ISSN 0375 8192

February 2004

Antarctic Data Series No 24

A COMPILATION OF TEXTURAL DATA FOR MODERN AND ANCIENT SEDIMENTS IN THE MCMURDO SOUND AREA, ANTARCTICA

G.B. Dunbar and P.J. Barrett

ANTARCTIC RESEARCH CENTRE
in association with the

SCHOOL OF EARTH SCIENCES
Te Kura Tātai Aro Whenua

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

Antarctic Data Series No. 24
A Publication of the Antarctic Research Centre:
Victoria University of Wellington
PO Box 600, Wellington, New Zealand

This publication is available in pdf format at our ftp site.
ftp://ftp.geo.vuw.ac.nz/ARC/

Contents

List of Figures

List of Tables

List of Appendices

**Note:: DVDP – Dry Valley Drilling Project*
MSSTS - McMurdo Sound Stratigraphic and Tectonic Studies
CIROS - Cenozoic Investigations in the Western Ross Sea
CRP- Cape Roberts Project

This report and data available electronically at ftp://ftp.geo.vuw.ac.nz/ARC

Abstract

This report presents the data from grain size analyses of almost 1000 samples from the McMurdo Sound area, Antarctica. Some represent present day sedimentary environments and reflect modern transport processes, but most come from a succession of drilling projects, and represent a range of depositional environments both onshore and offshore over the last 35 million years.

Most of the data were obtained using sieves for the sand fraction and either pipette (to 1976) or Sedigraph Particle Size Analyzer subsequently for the mud fraction. Analyses from smaller and more closely spaced samples from two of the Cape Roberts drill cores are also presented.

The data are presented as a series of tables with sample ID, location and other relevant information, along with the size frequency percent in each 0.5 phi class (or 0.3 phi in the case of laser data) in EXCEL 4.0. These are available, along with a copy of the report itself, in digital form at ftp://ftp.geo.vuw.ac.nz/ARC.

Introduction

Early Victoria University of Wellington Antarctic expeditions (VUWAE 1-16) from 1957 to the late 1960's concentrated on geological mapping in the McMurdo Dry Valleys (MDV), the Beacon Sandstone capping the mountains at the head of the MDV and studying the Dry Valleys lakes (Clark, 1967). In the early 1970's, though, attention turned to the history of the Antarctic ice sheet through the development of the multi-national Dry Valleys Drilling Project from 1970-74 (McGinnis, 1981) and the cruise of the deep-sea drilling ship Glomar Challenger in the Ross Sea (DSDP Leg 28, Hayes and Frakes, 1975). This called for a better understanding of present day sedimentary processes as a basis for interpreting the past depositional record, and this has been achieved through a series of VUW student and staff projects and theses on various aspects of stratigraphy and sedimentation of sediments in the McMurdo Sound area.

These studies have invariably included analysis of sediment samples for their size frequency distribution. This is the most basic aspect of a clastic sediment, and carries a great deal of information on transport history and depositional process(es), especially when interpreted in the context of their stratigraphic and geographic setting. Individual analyses have limited value, but patterns in suites of samples can reveal a great deal about processes (wind transport, water-sorting, wave-grading, ice rafting, subglacial deposition) both spatially and through time. A summary of the early work on sedimentary processes in McMurdo Sound can be found in Barrett et al., (1983).

While an updated review of modern and ancient sedimentary processes in the McMurdo Sound area has yet to be written, we thought it useful to make available the existing body of grain size data carefully collected through work in the VUW Sedimentology Laboratory over the last 3 decades. They represent samples of sediments transported and deposited by wind, ice and ocean currents both onshore and offshore.

We have also included a substantial body of data generated by several multi-national drilling projects, beginning with the Dry Valley Drilling projects and concluding with data from the Cape Roberts Project (CRP) in the late 1990's. The availability of a laser particle size analyzer during the CRP allowed high-resolution grain size analysis of selected sections of the drill core to be carried out. These data complemented the more traditional sieve measurements helped define sedimentary cycles subsequently published by Naish et al. (2001). The location of each suite of data is shown in Figure 1, and in Table 1 reference made to information on sample collection, and where possible the primary source.

Table 1. Descriptive outline of datasets presented as Appendices to this report (and on CD-ROM).

