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A Novel Over-Sea-Ice Seismic Reflection Survey in McMurdo Sound, Antarctica

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Abstract - During the austral spring of 2005, approximately 28 km of over-sea-ice seismic reflection data were recorded over McMurdo Sound, Antarctica, in support of the ANtarctic geological DRILLing Program (ANDRILL). The 2005 ANDRILL Southern McMurdo Sound Project (SMS) seismic survey incorporated techniques that improved the quality of over-sea-ice seismic data. Previous over-sea-ice seismic experiments have had limited success because of poor source coupling caused by thin sea ice and source bubble-pulse effects caused by explosive seismic sources placed in the water column. To mitigate these problems, a Generator-Injector (GI) air gun was used as the seismic source. The GI air gun was lowered into the water column through holes drilled through the sea ice. The GI air gun minimized the source bubble effects that had plagued previous over-sea-ice experiments in the Antarctic. A 60-channel seismic snow streamer consisting of vertically oriented gimbaled geophones with 25-m takeout spacing was employed to aid rapid data collection. The 2005 SMS seismic survey produced data that accurately tied into existing single-channel marine seismic data and demonstrated the value of the air-gun/snow-streamer system for future over-sea-ice seismic surveys in the Antarctic.

INTRODUCTION

Over-sea-ice seismic reflection data quality has typically been poor in polar regions. In his discussion on seismic reflection measurements in the Canadian Arctic, Merritt (1973) displays a shot record collected on sea ice that highlights both bubble-pulse and flexural-mode noise trains that interfere with seismic reflections, producing poor stacked sections. Various seismic sources have been tested on Arctic sea ice, but data quality is variable between seasons and also varies between source types and if the sea ice is floating or grounded (Cobb, 1973; Cook, 1973; Mertz, 1981; Proubasta, 1985; Rendleman & Levin, 1990). Previous seismic reflection data collected over sea ice in the Antarctic have produced data of poor quality, with the generation of a bubble pulse being the primary problem (McGinnis et al. 1985; Davy & Alder, 1989; Barrett et al., 2000; Bannister & Naish, 2002). Moreover, placing explosives within the sea-ice column does not produce an effective source because of poor coupling (Horgan & Bannister, 2004).

The bubble pulse is created by the expansion and collapse of gas when a controlled explosive source is used in the water column. Although the amplitude of the bubble pulse decays with time, each expansion and collapse of the air pulse acts as a separate repeating source on a shot record. The bubble-pulse problem is exacerbated by the presence of sea ice at the ocean surface in polar regions. The gas bubbles can not freely escape into the atmosphere, but instead become trapped under the sea ice. Data containing a bubble-pulse signature are difficult to process and often yield final stacked sections that are difficult to interpret (Horgan & Bannister, 2004).

Most over-sea-ice seismic reflection surveys conducted in Antarctica have used explosives as the energy source. Results of a explosive-source test conducted over sea ice in Antarctica showed that the bubble pulse is a problem regardless of shot depth below sea ice and a significant loss of energy is caused if the shot is detonated within the sea-ice column, suggesting that one possible way to mitigate these problems would be to use an alternative energy source (Horgan & Bannister, 2004). In modern marine seismic acquisition, the use of explosives, such as dynamite, as a source has been replaced by the use of air-gun arrays. These air-gun arrays are tuned so that interactions of the multiple air pulses effectively cancel out the bubble pulse (Bailey & Garces, 1988). Single air-gun-source marine seismic surveys typically use a Generator-Injector (GI) technique in which a secondary air pulse is injected into the primary air pulse on a short time delay. The injection of the secondary air pulse dampens the generation of the bubble pulse. Davy & Alder (1989) tested two air-gun sources below the sea ice in Antarctica but