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USGS seismic refraction surveys in the Ross Sea, 1984-1990

By

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USGS SEISMIC REFRACTION SURVEYS IN THE ROSS SEA 1984-1990

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Seismic refraction experiments using sonobuoys were conducted throughout the Ross Sea by the U.S. Geological Survey in February 1984, December/January 1988/1989, February 1989, and January/February 1990. The experiments were conducted aboard three research vessels operated by different organizations (Table 1). Previous sonobuoy studies in the Ross Sea are described by Davey and others (1982, 1983). In 1984, the USGS conducted an MCS survey of the western and central Ross Sea with the R/V S. P. LEE, and recorded 24 sonobuoy stations. The results of the 1984 USGS survey are summarized in Cooper and others (1987b) (Figure 1). In 1988 the USGS deployed sonobuoys in the area of the Central Trough during a survey conducted by the German Federal Institute for Geosciences and Natural Resources (BGR) on their Fifth German Antarctic North Victoria Land Expedition (GANOVEX V) (Figure 2). Results from the 1988 survey are discussed in Cochrane et al. (in press). In 1989 and 1990 the USGS participated in the Osservatorio Geofisico Sperimentale (OGS) IntaliAntartide surveys that covered most of the Ross Sea (Figure 3, 4). A detailed discussion of the ItaliAntartide sonobuoy data is in Childs et al. (1991), Cochrane and Cooper (in press) and Cochrane et al. (in press).

SONOBUOY SYSTEM

Sonobuoys are expendable, floating radio transmitters with a single hydrophone that is deployed to a preset water depth (Figure 5). The sonobuoys used were provided by the U.S. Navy, and consisted of three types: Model 57-A and Model 53-B (400 foot hydrophone depth), and Model 41-B (1000 foot hydrophone depth). The sonobuoy signal is received with a conventional VHF radio receiver, is recorded on analog tape and is displayed with a line-scan recorder (LSR). In 1990, the sonobuoy signal was also recorded digitally on an auxiliary channel of the MCS recording system. Additional information about the data collected on individual cruises is shown in Table 2. Some analog sonobuoy data have been digitized from the analog tapes for redisplay and analysis at the USGS.

Initial interpretations of the data are done onboard ship using analog paper records and analysis techniques (see Childs and Cooper, 1978) that can be used on an IBM compatible personal computer. In the shipboard analysis, velocity gradients were approximated by a series of straight-line segments. More detailed analysis requires an inversion method, such as described by Bullen (1979), or the modeling of sonobuoy results by ray-tracing, as was done by Cooper and others (1987a) and Cochrane et al. (in press), using the technique of McMechan and Mooney (1980).

RESULTS

The sonobuoy station locations are shown in Figures 1 (1984), 2 (1988), 3 (1989), and 4 (1990). The range to which seismic energy was detected varied from 2 to 40 km. Figure 6 shows two examples of sonobuoy records, from stations 98 and 105, and the corresponding near-trace reflection profiles. Sonobuoy 98 was deployed over a proposed drillsite at the western edge of the central Victoria Land Basin, and sonobuoy 105 at the southern edge of the basin. The shipboard results of the refraction analysis are included in the figure.

As noted by several authors, the velocity structure of the Ross Sea is characterized by distinct refraction boundaries at some locations, and by refraction-velocity gradients at others. Velocity gradients result in smoothly increasing first arrivals rather than distinct straight-line refractions. A clear example of a velocity gradient is seen at station 98 where the first arrivals are continous and curved at distances of 3 to 6 km from the sonobuoy (Figure 6). In contrast, the refracted arrivals of station 105 at the equivalent distances from the sonobuoy are characterized by distinct slope breaks (Figure 6). Sequences of distinct linear refractions sometimes separated by travel-time delays are attributed to glacial advance and retreat by Cochrane et al., (in press).

Several sonobuoy profiles have distinct wide-angle reflections at ranges from 20 to 30 km, indicating a reflecting interface at considerable depth. Similar wide-angle reflections were reported by Cooper and others (1987b; Figures 6 and 9). Ray-trace modeling indicated that these reflections probably originate from an acoustic interface at a depth of 16 to 18 km (Cooper and others, 1987b).

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Figure 1 Index maps of the western Ross Sea and Victoria Land basin for sonobuoys deployed in 1984. A. Bathymetry, in meters, from Davey and Cooper (1987b). B. Location of sonobuoy stations. Arrows indicate direction of ship travel and length of arrow (for USGS sonobuoy stations) indicates duration of sonobuoy station. "B" sonobuoy stations are from Davey et al. (1982). "WG" sonobuoy stations are from Davey et al. (1983). "J" sonobuoy stations are from Sato et al. (1984). Other buoys are USGS buoys, see Table 3. Figure modified from Cooper et al. (1987b).