A. Data processed by sieve and Sedigraph (apart from Powell, 1976, whose mud-size analyses were carried out by pipette).

Datasets	DESCRIPTION	APPENDIX - SOURCE*
MM-1 to-6	Sediments from Winterquarters Bay, McMurdo Station	Appendix 1 – Powell, 1976 (RDP)
80-1 to 81-18 83-01 to 83-31	Sea floor sediments from McMurdo Sound and Granite Harbour	Appendix 1 – Ward, 1984 (BLW)
81-12 to 81-17 82-1 to 82-3 83-01 to 83-86+ 84-1 to 84-berg	Sediments from Granite Harbour, including sea floor cores, suspended sediment, basal glacial debris, super-glacial sediment	Appendix 1- Macpherson, 1987 (AJM)
85-1-2 to 85-8-1	Sea floor off Ferrar Glacier snout	Appendix 1 – Kelly, 1986 (DK)
87-1-1 to 87-8-4	Sea floor sediments from a series of transects along the Victoria Land coast	Appendix 1 – Pyne and Ward. 1988 (ARP1)
NH 31 to NH 42	Sea floor sediment from New Harbour	Appendix 1 – Powell, 1976 (RDP)
NH 50 to NH72, ITL, BP, FG, SMS	Windblown sediment on sea ice off New Harbour, sea floor and beach samples, iceberg debris	Appendix 1 – Bentley, 1979 (BEN)
SM	Englacial and surficial sediments from the "Strand Moraines"	Appendix 1 – Currie, 1986 (PJC)
Y-, TS-, TG-	Outwash stream sediments from Taylor Valley	Appendix 1 – Powell, 1976 (RDP)
DVDP-8-12	Late Miocene-Recent strata from Taylor Valley	Appendix 2 – Powell, 1976 (RDP)
DVDP-15	Plio-Pleistocene strata from the DVDP-15 drill hole off Marble Point	Appendix 2 - Barrett and Treves, 1981 (PB1)
MSSTS-1	Pliocene to late Oligocene sediment samples from the MSSTS-1 drill hole off Marble Point	Appendix 3 – Barrett, 1986 (PB2)
CIROS-2	Plio-Pleistocene strata from the CIROS-2 drill hole in Ferrar Fjord	Appendix 4 – Pyne et al., 1985 (ARP)
CIROS-1	Oligocene and early Miocene strata from the CIROS-1 drill hole off Marble Point	Appendix 5 – Robinson et al., 1987 (PHR)
CRP-1	Early Miocene strata from the CRP-1 drill hole of Cape Roberts	Appendix 6 – DeSantis & Barrett, 1998 (PB3)
CRP-2/2A	Oligocene and early Miocene strata from the CRP2/2A drill hole off Cape Roberts	Appendix 7 – Barrett & Anderson, 2000 (PB4)
CRP-3	Early Oligocene strata from the CRP-3 drill hole off Cape Roberts	Appendix 8 – Barrett, 2001 (PB5)

B. Data processed by laser particle sizer.

CRP-2/2A	High spatial resolution sampling of Oligocene and early Miocene strata from the CRP2/2A drill hole.	Appendix 9 –unpublished
CRP-3	High spatial resolution sampling of the upper 300 m of Early Oligocene strata from the CRP-3 drill hole	Appendix 10 – unpublished

*Note the source reference is abbreviated as a two or three digit code (shown here in brackets) in the appendices.

