McMurdo Ice Shelf seismic reflection data and correlation to the AND-1B drill hole

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Summary Surface seismic reflection data from the ANDRILL-MIS Project site surveys are integrated with a regionally extensive McMurdo Sound seismic stratigraphic framework. In addition, these seismic data are correlated to the AND-1B drill hole using vertical seismic profiles acquired during drilling operations (December/January 2006/7). Six regionally interpreted reflectors are identified in core as distinct lithostratigraphic boundaries.

Citation: Hansaraj, D., Henrys, S.A., Naish, T.R., and ANDRILL MIS-Science Team (2007), McMurdo Ice Shelf Seismic Reflection Data and Correlation to the AND-1B drill hole, in Antarctica: A Keystone in a Changing World - Online Proceedings of the 10th ISAES X, edited by A. K. Cooper and C. R. Raymond et al., USGS Open-File Report, Extended Abstract 101, 3 p.

Introduction

On-ice seismic surveys have been conducted on the McMurdo Ice Shelf (MIS) over a number of seasons (Balfour, 2002; Bannister, 1993; Bannister and Naish, 2002; Horgan and Bannister, 2004; Horgan et al., 2003; Horgan et al., 2005) to help locate the optimum site for the ANDRILL-MIS Project drill hole (Fig. 1) and to provide regional context of key stratigraphic horizons targeted by the MIS Project. Seismic surveying on the McMurdo Ice Shelf during November/December 2005 represents the fourth phase of ANDRILL-MIS Project site surveying in the area (Fig. 1) and extends the coverage of all earlier seismic reflection profiles.

Combined, these surveys have been successful in imaging the sedimentary succession below the ice-shelf in southern McMurdo Sound, which can be tied into an extensive database of marine seismic data in the Victoria Land Basin and Ross Sea (Wilson et al., 2004). In addition, vertical seismic profiling (VSP) conducted through the AND-1B borehole provides a link between cored stratigraphy and MIS surface seismic reflection data.

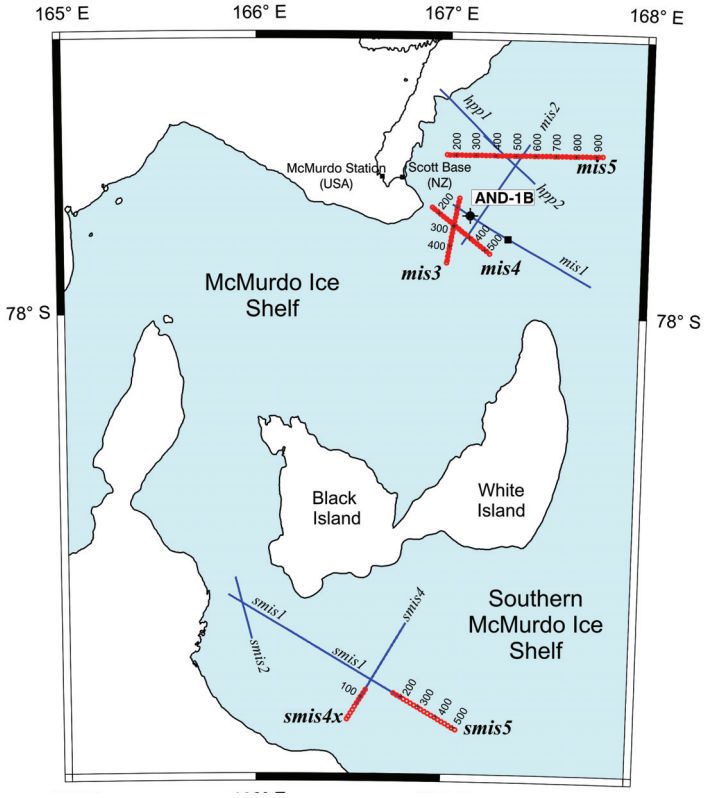

Figure 1. Location of multichannel seismic lines in the vicinity of the MIS drill site. The red lines are seismic data collected during November/December 2005.

Seismic reflection data

Thirty-three kilometers of seismic data were collected on the McMurdo Ice shelf in 2005 using a 48 channel SEISTRONIX recording system with roll-along capacity of 96 channels on the ground. Cables were deployed from towed sledges in split spread configuration (Henrys et al., 2006). All profiles used 40 Hz single geophones spaced 48 m apart. Explosives (3.2 kg) were preloaded in 18 m deep holes and spaced 96 m apart, resulting in 12 fold data. Seismic processing aimed to suppress strong surface-wave noise prevalent on the seismic records. This was achieved through frequency filtering and post-stack deconvolution.

Stacking of the data and a static correction further reduced noise and alleviated the effects of intra-ice and intra-water multiples. Detailed velocity analyses were conducted iteratively, with attention to areas displaying sedimentary layering. The data were also migrated, whereby reflections were moved to their correct positions relative to shot points.