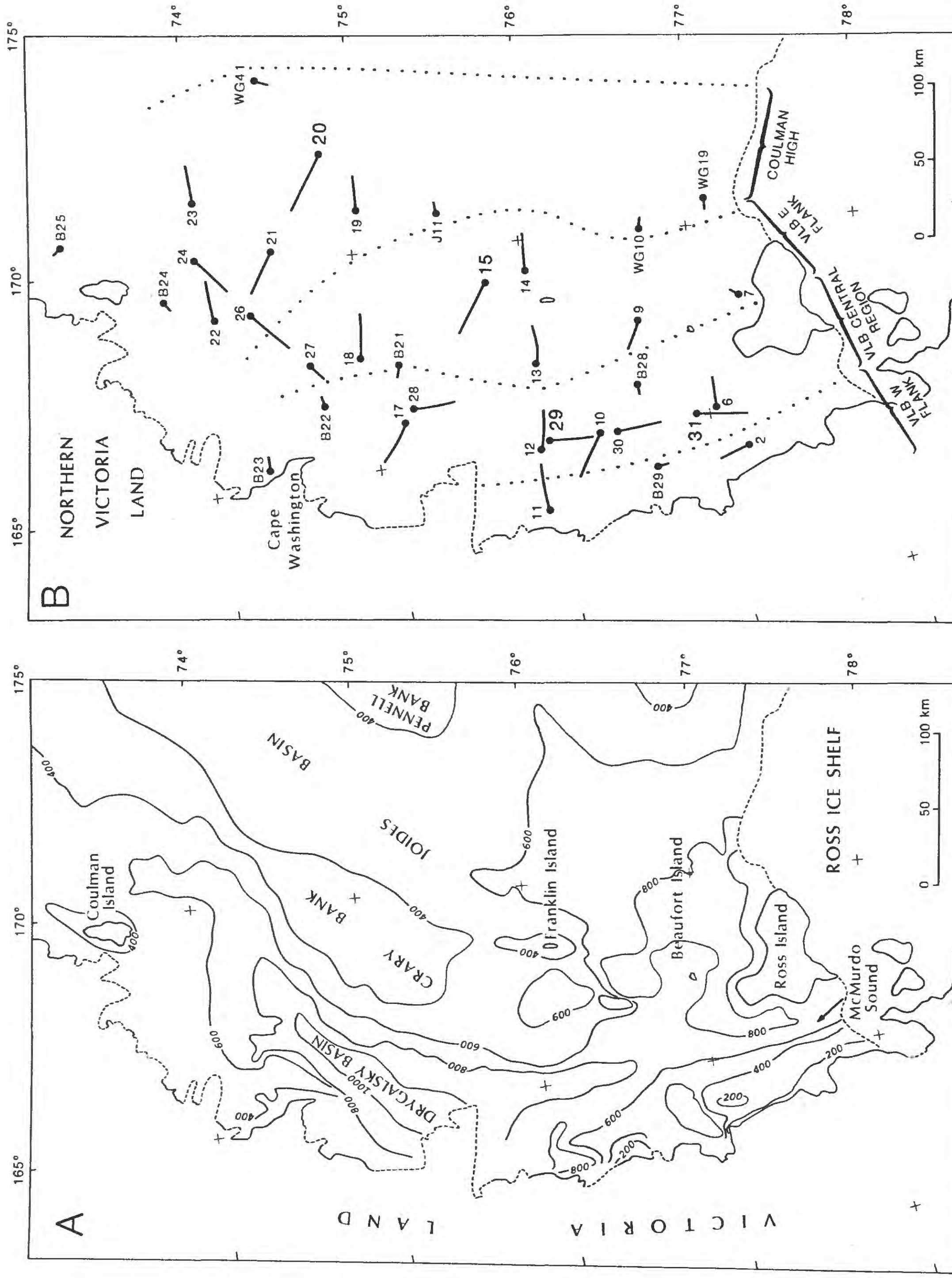

Figure 2 Location map of the Ross Sea, with locations of 1988 sonobuoy stations. General area of the three major sedimentary basins VLB=Victoria Land Basin, CT=Central Trough and EB=Eastern Basin are shown. Arrows indicate the starting position of the sonobuoys and the direction of shooting after deployment. Numbers correspond to those in Table 4.