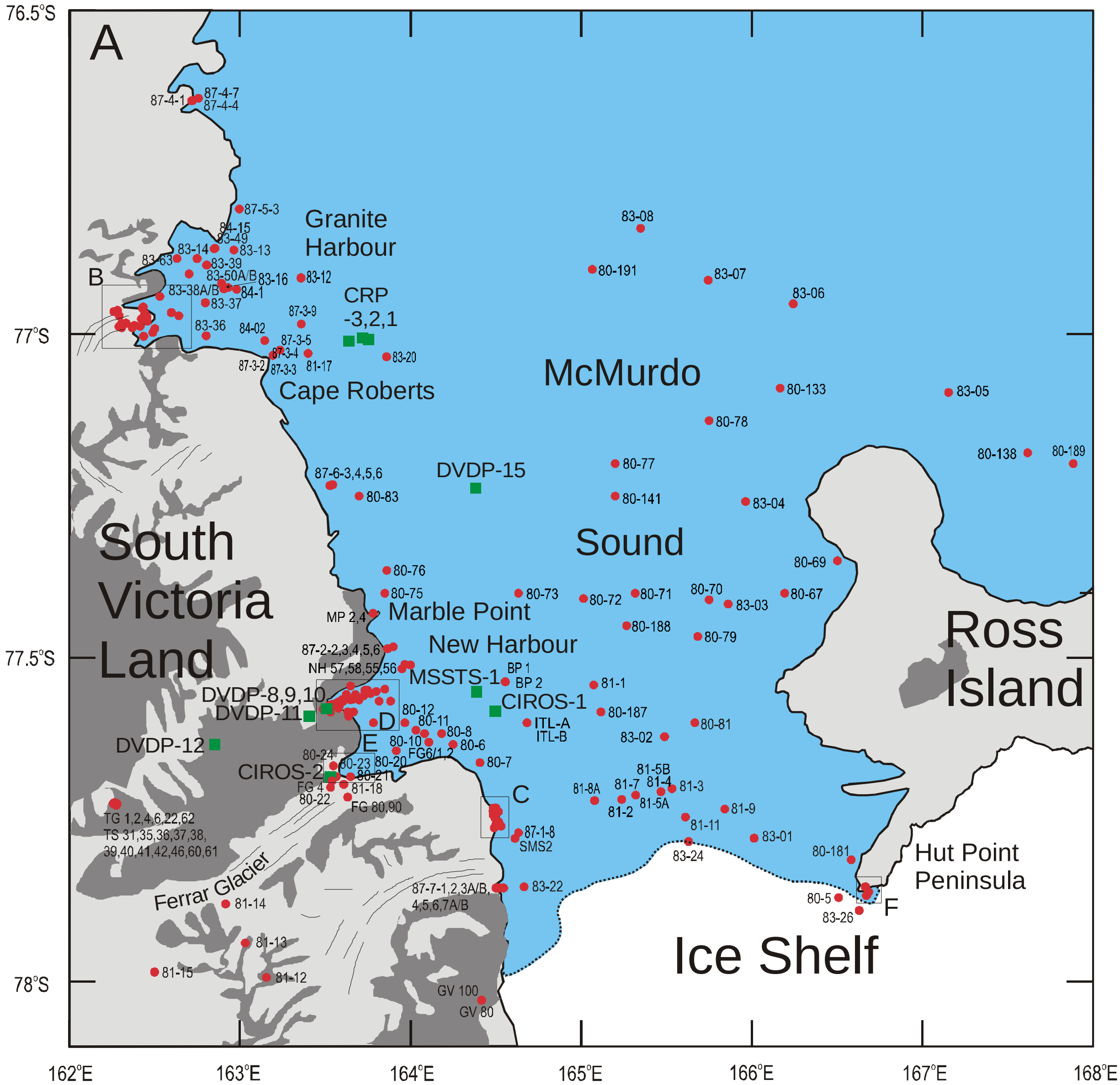

Figure 1 A. **Map of McMurdo Sound showing the location of core and drill hole sites from which samples have been analysed. Insets showing more detailed maps of Granite Harbour, Strand Moraines, New Harbour, Hut Point and Ferrar Fiord are shown as Figures 1B-E on the following page.**

Most of the samples (Appendices 1-8) were analysed for student and staff research projects in the Sedimentology Laboratory, Geology Department (now School of Earth Sciences), at Victoria University of Wellington between 1974 and 2000, either by or supervised by the technical staff in Table 2.

Table 2. Sedimentology technicians and equipment at VUW between 1974 and the present day

Technician	Date	Method
Frank Williams	1974-1984	Sieve/Sedigraph 5000/pipette
Louisa Wolley	1984-1995	Sieve/Sedigraph 5100
John Carter	1995-1996	Sieve/Sedigraph 5100
Jo Anderson	1996-2000	Sieve/Sedigraph 5100
John Carter	2000-	Sieve/Sedigraph 5100

