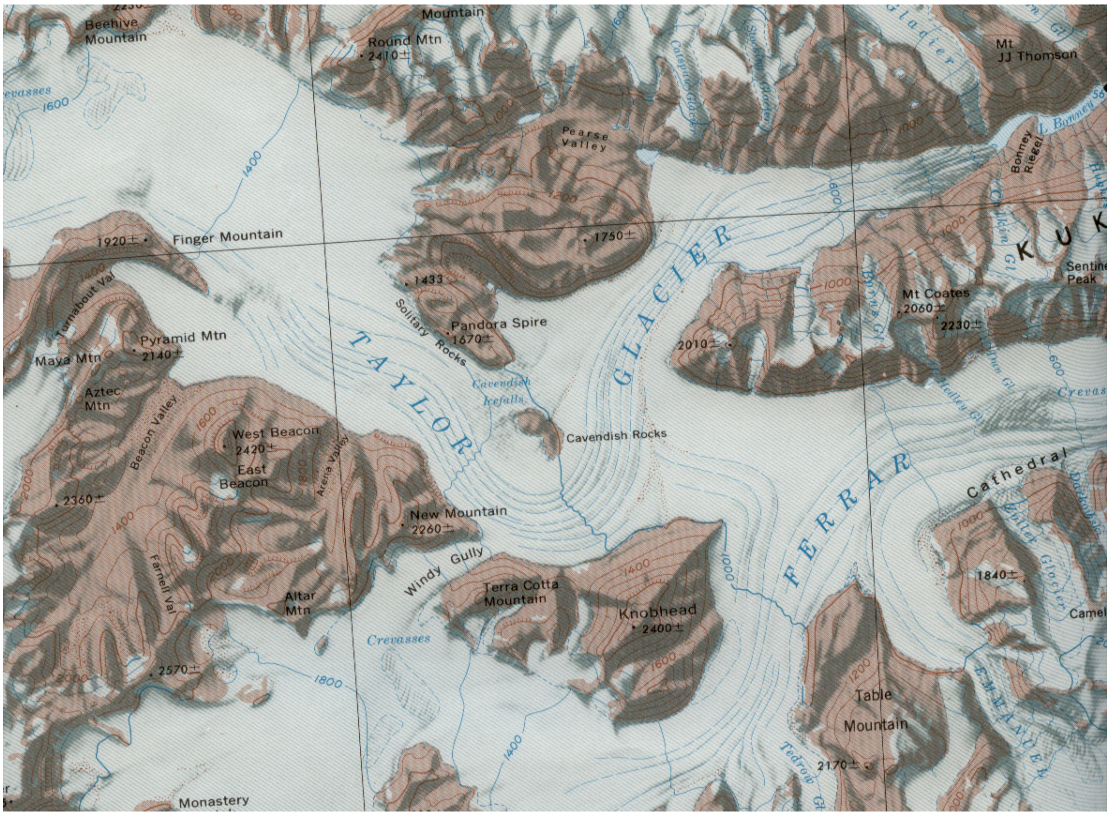


Figure 1. Topographic map of Table Mountain.

The Table Mountain camp (fig. 1) was located on a small patch of snow at (altitude 1850m; S77°57.631' E161°57.324') and was selected for the snow patch and close location to the temperature probes. Winds during the field visit were mostly between 10 and 30 knots with gusts up to 40 knots.

The Pearse Valley camp (fig. 2) was on an alluvial terrace located at the eastern edge of Lake House (325m; S77°42.101' E161°26.924') and was selected for its proximity to a source of water (Schlatter glacier). Wind direction and strength seems highly variable throughout the valley and diurnal variations were common. During the field visit, winds did not exceed 20 knots and seemed strongest from 2 – 5 am.

The Victoria Valley camp (fig. 3) was located on an alluvial terrace derived from meltwater off the Packard glacier and situated adjacent the dune field (400m; S77°22.082' E162°12.720'). It was selected because of its flat nature and close proximity to the working environment. There was little snow around so water had to be obtained from the Packard glacier, a short walk up Packard Creek. The majority of winds were easterly or down valley with a few periods of stronger, reversed directional westerly winds.