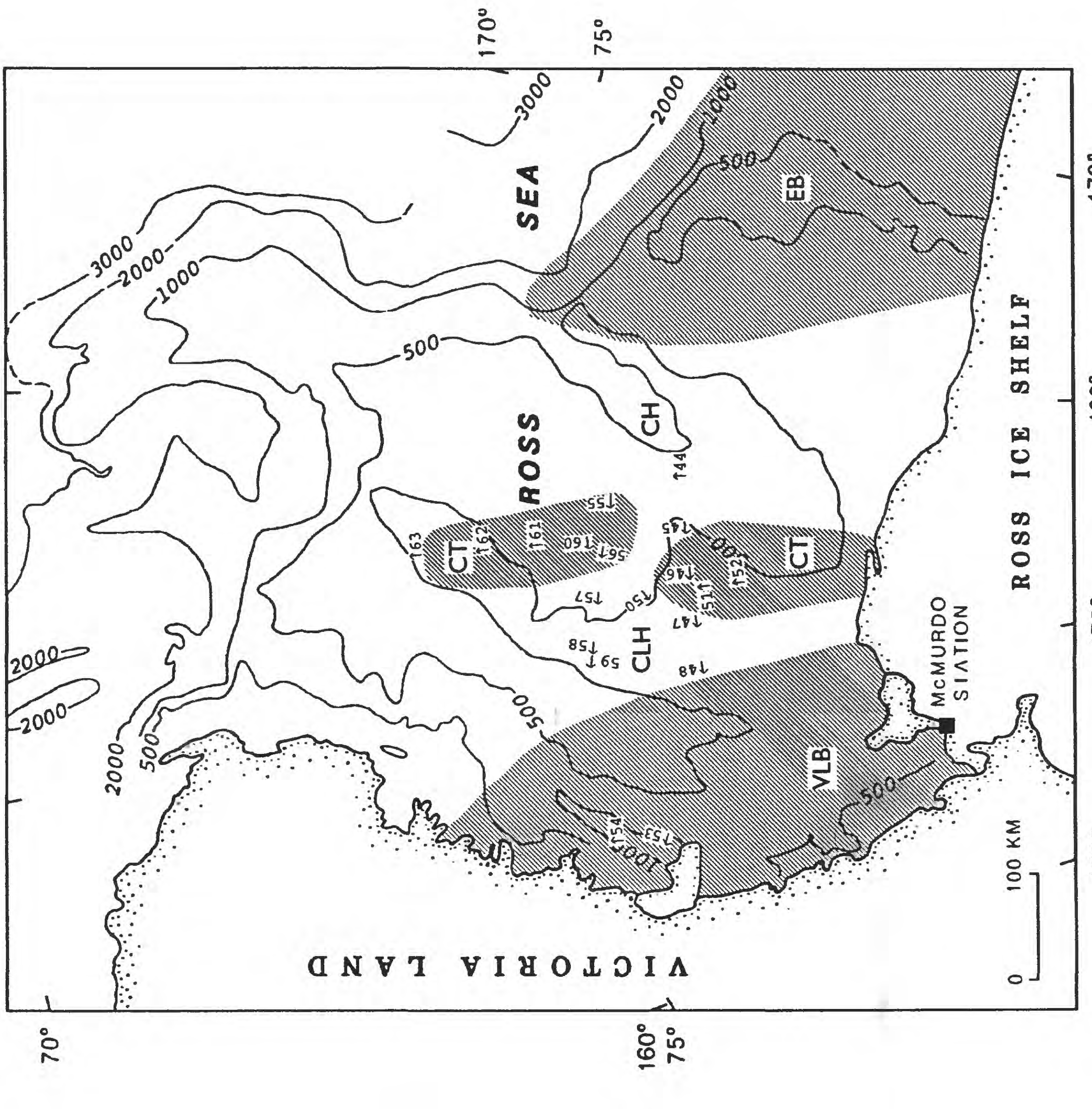

Figure 3 Location map of the Ross Sea, with locations of 1989 sonobuoy stations. Arrow length denotes range of the sonobuoy (see Table 5). Solid dots indicate locations of DSDP drillsites. Also indicated are the locations of the CIROS-1 and MSSTS-1 drillsites. Bathymetry is in meters.