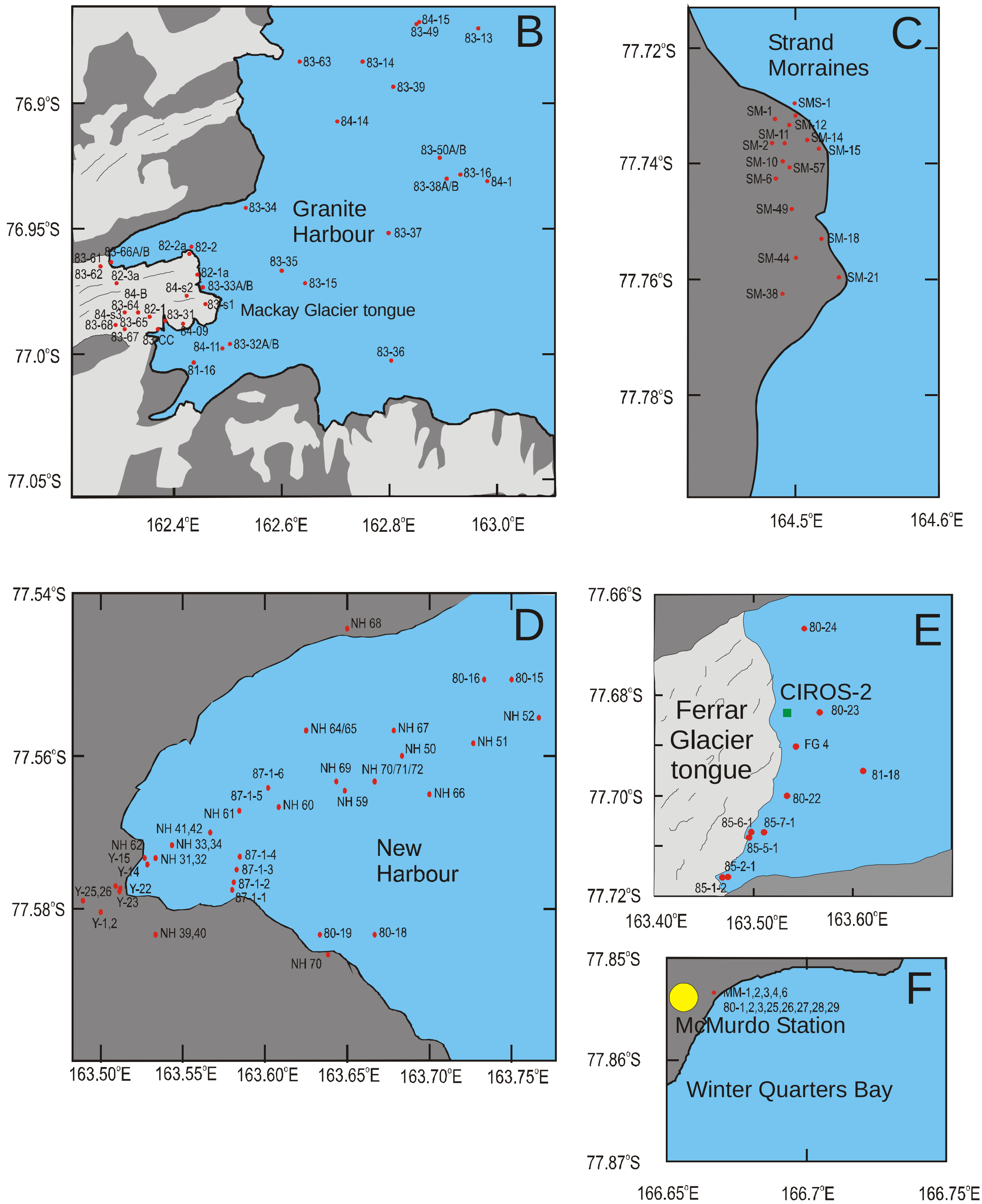

Figure 1. **B-F. Location of samples in B. Granite Harbour, C. Strand Moraines, D. New Harbour, E. Ferrar Glacier Tongue, and F. Winter Quarters Bay. Sea floor samples were taken by core or grab through holes in the fast ice. Samples were also collected from windblown sand on the sea ice and icebergs frozen in. Some bergs were sediment-free, but others near shore acted as traps for particles blown offshore and others still carried volcanic debris on their surface having calved from the "dirty ice" section of the McMurdo Ice Shelf. The Strand Moraines were aptly named as they represent the stranded margin of the McMurdo Ice Shelf stranded from early Holocene times (Kellogg et al., 1996).**

Figure 2. **View southwest across the debris-covered McMurdo Ice Shelf to the foothills of the Royal Society Range, with open water in the foreground and fast ice in the middle distance. Bergs calving from the ice shelf deposit carry super-glacial debris onto a muddy sand sea floor as they drift north.**

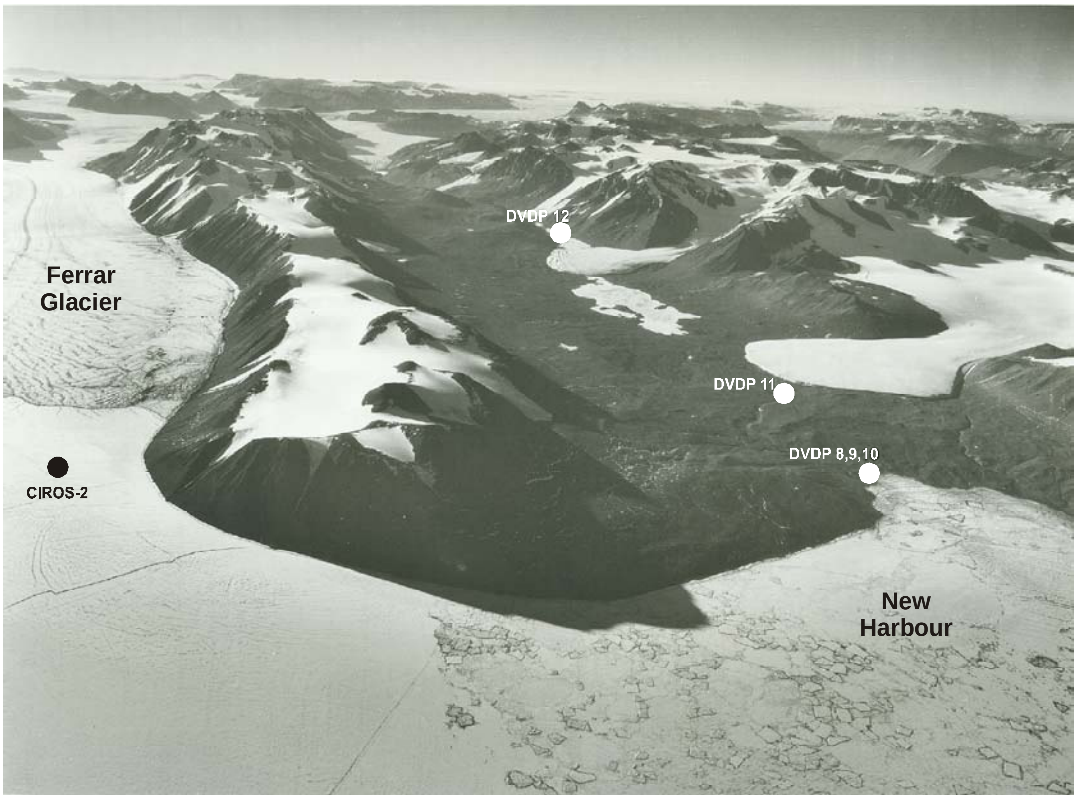

Figure 3. **Aerial photograph showing the locations of Dry Valley Drilling Project Sites 8-12 in lower Taylor Valley and the location of the CIROS-2 drill hole in Ferrar Fiord (after Powell, 1976).**

Figure 4. **View north across New Harbour, showing the sand blown out of Taylor Valley (left) onto the fast sea ice (see also Bentley, 1979).**

Figure 5. **View west over Lake Bonney to the terminus and lower reaches of the Taylor Glacier with Beacon Heights in the distance on the skyline. Samples were collected from basal and englacial debris layers around the terminus and from the meltwater channels on the glacier surface (Powell, 1976, Robinson, 1979). Samples were also taken from streams on either side and from exposures of basal till above the true left margin of the glacier.**

Figure 6. **Ice marginal stream and sediments on true right side of Taylor Glacier terminus. Ice-cored basal debris forms ramp beneath ice cliff.**

