PROPOSED DRILLING IN McMURDO SOUND–1979

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***Abstract*:** The purpose of drilling is twofold. We expect to obtain a record of the early history of the East Antarctic Ice Sheet, and to date its initiation in the Ross Sea region. We also hope to relate the offshore sedimentary sequence in McMurdo Sound to the strata cored landward of the Transantarctic Mountain Front and hence gauge the extent of late Cenozoic movement.

The project calls for continuous coring at two sites in western McMurdo Sound to 300 m sub-bottom and in water 150 m deep, using the annual ice as a drilling platform. Drilling would take place between about October 20 and December 10, 1979. At the first site (MSS 1) 22 km southeast of Marble Point, the drill is expected to pass through about 120 m of Plio-Pleistocene basaltic sand and 160 m of Miocene diamictite (glacial debris) before reaching the "pre-glacial" strata. At the second site (MSS 2) in New Harbor, the sequence will probably be entirely glacial and Miocene or possibly older in age. A total of 25 scientists and assistants will be required. The core will be measured, described, photographed and sampled, and then shipped to New Zealand for storage.

1. Background

Two of the outstanding problems in Antarctic earth science are the early history of the East Antarctic Ice Sheet and the history of the Transantarctic Mountains, and they may well be linked. The GLOMAR CHALLENGER made the first major breakthrough in 1973 by recovering cores from the centre of the Ross Sea showing that ice rafting began there 25 m.y. ago and has been going on ever since (HAYES *et al.*, 1975), but whether the floating ice came from East or West Antarctica is still debated. The cores contained little information about the history of the Transantarctic Mountains because the holes were too far offshore, and there is unlikely to be much further information from on land, for no dateable sequences from the key time period (50–10 m.y.) are known to crop out on land in the McMurdo Sound region. The glacial history and the uplift of the mountains are likely to be best recorded in the thick sedimentary sequence seen in seismic profiles along the Transantarctic Mountain Front (NORTHEY *et al.*, 1975). This sequence can be sampled only by drilling.

Seismic profiling by NORTHEY *et al.* (1975) has shown that the relatively shallow waters of western McMurdo Sound are underlain by a thick (>1 km) well stratified

Table 1. Interpretation of velocity profile in McMurdo Sound.

Velocity (km·s⁻¹)	Reflector	Lithology	Comments
	Sea floor	——	
2.1		Basaltic sand	Unit 2 of DVDP 15
	A	~~~~	Unconformity that may correspond to provenance change in Taylor Valley (Fig. 2) and the major unconformity in the Ross Sea (HAYES *et al.*, 1975).
2.1		Till	Fragment of till with foraminifera occurs as inclusion in lava at Cape Royds (BARRETT, unpubl. data)
	C	——	
2.5		Tillite?	Velocity similar to late Oligocene marine tillite at DSDP site 270.
	D	——	
3.2		Calcareous sandstone	Boulders of early Cenozoic calcareous sediment of similar velocity (BARRETT and FROGGATT, 1978) occur in moraine on Black Island and Brown Peninsula.

sequence that dips gently (1–2°) eastward beneath Ross Island, a Plio-Pleistocene basaltic pile (Fig. 1). The sequence is geologically interpreted in Table 1 from a velocity profile obtained from sonobuoy measurements by Dr. F. J. DAVEY, Geophysics Division, DSIR, and from other geological information. The sequence has several prominent reflectors, which persist over many tens of kilometres, and three of these (A, C, D) have been keyed to the velocity profile. The character of the layer above A is known from DVDP 15 (Figs. 1 and 2) which cored down 65 m, the lower 53 of which were well stratified and slightly lithified basaltic sand (BARRETT and TREVES, 1976).

Major problems to be addressed in coring the offshore sequence in western McMurdo Sound are—

1. The time at which glaciation began in East Antarctica.

HAYES *et al.* (1975) have clear evidence of ice-rafting starting in the middle of the Ross Sea 25 m.y. ago, but KENNETT and SHACKLETON (1975) want extensive ice in East Antarctica in the early Oligocene—40 m.y. ago.

2. The tempo of early glacial sedimentation.

Was the glacial regime established slowly building up over several million years, or did it fully develop in a few tens of thousands of years?

3. The change in vegetation.

KEMP and BARRETT (1975) observed that, at DSDP site 270, the disappearance of palynomorphs in the oldest glacial strata was remarkably fast, with no record of transitional cold climate forms. They could offer no explanation.