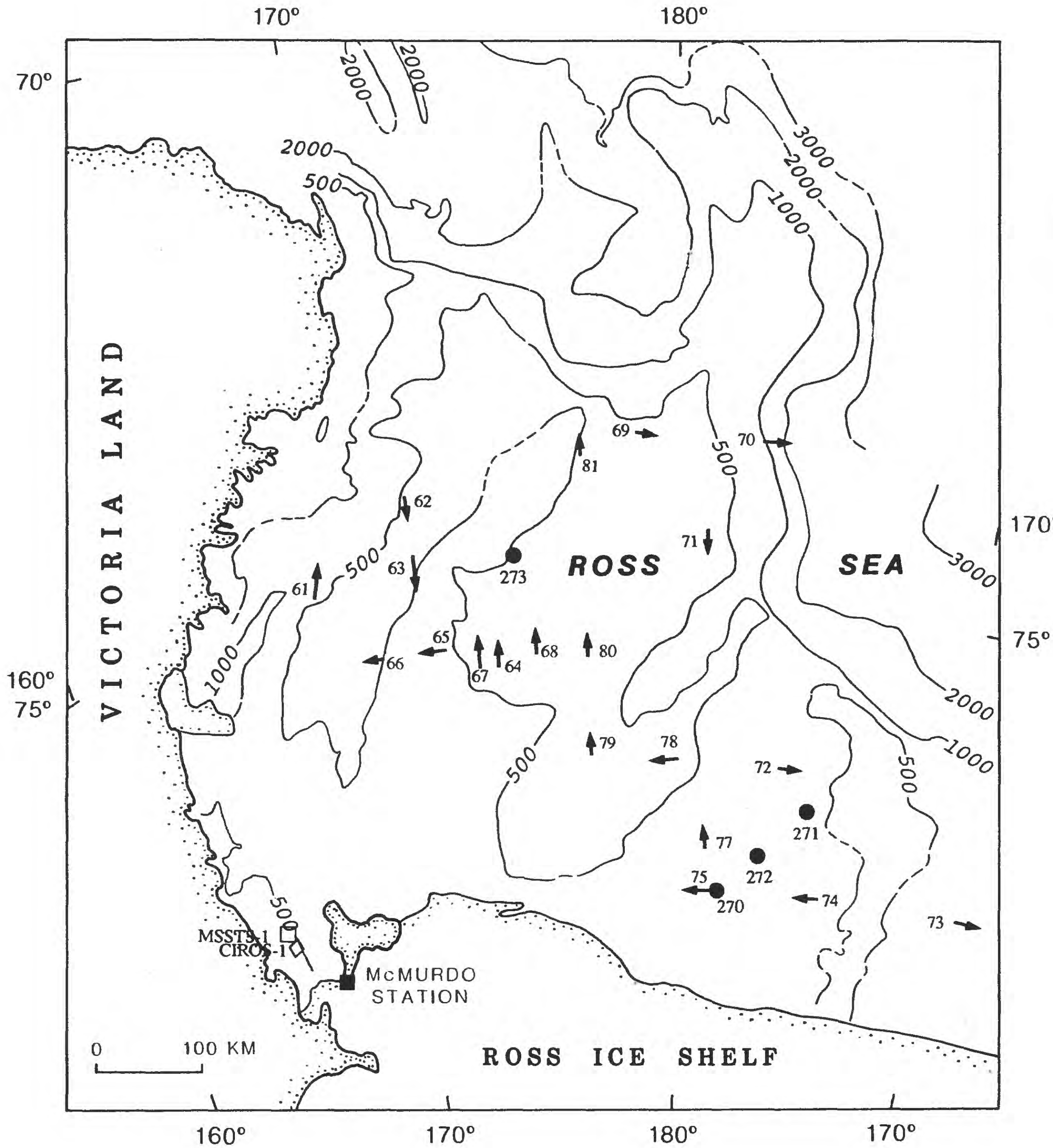

Figure 4 Locations of sonobuoy stations collected in 1990. Arrow length denotes range of the sonobuoy (see Table 6). Figure from Childs et al. (1991).

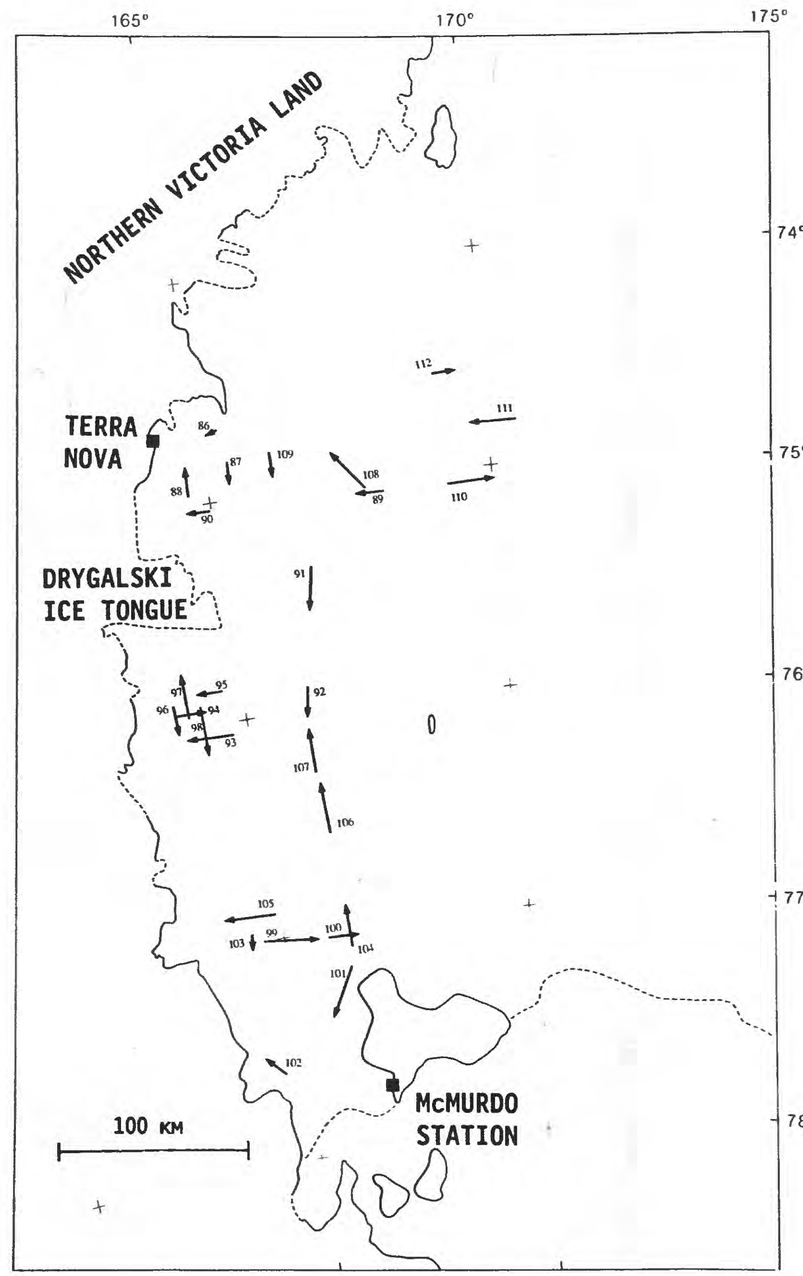

Figure 5 Schematic illustration of sonobuoy data colledtion, with various seismic travel paths indicated. Only one interface (the seafloor) is shown. Figure from Childs and Cooper (1978).