All the seismic lines have been incorporated into a digital interpretation database to provide ease of correlating reflectors at line intersections and to allow consistency of interpretation with available marine data to the north. Stacked seismic data, along MIS-1, used to site the AND-1B drill-hole as well as regionally interpreted

reflectors are shown in Figure 2.

VSP

The VSP in the AND-1B bore hole was undertaken in two phases during drilling and logging operations in December/January 2006/7 (Niessen et al, this volume). During Phase 1, a VSP was successfully completed from the seafloor to 1018 mbsf. This interval included the open-hole section from the base of the HQ drill string (692 mbsf) to the maximum wireline depth of 1934 meters below rig floor (mbrf). The part of the VSP run within casing was found to be contaminated by tube wave noise, and wave trains dominated by arrivals having a velocity of the steel casing (~4000 m/s). During Phase 2, the VSP was repeated over the interval from the seafloor to 446 mbsf. For this experiment, the amount of cable noise was reduced by allowing the hydrophone cable to stand for approximately 15 minutes between steps. The seismic source for both phases of the VSP was provided by repeatedly loading 0.4 kg of explosive into an 18 m deep hole, offset 75 m from the rig floor. Picked first or direct arrival times from the VSP were used to derive a time-depth conversion curve in order to map the seismic reflection section to depth (Fig. 2) and correlate major reflectors to the AND-1B well.

Seismic correlations

The regionally-extensive discontinuity Rg is characterized by truncation of underlying locally-hummocky and lobate, continuous, high-amplitude reflections, and by regional onlap of moderate to high amplitude reflections above. The surface is correlated with top of ~ 60 m-thick interval of Late Miocene volcanic sandstone.

Rh is characterized by truncation of underlying discontinuous to continuous, moderate-amplitude reflections, and regional onlap of high amplitude reflections above. It is correlated with the base of a ~180m-thick interval pyrite-cemented, high-velocity volcanic sandstone and mudstone. Regionally, the Rh reflector correlates with the base of volcanic bodies (Rv) in the Victoria Land Basin north of Ross Island. It is correlated with the base of White Island volcano dated at ~ 7.6 Ma (Alan Cooper, unpublished data).

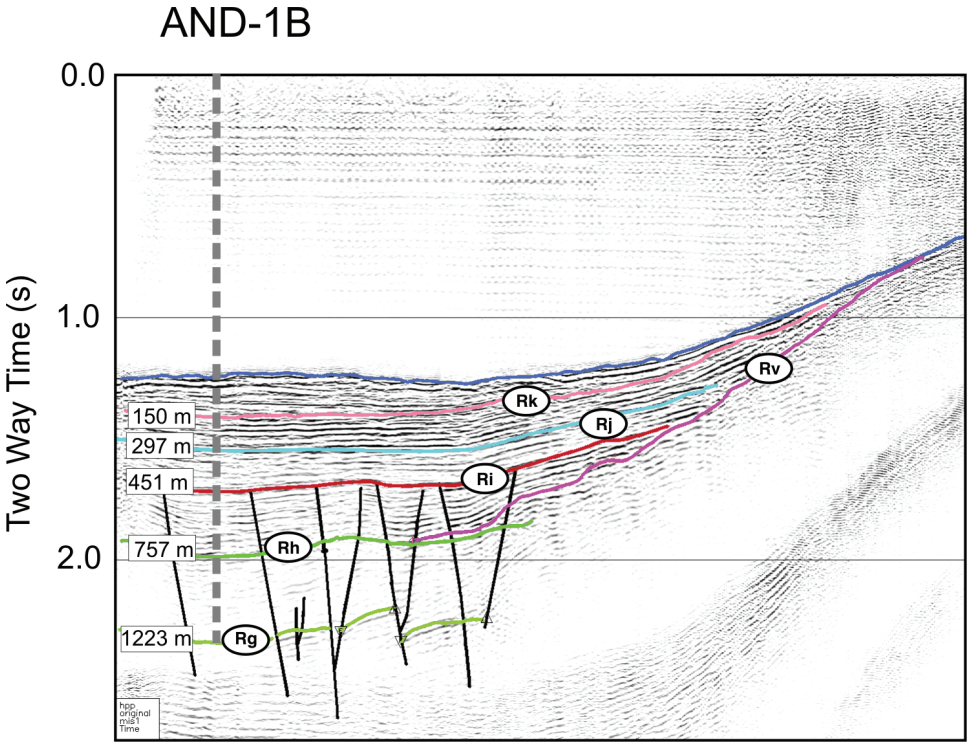

Figure 2. Regionally interpreted reflectors along stacked section of MIS-1 with location of the AND-1B drill-hole.