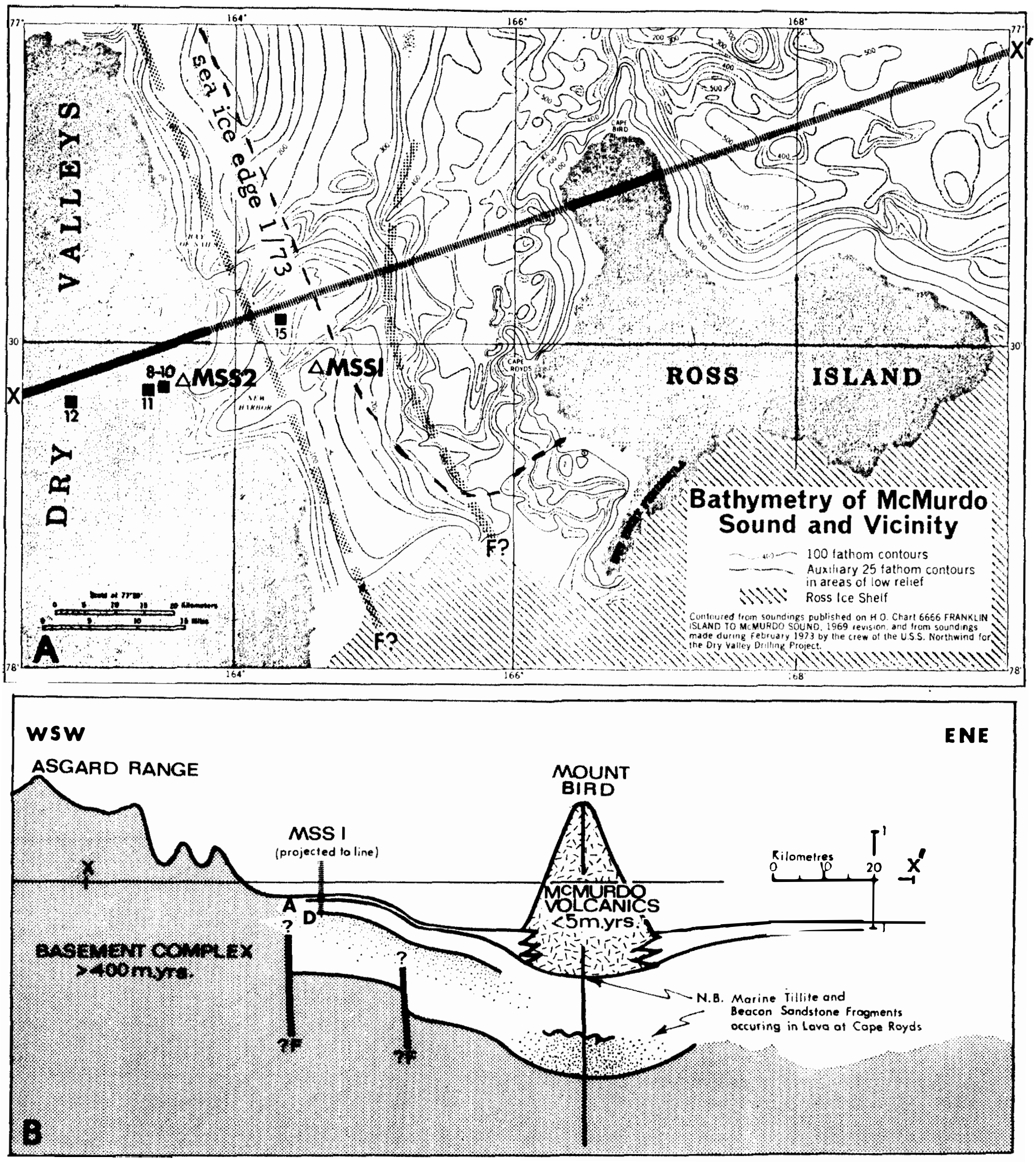

Fig. 1. Map of McMurdo Sound (from MCGINNIS, *1973) showing the location of DVDP and proposed drill sites (A), and a postulated cross-section through McMurdo Sound (B) from limited seismic and other data.*

4. The character and possible extent of the pre-glacial strata.

All data so far come from a few erratic boulders of littoral or very shallow water calcareous sandstone. Such strata cored in place would provide an excellent