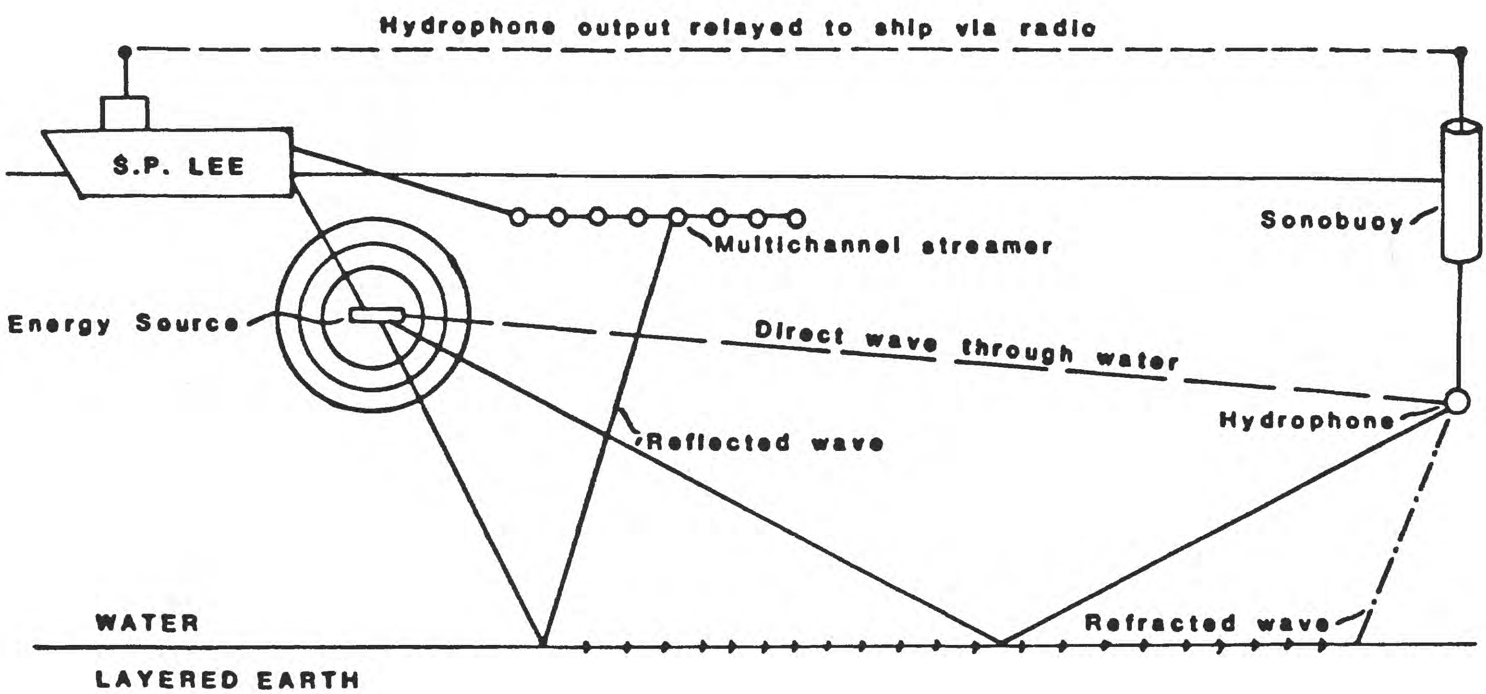

Figure 6 Analog representations of sonobuoy stations 98 and 105, with preliminary refraction results and corresponding near-trace reflection profiles. Both were collected under ideal weather and sea conditions. Refraction data are unreversed, and results have not been corrected for interface dip or other structure. Figure from Childs et al. (1991).