***Figure 7*. Looking north across Granite Harbour from Mt England with New Glacier and recent berg in the foreground and Mackay Glacier Tongue in the middle distance. Sea floor sediment is largely biogenic mud. Water depths range down to 900 m. Some samples come from coring through the 3-m-thick sea ice; others come from an ice-breaker cruise in early 1983.**

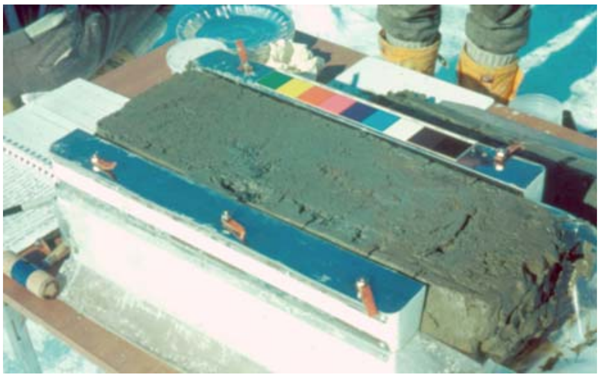

***Figure 8*. Core 20 cm across from the sphincter corer in Granite Harbour. Light brown core top to right.**

***Figure 9*. Sediment trap built by Alex Pyne with assistance from Rob Dunbar, Rice University.**

Figure 10. **Overturned iceberg in a fractured re-entrant of the Mackay Glacier Tongue showing a fragment of the grooved sole of the glacier and a well developed basal debris layer.**

Methods

The process used for disaggregation and analysis

The samples have been collected and analysed with considerable care, and using well established procedures. In particular, it was quickly established that special care had to be taken to ensure that samples were properly disaggregated. The procedure followed for this, and for the subsequent analysis is outlined in the following section.

This publication also includes a suite of samples analysed by laser sizing at the Environmental Sedimentology Laboratory, James Cook University for the Cape Roberts Project (Appendix 9, 10).

Sieve/Sedigraph

All sample preparation for sieve/Sedigraph analysis followed the instructions below:

1. Take about 20 g of sample. If lithified crush between wooden blocks to pass a 2 mm sieve. If sample is carbonate-cemented (check with acid), place sample in labelled beaker with 50 ml of 10% HCl, stir and leave. When the carbonate has dissolved, pour into centrifuge bottle and top up with distilled water, stir and centrifuge. Decant excess liquid and repeat twice to ensure all HCl and salts are removed from sample. Dry for 12+ hours at 40ºC and weigh to 0.01 g.
2. Add 200 ml of 0.1% Calgon to sample & disaggregate in ultrasonic tank for 30 mins or until disaggregated. NB For lithified samples it is essential to check for aggregates under the microscope, and continue stirring if still visible. Some samples may take 20 hours or more to disaggregate.
3. Wash through 60 µm wet sieve, retaining mud fraction in centrifuge container. Once all mud has been washed through the wet sieve, upend the sieve over a labelled beaker, and wash the coarse fraction into it. Decant excess liquid and dry. Then weigh the coarse fraction for dry sieving.
4. Remove water from the mud fraction by centrifuge (10 mins @ 5000 rpm). Pour off liquid. Stir with distilled water and centrifuge again. Repeat. Pour off liquid and transfer mud to beaker, dry in small oven and weigh.
5. Take 1.5 g of the fine fraction, and put in labelled 50 ml beaker for Sedigraph analysis
6. Combine dry sieve and Sedigraph data into a single analysis.

Malvern Laser particle size analyser

All laser particle size analyses were carried out at the Environmental Sedimentology Laboratory at James Cook University, Australia, using a Malvern Instruments Mastersizer-X laser particle size analyser (e.g. Woolfe et al., 1998) fitted with a 300 mm focal length lens.

1. Take a sample between about 0.3 g for mud-sized or ~3 g for sand-sized material (the different sample masses are necessary to obtain a correct laser "obscuration" value of ~20%). If lithified crush between wooden blocks to pass through a 2 mm sieve.
2. Remove organic material with 10% H_2O_2 solution and placed in a heated (60°C) ultrasonic water bath for approximately one hour, or until inspection under binocular microscope showed complete disaggregation to primary depositional grain sizes. Centrifuge and decant supernatant. Wash X 3 in distilled water. Do not allow samples to dry.
3. Test for carbonate by adding a drop of 10% HCl. If a reaction is visible, add futher HCl until effervescence ceases. Centrifuge and wash 3 times with distilled water.
4. Suspend sample in distilled water and sonicate for 10 mins. Wet sieve at 1000 µm to remove coarse sediment immediately prior to analysis.
5. Add suspended sample to instrument mixing chamber.

Sieve/Sedigraph – Laser comparison

In recent years the development of Laser particle size analysis has allowed faster analysis of smaller samples, attributes particularly suitable for analyzing core material. Although the physical principles behind the two techniques are different and resulting differences in the size frequency distribution are to be expected, the question remains "to what extent does the method of measurement affect the interpretation of the resulting data?"

We have compared the sieve/Sedigraph data with laser data percent sand from the upper section of the CRP2/2A drill core (Fig. 11) and the size frequency distribution for six samples from the same drill core (Fig. 12). The samples cover a range of sizes from well-sorted sand to poorly sorted mud.

