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Seismic and Sonar Investigations Carried out by the British Antarctic Survey in the Southern Ocean

by Robert D. Larter[1]

Marine geoscientists from the British Antarctic Survey BAS) have carried out a wide range of seismic and sonar investigations over the past eighteen years in the sector of the Southern Ocean between 100 °W and 5 °E. Earlier UK seismic investigations in this region were mainly carried out by a research group based at the University of Birmingham, which was absorbed by BAS in mid-1980s.

The main achievements of BAS seismic and sonar investigations have been:

1) to elucidate the tectonic history of a wide sector of the Southern Ocean (e.g., TECTONIC MAP OF THE SCOTIA ARC 1985, LIVERMORE & WOOLLETT 1993, LARTER et al. 1997, CUNNINGHAM et al. 2002);
2) to improve understanding of active tectonic processes (e.g. LIVERMORE et al. 1997, CUNNINGHAM et al. 1998, VANNESTE & LARTER 2002);
3) to contribute to the development of Southern Ocean palaeoceanography (e.g. BARKER et al. 1988, CUNNINGHAM & BARKER 1996, HOWE et al. 1997);
4) to reveal the stratigraphic record of Antarctic glacial history preserved in sediments on the continental margin (e.g. LARTER & BARKER 1989, LARTER & CUNNINGHAM 1993, NITSCHE et al. 2000), and
5) to provide insight into the dynamics of ice that extended across the Antarctic continental shelf during glacial intervals (e.g. PUDSEY et al. 1994, LARTER & VANNESTE 1995, O'COFFAIGH et al. 2002).

The methods employed include multichannel seismic reflection survey, single channel seismic reflection survey, deeptow boomer survey, GLORIA (Geological Long Range Inclined Asdic) side-scan sonar survey, and HAWAII-MR1 swath bathymetry and side-scan sonar survey (Tab. 1). Since the launch of RRS *James Clark Ross* in 1991 all BAS cruises involving seismic and sonar surveys have been carried out on this vessel. In June 2000 a deep-water multibeam echo sounder and parametric sub-bottom profiler were installed on RRS *James Clark Ross* (Kongsberg Simrad EM120 and TOPAS systems). These new sonar systems have already been used extensively on five Southern Ocean cruises and it is likely that multibeam echo sounder surveys will be a major component of most marine geoscience cruises on RRS *James Clark Ross* over the next few years. Source parameters of sonar systems that have been used by BAS are presented in Table 2. Source parameters of air-gun arrays used in seismic surveys are highly variable depending on the number, volume and configuration of air-guns used. Typical air-gun arrays produce signals that are lower frequency (mainly <200 Hz) and less directional than the sonar systems listed in Table 2.

survey type	no. of cruises since 1984	total line-km
Multi-channel seismic	4	11,950
Single-channel seismic	8	25,780
Side-scan sonar (towed)	2	33,110
Multi-beam echo sounder	4	>20,000

Tab. 1: Amount of seismic and sonar data collected in the Southern Ocean by British Antarctic Survey (BAS).

However, most seismic surveys carried out by BAS have involved single air-guns or small air-gun arrays that output lower amplitude signals than the most powerful sonar systems listed in Table 2.

sytem	RMS amplitude (dB re. 1µPa @ 1m)	frequency (kHz)	pulse length (ms)	beam widths* (degrees)
HUNTEC deep-tow boomer	220	0.8-10	0.2	20
GLORIA	†	6.2-6.8	2000	2.5
HAWAII-MR1	228	11-12	1-10	2
EM120 multi-beam	237	11.25-12.75	2-15	1
TOPAS PS 018‡ pri.:	243	15	0.3-5	5
second.:	204	0.5-5		

Tab. 2: Source parameters of sonar systems used in the Southern Ocean by British Antarctic Survey (BAS).
* Beam width is defined as the angle within which the signal level is within 3 dB of the level in the centre of the beam.
† GLORIA amplitude has not been calculated in the units used in this table, but according to MITCHELL & SOMERS (1989) the source power is 4.5 kW and the directivity factor is 160.
‡ The TOPAS PS 018 system transmits primary signals at two frequencies close to 15 kHz that are designed to produce a secondary signal between 0.5-5 kHz as a result of non-linear interaction in the water close to the transducers. Sources of information: HUTCHINS et al. 1976, SIMPKIN 1978, LAUGHTON 1981, ROGNSTAD 1992, pers. comm. 2002, and Kongsberg Simrad product description documents for EM120 and TOPAS PS 018 systems.

[1] British Antarctic Survey, High Cross, Madingley Road, Cambridge CB3 0ET, UK; <r.larter@bas.ac.uk>

Factors that are likely to mitigate any environmental impacts of seismic and sonar surveys include the fact that the highest intensity seismic and acoustic sources are directional to varying extents, and thus only affect a relatively small area at any one time. These kinds of survey are usually carried out at speeds between 9-22 km/hr, and during a survey the ship rarely returns to within 5 km of any point through which it has passed previously. Therefore any point in the ocean is only subject to high intensity signals for a few minutes at most. Moreover, even the most intensively studied parts of the Southern Ocean have been subjected to only a small fraction of the seismic and sonar survey activity that has taken place in parts of the world where offshore hydrocarbons have been exploited.

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