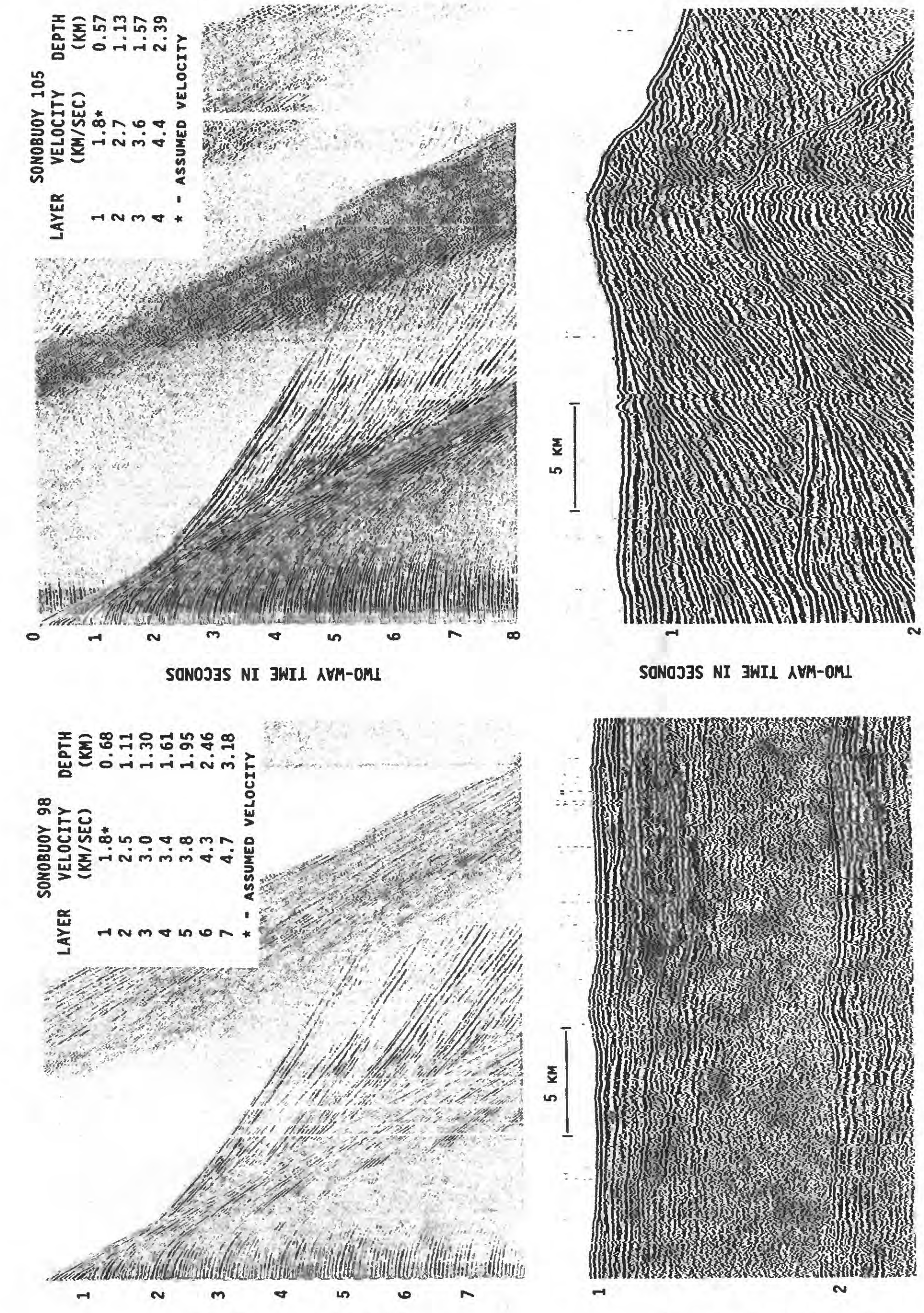

TABLE 1: Summary of USGS Ross Sea sonobuoy operations.

Year	Ship	Organi-zation	Working area	Types of data collected				
				sono	MCS	Grav	Mag	OBS
1984	S.P.Lee	USGS	Western RS	X	X	X	X*	
1988	Polar Queen	BGR	Centra RSl	X		X		X
1989	OGS Explora	OGS	Central & Eastern RS	X	X	X	X	
1990	OGS Explora	OGS	Western RS	X	X	X	X	

BGR = Federal Institute for Geosciences and Natural Resources (Germany).
OGS = Osservatorio Geofisico Sperimentale (Italy).
USGS = United States Geological Survey
Grav = Seagravimeter data.
Mag = magnetometer or magnetic gradiometer (*) data.
MCS = Multi-channel seismic reflection data.
OBS = Ocean Bottom Seismometer Refraction Data.

TABLE 2: Summary of USGS Ross Sea sonobuoy data.

Year	Cruise	Sonobuoys		Seismic Source			Data		Reference
		Deployed	Useable	Array	Volume liters	Depth meters	Analog	Digital	
1984	L284AN	29	24	5 airguns	13.1	6	y	n	1
1988	Q188AN	23	18	12 airguns	43.5	6	y	y	2
1989	E189AN	25	23	30 airguns	44	?	y	y	2,3,4
1990	E190AN	31	29	14 airgins	22	?	y	y	2,3,4

REFERENCES

1) Cooper et al. (1987,b), 2) Cochrane et al. (in press), 3) Cochrane and Cooper (in press), 4) Childs et al. (in press).

TABLE 3: Seismic refraction solutions for sonobuoy measurements made aboard the R.V. S.P. Lee in the Ross Sea in 1984. Modified from Cooper et al. (1987,b).