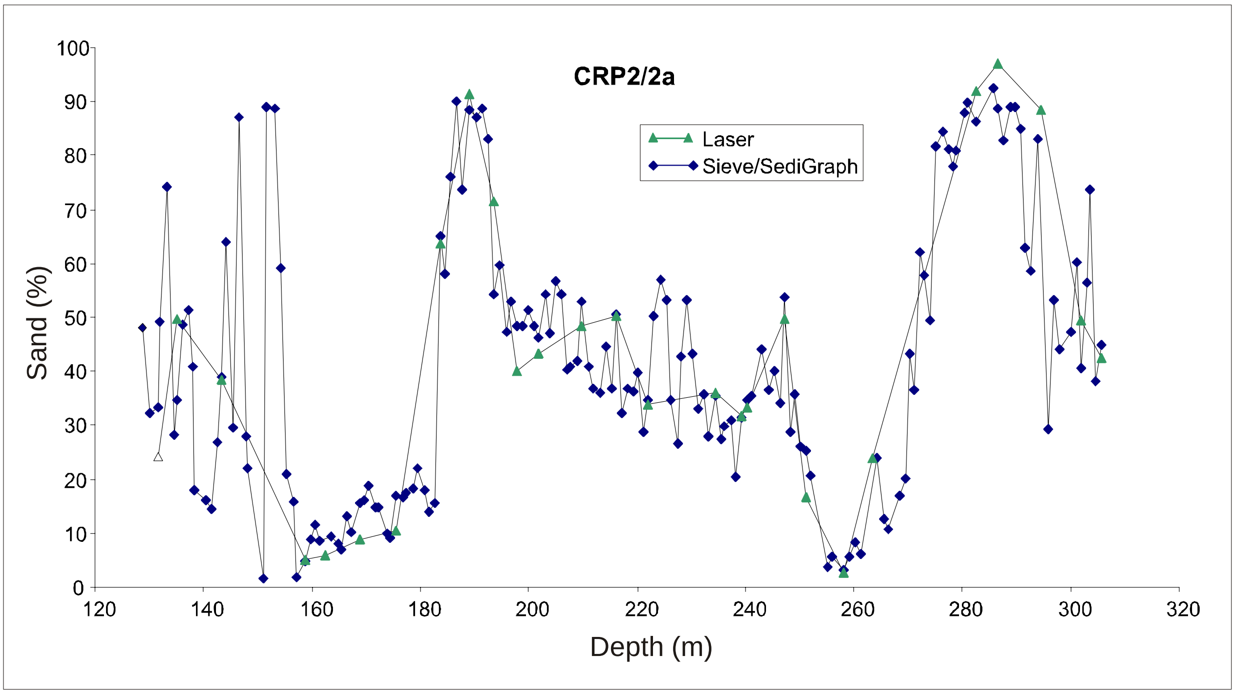

***Figure 11*. Comparison of percent sand as estimated by Malvern Laser particle sizer and sieve/ Sedigraph methods.**

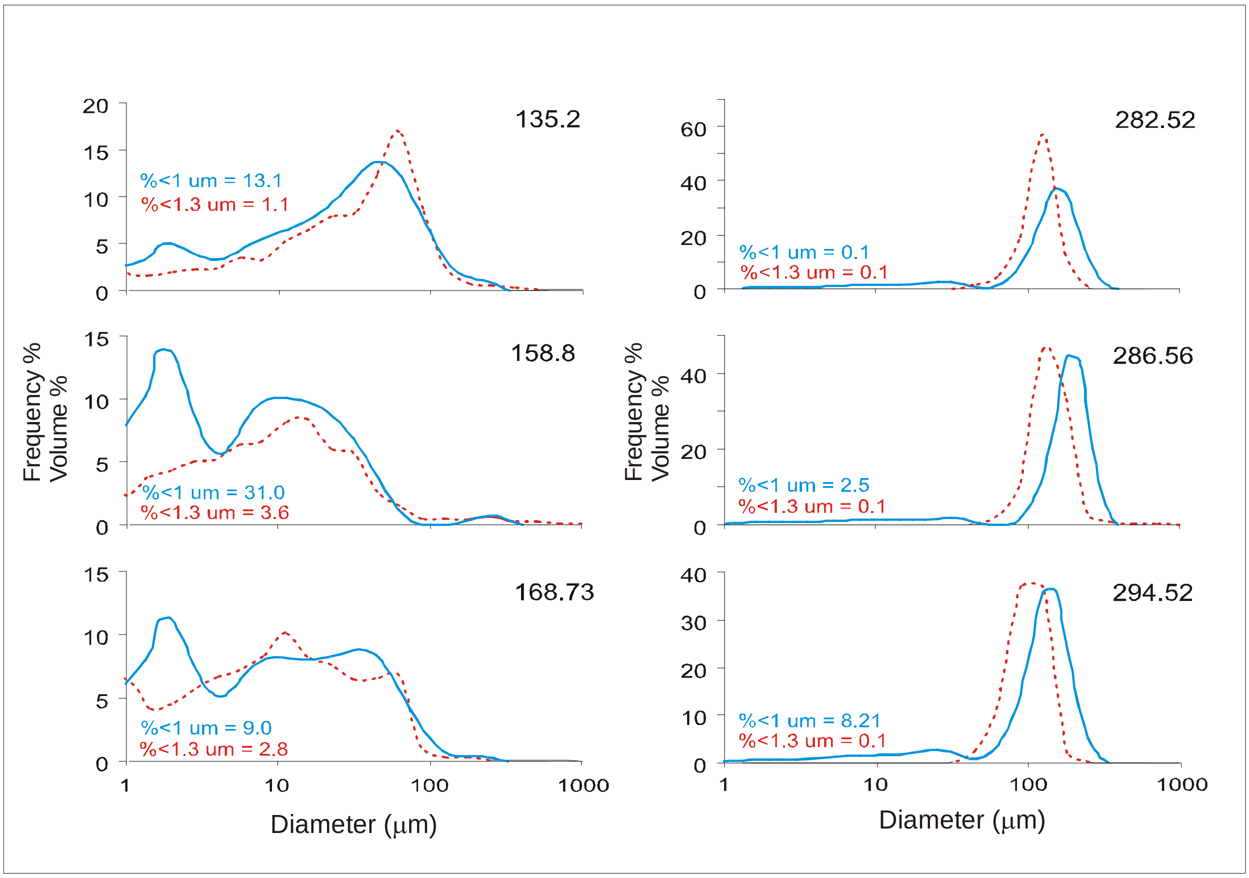

***Figure 12*. Comparison of size-frequency data for samples from CRP-2A drill core, measured by both sieve/Sedigraph and Malvern Laser. Sieve/Sedigraph data are dashed in red.**

Although the frequency curves are similar overall, there are clear differences, particularly for material finer than 10 μm. For laser analysed samples with a significant fine fraction there is a prominent mode at 2.2 μm. Experience shows this mode is an instrumental artifact which is caused by the presence of sample material finer than the effective lower measurement limit of the lens used. Although the actual frequency distribution is spurious, the area under the mode is approximately proportional to the amount of material finer than 10 μm. There are also smaller differences observed for modal sizes in the coarse fraction that are most likely due to deviations in particle shape from the modeled sphere in the Malvern Laser software.

Dataset description

The appendices contain results from sea floor samples (by grab and corer), sediment traps, sediment in icebergs, sand blown by the wind onto sea ice and glaciers, and a range of glacial, fluvial and beach sediment from Taylor Valley. Information on the location and setting of each sample, along with the primary source of the data is given in simple coded form that is explained in Table 3.

Table 3. Key to abbreviations used in appendices.

SAMPLE/CORE #	Identifying code for sample/core - for cores add downcore depth
WATER DEPTH	Depth to sea floor of core in meters – blank for terrestrial samples
CORE DEPTH	Depth from which sample was taken down core in cm
LAT	Latitude in decimal degrees (South is negative)
LONG	Longitude in decimal degrees (West is negative)
SAMPLER	Sampling method used – see notes below
SITUATION	Geological/glaciological setting from which samples were taken - see notes below
SIZING TECHNIQUE	Method of analysis
REFERENCE	Abbreviated (2-4 character code) reference to original data. The abbreviations are related to the full reference in the reference list on pages 16 & 17.

Codes for sampling modern sediments	*Codes for situation of sampled sediment*
SC - sphincter corer	SF – sea floor sediment
ST – sediment trap in water column	BSF – sediment from below the sea floor