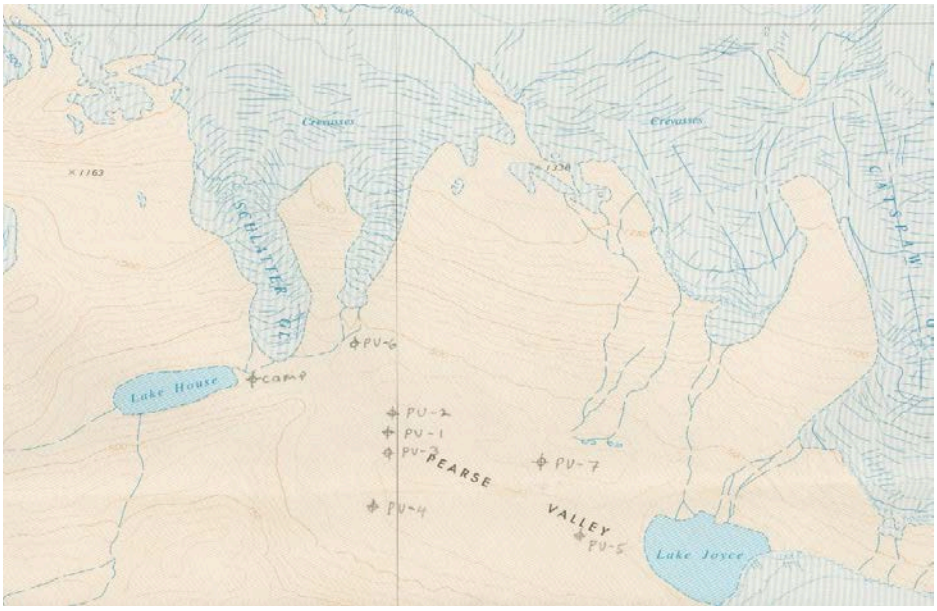


Figure 2. Topographic map of Pearse Valley.

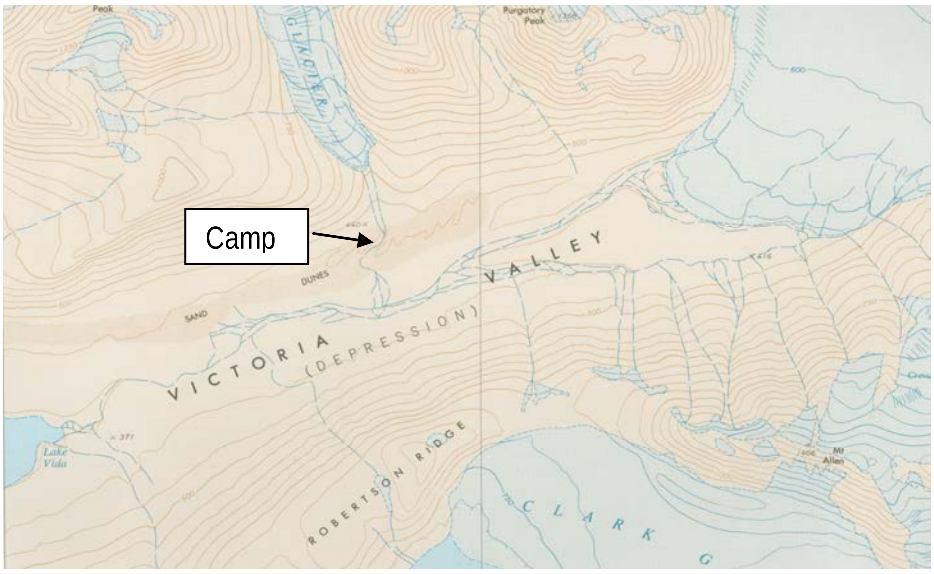


Figure 3. Topographic map of sand dunes at Victoria Valley.

*WEATHER

For most days in the field the weather was generally good. Field movements by helicopter were not constrained by the weather although it was a close call for the movement scheduled on 29 November. Field work was not restricted due to weather conditions at any time. Temperatures at Table Mountain ranged from -20°C at night to -12°C during warmer days but strong wind chill occasionally caused temperatures down to -30°C. Pearse Valley was warmer with temperatures ranging mostly from -8°C to -4°C with a few nights of -14°C. Victoria Valley was colder again with –8°C to –12°C but warmed up to –1°C with the arrival of winds of up to 25 knots in the last few days.