Ri is marked above by onlap of low-amplitude reflections at the base of a ~90m-thick seismically-opaque interval onto high-amplitude reflections of the underlying unit. Ri corresponds to the base of prograding clinoforms north of Ross Island, and locally marks the base of flexure associated with Ross Island volcanic loading (Horgan et al., 2004). Regionally this reflector has been propagated into the area of CIROS-1 and MSSTS-1, where it can be correlated to the litho and biostratigraphy. In MSSTS-1, the red reflector correlates to about 20 mbsf in the core, close to a sample that contained Pliocene (4.6-4.0 Ma) microfossils and below which was barren of microfossils (Harwood et al., 2006).

Rj is characterized by truncation of underlying moderate-amplitude reflections and onlap by overlying reflections at the base of a ~150m-thick unit of strongly alternating high- and low-amplitude reflections. These dramatic cycles in density and velocity reflect regular alternations between diatomite and diamictite in AND-1B. The turquoise reflector has been correlated into the Erebus Moat area where it represents the oldest horizon that is clearly influenced by flexural loading imposed by construction of the Ross Island volcanic edifices. Rk is characterized by stratal onlap above and marks the top of the cyclic diatomite-diamictite in AND-1B.

These correlations together with those that will result from Southern McMurdo Sound drilling in late 2007 and a refined chronostratigraphy will be mapped into the regional McMurdo Sound seismic data set, and have the potential to provide a finely resolved stratigraphic architecture for the Neogene tectonic and climate history of the Victoria Land Basin.

References

ANDRILL-MIS Science Team [http://www.andrill.org/support/references/appendixc.html].

Balfour, N., 2002, Seismic Reflection and Interpretation on the McMurdo Ice Shelf, Antarctica. [BSc Honours thesis]: Wellington, Victoria University of Wellington.

Bannister, S., 1993, Seismic investigation of the Victoria Land Basin under Ross Island: New Zealand Antarctic Programme 1992/93, Event 101: Institute of Geological & Nuclear Sciences science report, v. 93/14, p. 16 p.

Bannister, S.C., and Naish, T.R., 2002, ANDRILL site investigations, New Harbour and McMurdo Ice Shelf, southern McMurdo Sound, Antarctica: Institute of Geological & Nuclear Sciences science report, v. 2002/01, p. 24 p.

Harwood, D.M., Florindo, F., Levy, R.H., Fielding, C.R., Pekar, S.F., Speece, M.A., SMS Science Team, 2006. ANDRILL Southern McMurdo Sound Scientific Prospectus. ANDRILL Contribution 5, Science Management Office, University of Nebraska-Lincoln, pp.1-29.

Henrys, S.A., Naish, T., Wilson, G., Gorman, A., Clifford, A., L., J., and Blakemore, H., 2006, ANDRILL 2005 Site Investigations/Seismic Surveys, McMurdo and Southern McMurdo Ice Shelf, McMurdo Sound, Antarctica.: GNS Science Report, v. 2006/13, p. 42.

Horgan, H., and Bannister, S.C., 2004, Explosive source seismic experiments from a sea-ice platform, McMurdo Sound 2003: Institute of Geological & Nuclear Sciences science report, v. 2004/15, p. 23 p.

Horgan, H., Bannister, S.C., Naish, T.R., Wilson, G., Pyne, A., Clifford, A., and Finnemore, M., 2003, ANDRILL site investigations/seismic surveys, McMurdo and southern McMurdo Ice Shelf, McMurdo Sound, Antarctica: Institute of Geological & Nuclear Sciences science report, v. 2003/05, p. 47 p.

Horgan, H., Naish, T.R., Bannister, S.C., Balfour, N., and Wilson, G., 2005, Seismic stratigraphy of the Plio-Pleistocene Ross Island flexural moat-fill: a prognosis for ANDRILL Program drilling beneath McMurdo-Ross Ice Shelf: Global and planetary change, v. 45(1-3), p. 83-97.

Niessen, F., R. H. Morin, T. Williams, S. A. Henrys, T. Crosby, D. Hansaraj, D. Magens, A. C. Gebhardt and ANDRILL MIS Science Team (2007), Comprehensive Downhole and Core Physical-Property Measurements at the AND-1B Drillsite, ANDRILL McMurdo Ice Shelf Project, in Antarctica: A Keystone in a Changing World - Online Proceedings of the 10th ISAES X, edited by A. K. Cooper and Raymond C.R. et al., Expanded Abstract, USGS Open-File Report 2007-xxx

Wilson, T.J., Lawver, L.A., Henrys, S.A., Mukasa, S., Horgan, H., Weiderspahn, M., Davis, M., Whittaker, J., Lowe, A., and Watson, M., 2004, Cruise Report NBP0401 19 January to 18 February 2004 - McMurdo Station to McMurdo Station, Ross Sea, Antarctica, Institute of Geological and Nuclear Sciences Science Report 2004/03, p. 85p.