SG – Shipek Grab	BG – basal glacial sediment
HC – collected by hand	SG – super-glacial sediment
RC – rotary corer	EN – englacial sediment
	BT – basal till deposited on land by former glacier
	IB – iceberg debris (basal or super-glacial)
	AE – sediment blown onto sea or glacier ice
	IW - windblown sediment trapped on iceberg
	WC – sediment suspended in water column
	DC – drill core
	BCH – beach sand (but mud in hollow for Y22)
	STM – stream bed sand (mud drapes for TS31 & 35)

Data generated by sieve and/or Sedigraph are presented in phi (ϕ) classes with the lower limit and mid-point given for each class. Material finer than 10.0 ϕ is classified as "REST". To keep all the appendices consistent (to make digital reformatting of the data easier should it be desired) some ϕ classes contain no data in some appendices. Data generated by Malvern laser are presented slightly differently (due to differences in the format of the original data). The upper and lower limits for each class are given in microns. Note that particle size increases from left to right, as opposed to right to left for the sieve/Sedigraph data. Original references are abbreviated as two, three or four character codes that are explained in table 1, and also in the reference section. The data are also available in Microsoft Excel format at ftp://ftp.geo.vuw.ac.nz/ARC.

Acknowledgements

VUW has been fortunate in having throughout this period a well-equipped laboratory, and competent and committed technicians who maintained and advised on the use of the equipment and carried out many of the analyses (especially for the CIROS and Cape Roberts Project sieve-Sedigraph samples). Frank Williams deserves special mention for his work in replication of samples as we made the transition from the very time-consuming pipette analysis to the relative ease and speed of the Sedigraph. This collection of results is a tribute to their efforts.

We are also grateful to Professor Bob Clark, Head of the Geology Department from 1954 to 1984, who included space and equipment for a Sedimentology Laboratory in the new Cotton Building, which opened in 1978. The laboratory continues in undiminished activity for both teaching and research.

References for context and data

AJM
MacPherson, A.J. 1987. Glaciological, oceanographic and sedimentological data from Mackay Glacier and Granite Harbour Antarctica. Geology Board of Studies, Publication #1 (Antarctic Data Series #12). 81p.