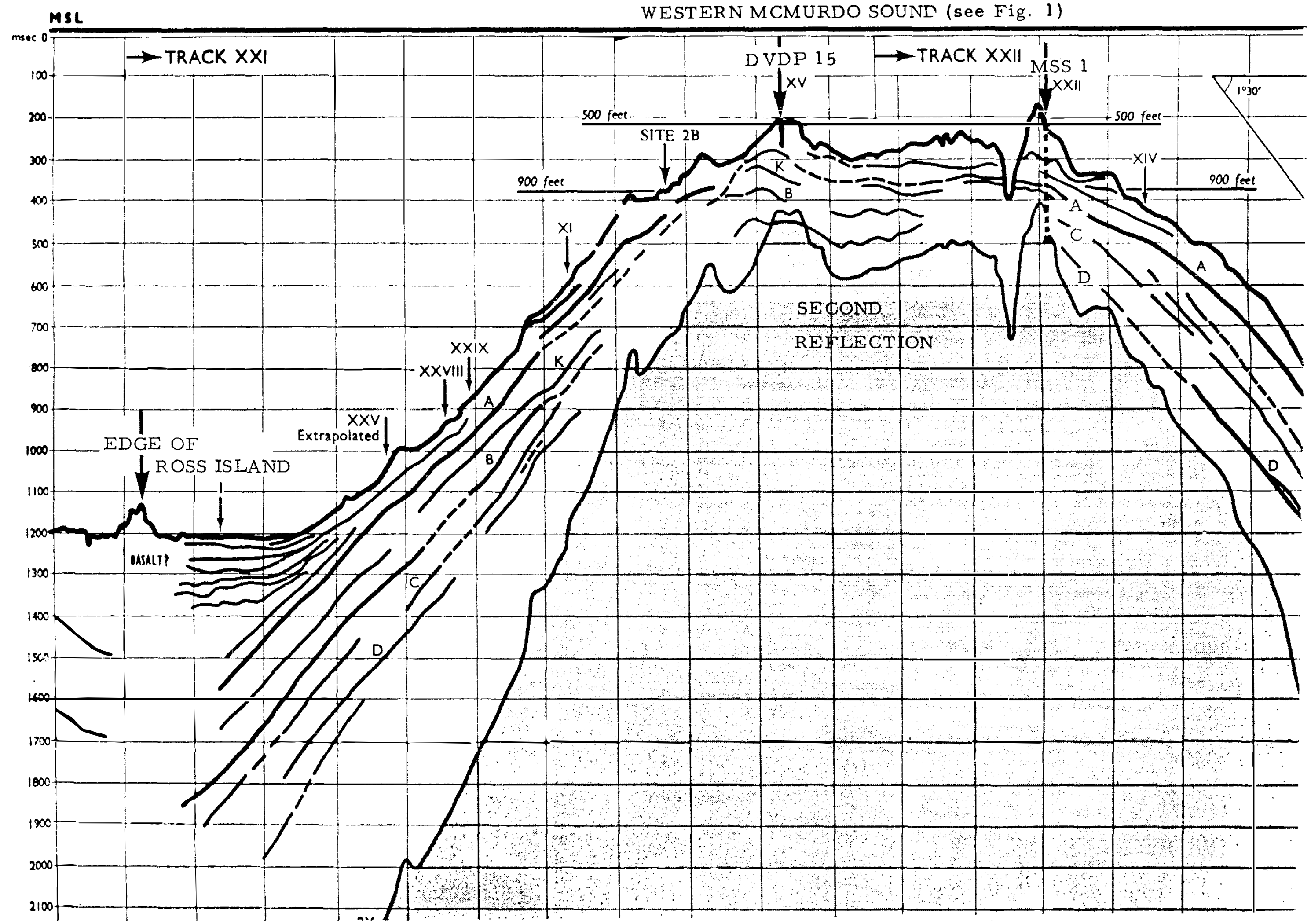

Fig. 2. Interpreted seismic profiles (from NORTHEY *et al., 1975).*

bench mark for vertical tectonic movement over the last 30 million years or so.

Drilling in the Dry Valleys west of McMurdo Sound has substantially increased the time scale of glacial history in the area; it is clear now that it dates back not millions, but tens of millions of years. More is known of lower Taylor Valley, where the longest core was taken (DVDP 11, 320 m). Studies of the drill core thus far have shown that the older part of the core is late Miocene (WEBB and WRENN, 1977; BRADY, 1979; ELSTON *et al.*, 1978), providing a minimum age for the cutting of Taylor Valley. The sediment is marine till with interbedded mudstone, and is believed to be a fjord deposit derived from upper Taylor Valley. The younger strata (Pleistocene) are also mainly of marine glacial origin, but they have a high proportion of basaltic volcanic debris from McMurdo Sound, carried into Taylor Valley by more extensive Ross Sea ice (PORTER and BEGET, 1978). This two fold division into a McMurdo and an upper Taylor provenance appears to be reflec ed in the magnetic intensities reported by ELSTON *et al.* (1978), low intensities characterizing the older upper Taylor sediment, and high intensities the younger McMurdo sediment. If this is the case then a change in provenance should be found in DVDP 12 at 96 m, where ELSTON *et al.* show a change in magnetic intensity. The change in provenance should prove to be a very useful horizon for correlation across the Transantarctic Mountain Front, especially if it does in fact correspond to reflector A, as is suggested in Table 1.