Sonobuoy No.	Water depth (m)	Layer 1 V_c (V_0) h D	Layer 2 V_c (V_0) h D	Layer 3 V_c (V_0) h D	Layer 4 V_c (V_0) h D	Layer 5 V_c (V_0) h D	Layer 6 V_c (V_0) h D	Layer 7 V_c (V_0) h D
2	-77° 11.42' 401	163° 55.86' 1076	271	2.09 (2.1*) 0.5 0.4	3.1 (3.23) 0.44 1.9	3.73 (3.95) 2.3 1.9	4.98 (5.62) 4.1	
6	-77° 01.80' 403	165° 50.71' 1530	860	1.86 (1.85) 0.18 -0.4	1.94 (1.92*) 0.31 -0.9	2.53 (2.48) 0.58 -1.2	3.69 (3.53) 0.46 -1.5	4.09 (3.91) 0.75 -1.0
7	-77° 15.94' -	163° 53.46' -	945	1.92 (1.92*) 0.65 0.0	2.83 (2.86) 0.73 0.5	4.18 (4.29) 0.9		
9	-76° 38.91' 406	167° 43.39' 310	827	1.92 (1.92*) 0.03 0.0	2.11 (2.11) 0.58 0.0	3.30 (3.30) 0.78 0.0	4.05 (4.05) 1.57 0.0	5.15 (5.15) 0.0
10	-76° 18.41' 406	164° 55.55' 2010	850	1.90 (1.92*) 0.81 0.6	3.18 (3.28) 0.87 1.0	4.19 (4.42) 2.43 1.7	5.26 (5.60) 1.1	
11	-75° 57.07' 407	163° 10.26' 119	728	2.97 (2.97) 0.12 0.0	3.05 (3.05) 0.61 0.0	4.10 (4.10) 0.0		
12	-75° 57.56' 407	164° 49.04' 1038	898	1.93 (1.93) 0.90 0.0	3.03 (3.25) 0.49 3.1	3.44 (3.79) 0.39 4.1	3.62 (4.03) 0.78 4.7	3.95 (4.58) 1.38 6.7
13	-76° 00.67' 407	166° 46.04' 2155	690	1.92 (1.92*) 0.19 0.0	2.39 (2.39) 0.46 0.0	3.50 (3.50) 1.02 0.0	4.33 (4.33) 0.79 0.0	4.57 (4.57) 2.83 0.0
14	-76° 00.99' 407	169° 14.13' 3480	569	1.93 (1.92*) 0.12 -0.2	2.13 (2.13) 0.22 0.0	2.68 (2.70) 0.66 0.7	3.83 (3.88) 0.78 0.5	4.45 (4.50) 1.54 0.1
15	-75° 46.22' 408	169° 02.05' 943	486	1.91 (1.92*) 0.09 0.4	2.19 (2.18) 0.51 -0.7	3.11 (3.09) 0.83 -0.4	4.29 (4.27) 1.26 0.0	4.96 (4.94) 2.69 0.0
17	-75° 09.83' 408	165° 54.40' 3156	856	1.95 (1.92*) 0.15 -1.1	2.37 (2.34) 0.57 -0.3	2.74 (2.73) 0.41 0.7	3.57 (3.59) 0.61 1.1	3.94 (4.02) 1.08 2.3
18	-74° 59.85' 409	167° 30.49' 1423	525	1.90 (1.92*) 0.16 0.6	2.28 (2.29) 0.26 -0.2	2.66 (2.67) 0.30 0.0	3.11 (3.12) 0.35 0.0	3.69 (3.71) 0.47 0.0
19	-75° 01.05' 409	170° 56.60' 3490	541	1.93 (1.92*) 0.02 -0.2	2.37 (2.37) 0.51 0.0	3.24 (3.25) 0.36 0.3	3.69 (3.73) 0.52 0.9	5.53 (5.66) 1.33 0.9
20	-74° 49.68' 410	172° 20.39' 594	592	2.19 (2.19) 0.03 0.0	2.62 (2.62) 0.46 0.0	3.55 (3.55) 0.49 0.0	5.11 (5.11) 1.81 0.0	6.61 (6.61) 0.0
21	-74° 29.21' 410	170° 08.77' 2086	465	1.94 (1.92*) 0.32 -0.9	2.73 (2.71) 0.53 0.0	3.66 (3.63) 1.06 0.0	5.56 (5.48) 1.37 0.0	6.46 (6.36) 0.0
22	-74° 07.67' 411	168° 45.16' 225	629	2.28 (2.28) 0.20 0.0	2.34 (2.34) 0.21 0.0	3.01 (3.01) 0.82 0.0	5.37 (5.37) 2.15 0.0	7.40 (7.40) 0.0
23	-74° 03.25' 411	171° 14.71' 1730	569	1.93 (1.94) 0.34 0.4	2.91 (2.94) 0.41 0.4	3.82 (3.91) 1.20 0.8	5.52 (5.68) 0.70 0.4	6.87 (7.25) 1.7
24	-74° 01.16' 413	170° 11.77' 705	557	1.92 (1.92*) 0.29 0.0	2.90 (2.88) 0.32 -0.3	3.33 (3.31) 0.37 -0.3	4.74 (4.68) 1.49 -0.3	5.41 (5.24) -2.3

V_0 is the observed velocity in km/sec.