ARP
Pyne, A.R., Robinson, P.H., Barrett, P.J., 1985. CIROS 2 core log, description, photographs and grain size analysis, Ferrar Fjord, Antarctica. Antarctic Research Centre, Research School of Earth Sciences, Victoria University of Wellington. Antarctic Data Series # 11. 81p.

ARP1
Pyne, A.R., and Ward, B.L, 1988. Immediate Report of Victoria University of Wellington Antarctic Expedition 32 (1987/8). Unpublished Report, Victoria University of Wellington. 40 p.

BEN
Bentley, P.N., 1979. Characteristics and distrubtion of wind blown sediment, Western McMurdo Sound, Antarctica. Unpublished B.Sc. Hons. Thesis. Victoria University of Wellington. 46p.

BLW
Ward, B. L. 1984. Distribution of modern benthic foraminifera of McMurdo Sound, Antarctica. Unpublished PhD. Thesis. Victoria University of Wellington. 211 p. and Ward, B.L. unpublished data.

DK
Kelley, D.N. 1986. Modern sedimentation in Ferrar Fjord, Antarctica. Unpublished B Sc. Hons. Thesis, Victoria University of Wellington. 96 pp.

PB1
Barrett, P.J. and Treves, S.B. 1981. Sedimentology and petrology of core from DVDP 15, western McMurdo Sound. American Geophysical Union Antarctic Research Series, 33, 281-314.

PB2
Barrett, P.J., 1986. Sediment texture. In. Antarctic Cenozoic history from the MSSTS-1 drillhole, McMurdo Sound (Barrett, P.J. Ed.). Science Information Publishing Centre, Dept. of Scientific and Industrial Research, Bulletin 237 p.53-67

PB3
De Santis, L. and Barrett, P.J., 1998. Grain-size analysis of samples from CRP-1. Terra Antartica 5, 375-382.

PB4
Barrett, P.J. and Anderson, J., 2000. Grain-size analysis of samples from CRP-2/2A, Victoria Land Basin, Antarctica. Terra Antartica 7, 373-378

PB5
Barrett, P.J., 2001. Grain-size analysis of samples from Cape Roberts core CRP-3, Victoria Land Basin, Antarctica, with inferences about depositional setting and environment. Terra Antartica 8, 245-254.

PHR
Robinson, P.H., Pyne, A.R., Hambrey, M.J., Hall, K.J. and Barrett, P.J. 1987. Core log, photographs and grain size analyses from the CIROS-1 drillhole, Western McMurdo Sound, Antarctica. Antarctic Research Centre, Research School of Earth Sciences, Victoria University of Wellington. Antarctic Data Series # 14. 241p.

PJC
Currie, P.J., 1986. The structure and origin of the Strand Moraines, Antarctica. Unpublished B.Sc. Hons. Thesis. Victoria University of Wellington. 99 p.

RDP
Powell, R.D., 1976. Textural characteristics of some Glacial Sediments in Taylor Valley, Antarctica. Unpublished M.Sc. Thesis. Victoria University of Wellington. 316p.

UNK
Collector of the original sample material unknown.

Other references

Barrett, P.J., Pyne, A.R. and Ward, B.L., 1983, Modern sedimentation in McMurdo Sound, Antarctica. In Oliver, R.L., James, P.R. and Jago, J.B. (eds.), Antarctic Earth Science, Australian Academy of Science, Canberra: 550-554.

Clark, R.H. 1987. The Antarctic Research Programme of Victoria University, 1957-67. Tuatara, 15, 102-115.

Hayes, D.E., Frakes, L.A. et al. 1975. Initial Reports of the Deep Sea Drilling Project. Vol. 28, US Government Printer, Washington DC, 1017 p.

Kellogg, T.B., Hughes, T. and Kellogg, D.E. 1996. Late Pleistocene interactions of East and West Antarctic ice flow regimes: evidence from the McMurdo Ice Shelf. Journal of Glaciology, 42, 486-499.

McGinnis, L.D. (ed.) 1981. Dry Valley Drilling Project. American Geophysical Union Antarctic Research Series, 33, 465 p.

Naish, T.R., Woolfe, K.J., Barrett, P.J., Wilson, G.S., Atkins, C., Bohaty, S.M., Bücker, C.J, Claps, M., Davey, F.J, Dunbar, G.B., Dunn, A.G., Fielding, C. R., Florindo, F., Hannah, M.J., Harwood, D.M., Henrys, S.A, Krisseck, L.A, Lavelle, M., van der Meer, J., McIntosh, W.C., Niessen, F., Passchier, S., Powell, R.D., Roberts, A.P., Sagnotti, L., Scherer, R.P., Strong, C.P, Talarico, F., Verosub, K.L., Villa, G., Watkins, D.K., Webb, P.-N., and Wonik, T. (2001) Orbitally induced oscillations in the East Antarctic Ice Sheet at the Oligocene/Miocene boundary. Nature 413: 719-723

Robinson, P.H., 1979. An investigation into the processes of entrainment, transportation and deposition of debris in polar ice, with special reference to the Taylor Glacier, Antarctica. Unpublished Ph.D. Thesis, Victoria University of Wellington. 139p

Woolfe, K.J., Fielding, C.R., Howe, J.A., Lavelle, M.A. and Lally, J.H., 1998. Laser-derived, particle size characteristics of CRP-1. Terra Antartica, 5, 383-391.