*ACCIDENTS, INCIDENTS OR HAZARDS

There were no accidents or incidents during this field season.

RADIO COMMUNICATIONS

VHF radio communications at each of the valley campsites was extremely limited. At Table Mountain the VHF high-gain aerial worked in selected places and in Pearse Valley there was no VHF reception from Scott Base at the camp. Communication in Pearse Valley was possible only with the HF 'butterbox' with a very poor reception or by climbing .5 hr to a suitably high location.

Field operations in Antarctica now require reliable and quick communications with Scott Base. Because of this, I strongly recommend that satellite phones be provided to field parties that are out of VHF radio contact.

*ENVIRONMENTAL IMPACT

*Sites Visited

Site name	Table Mountain
Site location	S77°57.631' E161°57.324'
Dates occupied	16 – 19 Nov 2002
Total days (or hours) at site	4
Maximum number of people at site	5
Total person-days (or person-hours) at site	20
Main activity undertaken	Repair/programme temp probes, recon, soil sampling and description

Site name	Lake House (Pearse Valley proper)
Site location	S77°42.101' E161°26.924'
Dates occupied	20-28 Nov 2002
Total days (or hours) at site	9
Maximum number of people at site	4 + DV visitors
Total person-days (or person-hours) at site	36
Main activity undertaken	Recon, soil sampling and ice core extraction

Site name	Victoria Valley
Site location	S77˚57.011' E161˚59.350'
Dates occupied	29 Nov – 9 Dec 2002
Total days (or hours) at site	11
Maximum number of people at site	6 + DV visitors
Total person-days (or person-hours) at site	58
Main activity undertaken	Recon, soil & ice sampling, GPS surveys, weather observations

Geological Material

Pit and sample locations - for more detail, see table of samples in Scientific Report

Table Mtn and Pearse Valley

Name and Location of Pit/Drillhole/Sample	Type and approximate quantity of sample
TMCV-7 S77°58.071, E161°55.623	1 kg ice chunks
PVP-1 S 77°42.405', E161°28.881'	800g soil sample
PVP-2 S 77°42.168', E161°30.340'	75 cm ice core, 7 soil samples totalling < 3kg , 500g surface gravel
PVP-6 S77°42.274', E161°30.257'	75 cm ice core, 3 soil samples totalling < 1.5 kg; 500g surface gravel, 500g ice chips
PVP-16 S77°42.167', E161°30.318'	78 cm ice core, 500g ice chips, 2 soil samples totalling < 1kg, 500g surface gravel
PVRG-1 S77°42.259', E161°35.062'	1 kg ice chunks
PVRG-2 S77°42.211', E161°35.242'	1 kg ice chunks
Schlatter Glacier, Pearse Valley	1 kg ice chunks
Taylor Glacier/Lake Joyce tongue, Pearse Valley	2 kg ice chunks
Various locations in Pearse Valley	36 hand samples of surface lithology, totalling <10 kg

Victoria Valley

Name and Location of Sample	Type and approximate quantity of sample
VV1-RB S 77°22.114', E162°12.454'	500g soil sample
VV-C1 S 77°22.250', E162°12.330'	500g soil sample
VV-C2 S 77°22.130', E162°13.720'	500g soil sample
VV-C3 S 77°22.323', E162°10.713'	500g soil sample
VV-C4 S 77°22.528', E162°08.555'	500g soil sample
LB-1 S 77°22.533', E161°54.803'	500g soil sample
LB-2 S 77°22.499', E161°55.859'	500g soil sample
LVG-1 S 77°22.087', E162°17.470'	500g soil sample
LVG-2 S 77°22.326', E162°18.341'	500g soil sample
Various locations in Victoria Valley	40 hand samples of surface lithology, ≈20 kg

Equipment installed/left in field (Table Mtn)

Type of equipment/marker installed	2 temperature probes 2 m deep
Location of installation left in field	S77˚57.011' E161˚59.350' (install Table Mtn. 2000)
Size of items left in field	(2 m deep in ground, 0.25m^3 on surface) x 2
Number of items left in field	2 probes
Date of intended retrieval	Nov 2003

*Differences from original Preliminary Environmental Evaluation (PEE)

Environmental impact from the 2002-2003 season was well within the limits of the PEE which was approved.