Several of the important problems concerning the Taylor Valley sequence could be attacked by drilling in New Harbor, where the strata from 150 to 450 m below sea level could be cored.

1. The age of the basal strata in Taylor Valley and thus, of Taylor Valley itself.
2. Provenance of the older strata, which would show whether the Ross Ice Shelf expanded in the Miocene, as it has clearly done in the last 3 to 4 m.y.
3. Indications of water depth from faunas or sedimentology would be useful for recording vertical tectonic movement on the Transantarctic Mountain Front.

The two drill sites lie on either side of a physiographic break of continental proportions and significance—the Transantarctic Mountain Front.* Seismic profiles show that the thick offshore sedimentary sequence can be traced without a break, in the upper 300 m at least, from east of Ross Island to within 10 km of the coast, which is cut in metamorphic basement rocks. The difference in basement elevation across the Front is at least 2 km and may be much more. The Front is at present aseismic and shows no sign of recent movement, though the McMurdo

* The TMF as a physiographic feature is most readily defined by the western coast of the Ross Sea, which has the form of two enormous arcs intersecting in the McMurdo Sound region. The form suggests an origin by faulting in a tensional tectonic regime, but in only one place is there proof of a fault origin. At the mouth of the Shackleton Glacier a sliver of Beacon sandstone has been downfaulted 5 km (BARRETT, 1965). The physiographic feature is here assumed to be the result of a zone of normal faulting just seaward of the coast.

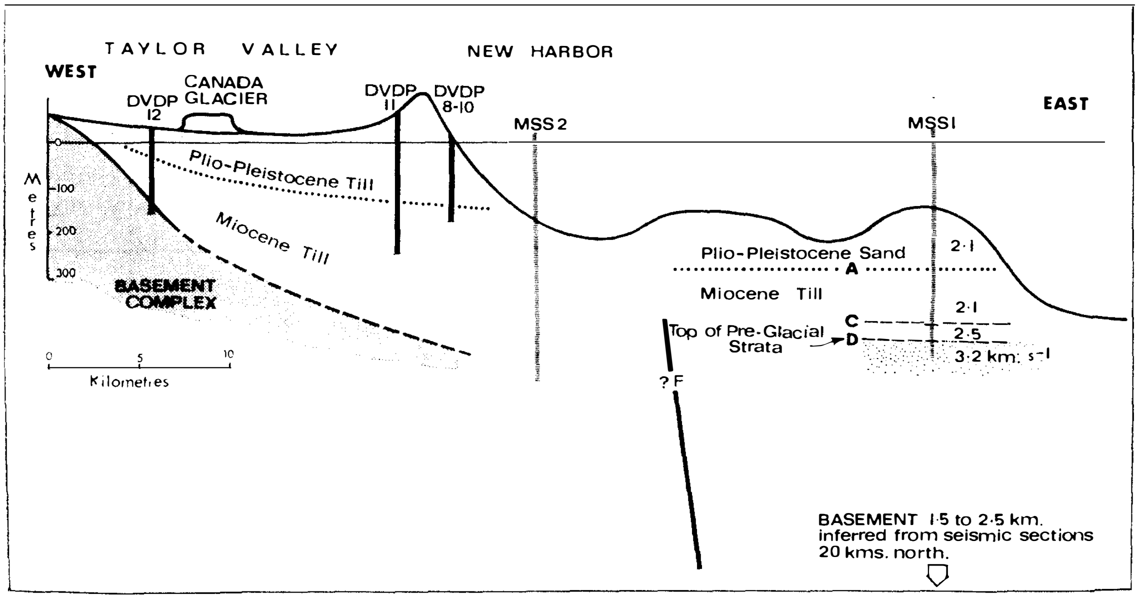

Fig. 3. Postulated cross-section through Lower Taylor Valley, New Harbor and the proposed drill sites.