IMMEDIATE SCIENCE REPORT

K047: Climate and Landscape History from shallow Drilling in the Dry Valleys
ANTARCTICA NEW ZEALAND 2002/03

Event Personnel :

Warren W Dickinson	Victoria University of Wellington
Nicola Wilson	Victoria University of Wellington
Cliff Atkins	Victoria University of Wellington
Camilla Colebatch	Victoria University of Wellington
Hamish McGowan	University of Queensland
David Neil	University of Queensland
Daniel Pringle	Victoria University of Wellington
Joe Trodahl	Victoria University of Wellington

1 Popular Summary of Scientific Work Achieved

A model to explain the occurrence of ground ice in glacial sediments and bedrock at high altitudes (>1000m) throughout the Dry Valleys where liquid water is rare was developed from work on Table Mtn. (Dickinson and Grapes 1997; Dickinson and Rosen 2003). The model is based on mineralogical, chemical and isotopic analyses of ground ice and frozen sediments that come from cores of Sirius Group sediments at Table Mtn. It indicates that the ground ice and diagenetic minerals accumulated over long periods of time from atmospheric water vapour and brine films formed on the surface of the ground. Although this model may apply at Table Mtn. for the very old glacial sediments of the Sirius Group, it has yet to be tested at other locations in the Dry Valleys.

Sugden et al. (1995) reported occurrence of massive ground ice believed to be at least 8 Ma old from Beacon Valley but this age was obtained by indirect dating of presumed *in situ* volcanic ash. Ice similar to that of the Beacon Valley was discovered in Pearse Valley during field season 2001/02. Pearse Valley ice originates from either the Taylor or local Schlatter glacier, but the main objective of this project is to establish whether it has the potential to yield palaeoclimatic data. In the 2002/03 season, massive ice was also found in Victoria Valley. Some of this ice was left behind by the retreat of the Lower Victoria glacier but other occurrences appear to have fed from the subsurface by ground water.

The field programme of the 2002/03 season aims to obtain representative cores and samples of this ice for isotopic dating and chemical analysis. Evaluation of analytical results may lead to deep core drilling of some of the sites to clarify further the glacial history of Pearse and Victoria Valleys

2 Proposed Programme

To investigate the nature and origin of massive ground ice and to establish whether it has the potential to yield palaeoclimatic data, a set of shallow ice cores and samples are needed for chemical analysis and cosmogenic isotope dating. The pits to be cored should represent the known distribution of the massive ground ice. In addition to the ice core pit soil profiles will be obtained by sampling the pit walls and the surface material on site to clarify any possible relationship of the ice and the overlying sediments. Evaluation of analytical results may lead to further shallow core drilling of certain sites in the future.

3 Scientific Endeavours and Achievements

Summary

Various people from the event spent 24 days in the field from 16 Nov to 9 Dec. Daniel Pringle (VUW) from K131 joined K047 at Table Mountain to reprogram the data loggers on two temperature probes for 2003. Samples and soil pits were dug as outlined in Table 1. Soil pits were generally dug either in the centers of polygons or between them, and in locations picked in relation to the previous pits containing massive ground ice. Polygon centres are thought to be the least active area and hence should contain the oldest most chemically developed soil.

Method

The following method was used in digging most all of the soil pits: In the area to be excavated (1m x 1m x.5m), the surface material was scrapped off and placed on a 2m square polythene tarpaulin. The underlying soil was then dug out and placed on another 2m square polythene tarpaulin. Loose soil material was dug to a depth of one metre or the top of the ice-cemented soil which ever was the shallowest. After the final pit depth, soil profile and possible permafrost or massive ground ice were described and sampled, all material from the respective polythene tarpaulins was replaced. The ground surface was raked and swept to restore as much as possible of the original appearance. Analyses of the samples will include; OSL (Optically Stimulated Luminescence) of selected dune and pit soil samples, stable oxygen and hydrogen isotopes and ^{10}Be dating for the ice core, and major cation and anion chemistry of soluble salts for the soil samples.

The term “ground ice” refers to all types of ice formed in freezing and frozen ground (Permafrost Subcommittee, 1988 p 46). Permafrost refers to the permanently frozen (<0º C) condition and includes both dry and wet (ice) materials. “Massive ground ice” in this report refers to clear ice with a variable content of sediment >10% of the ice by weight.. Subsurface conditions in the Dry Valleys are generally different from those in arctic and alpine environments in that there is usually 30 to 60 cm of dry frozen sediments above ice cemented sediments. However, because most workers think of permafrost as ice cemented, the term permafrost in this report will include only the ice cemented materials.

Table Mountain

The Table Mountain camp site was chosen close to the temperature probes on a patch of snow at S77°57.631' E161°57.324', altitude 1850m. We experienced winds of up to 40 knots with the temperatures remaining relatively constant around –18 °C.

On the floor of Columnar Valley (adjacent to Table Mtn) polygons have a diameter of 4-10 m and <1 m height differential between trough and polygon centres. Polygons extend from the valley floor up the valley walls up to slopes dipping up to 25° right to the debris flow boundary. The distribution and appearance of the surface material of the polygons in Columnar Valley varies with some polygons having a “brick wall-like appearance with whilst others were covered by randomly distributed boulders and cobbles of varying sizes.

Six pits were dug in total and in all pits permafrost was encountered at depths between 7 and 16 cm. Three pits dug in the cracks between the polygons contained clear ice at depths between 14 and 23 cm. The permafrost boundary appears to follow the surface topography of the polygon.

In general, the activity of any single polygon or part of it may be reflected by the distribution of the material in the troughs. Parts of troughs are flat having been filled with sand while other parts are steep and rocky with angular cobbles and boulders. This angular material may be sorted or unsorted. On the active part of a polygon, clasts may roll off the steep sides and into the trough. Sorting of clasts in the trough may occur by what the center crack is able to accommodate. On the inactive part of a polygon, wind blown sand may accumulate in the trough. This observation suggests that polygon activity may be dynamic so parts of it are active while at the same time other parts are inactive.

A major problem apparent from the fieldwork is to understand what controls the age of the surface and the relationship to polygon development in Columnar Valley. Alternatively, it may be the ice content below the surface that controls polygon development. Soil development and age may be more of a function of the material, aspect and moisture regime, rather than the depositional age of the material in which the soil is forming.

Pearse Valley

Our camp in Pearse Valley was on an alluvial terrace located at the eastern edge of Lake House (325m; S77º42.101' E161º26.924') and was selected for its proximity to a source of water (Schlatter Glacier). Wind direction and strength seems highly variable throughout the valley and diurnal variations were common. During the field visit, winds did not exceed 20 knots and seemed strongest from 2 – 5 am. Pearse Valley contains mostly glacial deposits representing the retreat of the main Taylor Glacier and subsequent retreat of the lateral valley glaciers. Polygonal ground covers 40 – 50% of the valley floor and slopes at different altitudes.

About 10% of the valley floor is covered by sand from eolian deposition and this does not include numerous pockets of sand lodged in troughs of polygons and in other sheltered areas. Much of this sand is protected by a lag of 5 – 8 mm granules and therefore is not mobile under winds of about 50 knots. Much of the sand probably came from stream systems draining meltwater from the retreating glaciers. The main sand dune, climbing the northeast slope of the valley apparently has brine flowing on top of ice cemented sand which accumulates in salt pond (dry on the surface) at the base of the dunes.

Sixteen pits were dug out of which three were also cored and sampled for OSL and soil chemistry. Depth to ice cement and massive ground ice under moraines varied from 0.25 m to >1m and was encountered in 8 out of 16 pits. In the eastern part of the valley clear ice was found extruding from a slope side of what looked like a gelifluction lobe. It is not clear what factors control the depth to ice cement and the massive ground ice but aspect and moisture regime do not seem to have a direct relationship.

In addition to the ice core and soil samples a comprehensive set of hand specimens and surface material was collected. These samples represent the petrologic modal distribution in the till within the valley and reflect the different source areas from which they were transported (ie. direction of glacial transport).