Sound area has unusually high heat flow measurement values (DECKER, 1978). An important part of the project will be locating an older reference surface, such as the 4–5 m.y. break in Taylor Valley (corresponding to the change from Taylor to McMurdo provenance, Fig. 3), so that movement across the Front in the last 5 m.y. can be gauged. The interpretation in Fig. 3, suggests a vertical movement of about 100 m, but is extremely speculative.

2. Drill Site Selection and Limitations of Equipment

Location of the two drill sites has been dictated largely by three factors:

1. Capability of the drilling rig,
2. Extent of the seismic survey,
3. Extent of the sea ice, which is the drilling platform.

The rig was designed for drilling on land, and has been adapted to use the sea ice as a platform. According to Mr. HOFFMAN, drilling superintendent, DSIR, the maximum safe water depth for drilling is around 150 m, and a reasonable expectation for sub-bottom penetration is 300 m. This is just sufficient for the drill to reach the "pre-glacial" strata at MSS 1, if our interpretation of the seismic survey is correct. MSS 1 is, in fact, in the only place on the seismic survey where reflector D can be seen within 300 m of the sea floor and where the water is only 150 m deep.

No seismic data exist for New Harbor and MSS 2. It is assumed here that the fill of Taylor Valley continues to dip very gently eastward, and that by coring at MSS 2 from 150 m to 450 m below sea level, we will encounter the older part of the sequence already cored at DVDP 8–12.

The sea ice in early spring breaks out north into the Ross Sea, leaving a fringe about 15 km wide around McMurdo Sound (Fig. 1). This fringe may last right through to February, or it may begin to move in late November (as with DVDP 15 in 1976). We expect to avoid such problems by leaving the more exposed site in mid-November, and by strengthening the ice at each site (point 5 below).

The following points came from the experience of drilling DVDP 15, and will contribute to the success of further drilling:

1. The sea ice behaves as a set of plates, not as a continuous sheet. It is therefore important that plate boundaries are identified at the drill site, and that the rig is located in the middle of a plate.

2. The tidal movement is at least 1.5 m in western McMurdo Sound, a little larger than expected. The tide compensating system for MSS holes will handle tides of up to 2 m.

3. Small pockets of natural gas are expected, and a gland will be fitted to the casing to control pressures up to twice the hydrostatic pressure. Each core will be analyzed for its gas content as soon as it comes up.

4. Most of DVDP 15 was drilled (quite unexpectably) in friable sand, which is very difficult to core. A special barrel and an improved drilling technique should yield better core faster.

5. The drilling at DVDP 15 ended when radial cracks appeared around the rig. The sea ice at MSS sites will be strengthened by pumping sea water onto the selected plate to freeze and build up the platform.

3. Core Distribution and Publication

It is proposed to make the core material quickly and freely available, though recipients will have to pay for samples to be shipped. Investigators interested in ephemeral properties should arrange for sampling at the drillsite. Although it will not be practical to split the core, it is intended that least half of each core segment will be retained as archive material.

The publication of an initial report is planned. It will include a report on each drillsite similar to that prepared for DVDP 15 (Bull. No. 7) and hopefully also specialist articles. A workshop will be held in early November 1980 in Wellington for contributing scientists to attempt some measure of agreement before the initial report is finalised.

4. Personnel

Any interested scientists are invited to discuss participation either in the field

Table 2. Scientists interested in participating in the project.

Petrology, sea ice behavior	Prof. S. B. TREVES, University of Nebraska
Sedimentology	Dr. P. J. BARRETT, Victoria University of Wellington
	Dr. B. C. MCKELVEY, University of New England
Geochemistry	Dr. T. TORII, Chiba Institute of Technology
	Dr. N. NAKAI, Nagoya University
Paleontology	Mr. H. T. BRADY, Macquarie University
	Dr. H. LING, University of Washington
	Mr. D. WAGHORN, Victoria University of Wellington
	Prof. P. WEBB, Northern Illinois University
Heatflow	Prof. E. DECKER, University of Wyoming
Paleomagnetics	Dr. E. ELSTON, U. S. Geological Survey
Seismic, gravity and magnetic studies	Prof. D. A. CHRISTOFFEL, Victoria University of Wellington
	Prof. L. D. MCGINNIS, Northern Illinois University

programme or for working on samples. Those that have expressed interest so far are listed in Table 2.

Acknowledgments

This proposal is the result of discussion with many people, to whom I am indebted, but its development to this stage has depended to a considerable degree on three in particular; Mr. R. B. THOMSON, Antarctic Division, DSIR, Prof. S. B. TREVES, University of Nebraska, and Prof. R. H. CLARK, Victoria University of Wellington.

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