The massive ground ice possibly represents an ice cored moraine which may have derived from the Schlatter Glacier. The surface of this ice is smooth and undulating and it is not clear how the contact between it and loose sand above can be so sharp. Why there is not ice cemented sand above, suggests the clear ice is ablating under the sand. Although the clear ice seems to have a limited extent, it may have a greater extent if it lies below ice cemented soil in other parts of the valley. It is also possible that the ice is somehow related to development of patterned ground which in Pearse Valley is still of relatively limited extent. Initial visual analysis of the ice core at Scott Base confirms the appearance of remnant basal glacier ice. If the ice originates exclusively from ancient glaciers it should be geochemically distinguishable from modern glacier ice.

If the massive ground ice in Pearse Valley is remnant ancient glacier ice it is the oldest preserved ice on earth and has the potential to significantly expand the current palaeoclimatic record obtained from ice cores. Furthermore, preservation of ancient basal glacier ice underneath the valley floors would provide evidence for the stability of the climate in the area for extended periods of time despite of the Holocene climatic fluctuations.

4 Publications

A preliminary report on the massive ground ice descriptions and pit profiles from Pearse Valley will be published as an Antarctic Research Centre Report in June 2003. Results from the dune OSL sampling and profiling from Pearse and Victoria Valleys will be published as an Honours thesis during 2003. Copies of these will be sent to Antarctica NZ.

Further publications of the scientific results will be published in international peer-reviewed scientific journals. Copies of this work will also be sent, when available, to Antarctica NZ.

Table 1. Locations and samples from Dry Valley sites.

Name and Location of Pit/Drillhole/Sample	**Type and approximate quantity of sample**
TMCV-7 S77°58.071, E161°55.623	1 kg ice chunks
TMCV-1 S77°.58.217, E161°56.694	No samples collected
TMCV-2 S77°58.700, E161°58.137	No samples collected
TMCV-3 S77°59.135, E161°59.258	No samples collected
TMCV-4 S77°58.548, E161°56.096	No samples collected
TMCV-5 S77°58.411, E161°55.764	No samples collected
TMCV-6 S77°58.241, E161°55.762	No samples collected
PVP-1 S77°42.405', E161°28.881'	800g soil sample
PVP-2 S77°42.168', E161°30.340'	75 cm ice core, 7 soil samples totalling < 3kg , 500g surface gravel
PVP-6 S77°42.274', E161°30.257'	75 cm ice core, 3 soil samples totalling < 1.5 kg; 500g surface gravel, 500g ice chips
PVP-16 S77°42.167', E161°30.318'	78 cm ice core, 500g ice chips, 2 soil samples totalling < 1kg, 500g surface gravel
PVRG-1 S77°42.259', E161°35.062'	1 kg ice chunks
PVRG-2 S77°42.211', E161°35.242'	1 kg ice chunks
PV Schlatter Glacier	1 kg ice chunks
PV Taylor Glacier/Lake Joyce tongue,	2 kg ice chunks
Various locations in Pearse Valley	36 hand samples of surface lithology, totalling <10 kg
PVP-3 S77°42.479, E161°28.595	No samples collected
PVP-4 S77°42.515, E161°28.506	No samples collected
PVP-5 S77°42.516, E161°28.912	No samples collected
PVP-7 S77°42.383, E161°31.185	No samples collected
PVP-8 S77°42.358, E161°30.715	No samples collected
PVP-9 S77°42.356, E161°30.656	No samples collected
PVP-10 S77°42.280, E161°31.912	No samples collected
PVP-11 S77°42.590, E161°29.189	No samples collected
PVP-12 S77°42.553, E161°29.636	No samples collected
PVP-13 S77°42.347, E161°30.153	No samples collected
PVP-14 S77°42.307, E161°30.414	No samples collected
PVP-15 S77°42.293, E161°30.327	No samples collected
VV1-RB S 77°22.114', E162°12.454'	500g soil sample
VV-C1 S 77°22.250', E162°12.330'	500g soil sample
VV-C2 S 77°22.130', E162°13.720'	500g soil sample
VV-C3 S 77°22.323', E162°10.713'	500g soil sample
VV-C4 S 77°22.528', E162°08.555'	500g soil sample
LB-1 S 77°22.533', E161°54.803'	500g soil sample
LB-2 S 77°22.499', E161°55.859'	500g soil sample
LVG-1 S 77°22.087', E162°17.470'	500g soil sample
LVG-2 S 77°22.326', E162°18.341'	500g soil sample
Various locations in Victoria Valley	40 hand samples of surface lithology, ≈20 kg

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