V_c is the velocity corrected for layer dip.

* indicates assumed velocity.

h is the layer thickness in km.

D is the layer dip in degrees relative to the overlying layer (- indicates increasing depth along shotline).

TABLE 3 (Continued)

Sonobuoy No.	Water depth (m)	Layer 1 V_c (V_0) h D	Layer 2 V_c (V_0) h D	Layer 3 V_c (V_0) h D	Layer 4 V_c (V_0) h D	Layer 5 V_c (V_0) h D	Layer 6 V_c (V_0) h D	Layer 7 V_c (V_0) h D
26	-74° 18.62'	169° 05.07'	695	1.93 (1.92*)	2.85 (2.82)	3.66(3.62)	5.16 (5.05)	5.52 (5.36)
	413	1670		0.19	0.70	0.39	2.11	
				-0.4	-0.3	-0.1	-0.6	-1.5
27	-74° 41.20'	167° 27.16'	825	2.21 (2.22)	3.35 (3.41)	4.37 (4.47)	5.03 (5.19)	
	413	2968		0.42	0.92	1.39		
				0.2	0.8	0.4	1.0	
28	-75° 12.12'	166° 11.97'	873	1.79 (1.80*)	1.95 (1.96)	2.86 (2.92)	3.46 (3.54)	4.73 (4.91)
	414	1472		0.11	0.37	0.54	1.09	1.48
				0.4	0.6	0.8	0.5	0.9
29	-75° 59.43'	164° 55.98'	918	1.72 (1.72*)	2.59 (2.59)	3.15 (3.15)	3.49 (3.49)	3.80 (3.80)
	414	3650		0.46	0.42	0.31	0.46	0.24
				0.0	0.0	0.0	0.0	0.0
		29 (cont.)	layers 8,9		4.94 (4.94)	5.59 (5.59)		
					1.65			
					0.0	0.0		
30	-76° 25.78'	164° 55.14'	808	1.79 (1.80*)	2.03 (2.04)	2.35 (2.36)	2.99 (3.02)	3.69 (3.75)
	414	4649		0.15	0.51	0.36	0.21	0.55
				0.3	0.3	0.3	0.3	0.6
31	-76° 55.51'	164° 59.90'	565	1.78 (1.78)	2.09 (2.10)	3.05 (3.12)	3.67 (3.79)	4.14 (4.30)
	414	5700		0.14	0.47	0.42	0.63	0.64
				0.1	0.3	1.1	1.1	1.4
		31 (cont.)	layer 8		5.20 (5.50)			
					3.8			
32	-72° 33.15'	-178° 18.43'	554	1.92 (1.92*)	4.39 (4.39)	5.66 (5.66)		
	415	193		0.16	0.84			
				0.0	0.0	0.0		
33	-72° 31.69'	-175° 56.81'	818	1.97 (1.92*)	2.17 (2.12)	4.71 (4.50)		
	415	1745		0.27	0.39			
				-1.7	-0.6	-0.6		
34	-72° 31.01'	-173° 35.89'	3344	1.79 (1.80*)	2.02 (2.05)	2.59 (2.62)	3.35 (3.40)	5.24(5.27)
	416	191		0.49	0.20	0.81	0.41	
				0.6	0.9	0.3	0.3	-0.6
35	-72° 07.78'	-177° 17.45'	700	1.92 (1.92*)	4.95 (4.95)	6.59 (6.59)		
	417	677		0.18	3.97			
				0.0	0.0	0.0		
37	-72° 05.89'	179° 18.24'	2218	1.80(1.80*)	2.30 (2.30)	3.00 (3.00)	4.18 (4.18)	5.16 (5.51)
	418	156		0.69	0.58	1.03	1.95	
				0.0	0.0	0.0	0.0	4.8
38	-71° 22.94'	174° 53.77'	2330	1.70 (1.70*)	2.13 (2.13)	3.68 (3.68)	5.24 (5.24)	
	-	-		0.55	0.39	1.89		
				0.0	0.0	0.0	0.0	
39	-70° 43.48'	175° 16.54'	2416	1.70 (1.70*)	3.30 (3.30)	4.79 (4.79)	5.33 (5.33)	
	-	-		0.31	0.30	1.18		
				0.0	0.0	0.0	0.0	

V_0 is the observed velocity in km/sec.
V_c is the velocity corrected for layer dip.
* indicates assumed velocity.
h is the layer thickness in km.
D is the layer dip in degrees relative to the overlying layer (- indicates increasing depth along shot line.)

TABLE 4: Seismic refraction solutions for sonobuoys deployed in the Ross Sea from the R.V. *Polar Queen* in 1988. Modified from Cochrane et al. (in press).

Sonobuoy No.	Lat. Line no.	Long. Shotpoint	Water depth (m)	Layer 1 V_o h	Layer 2 V_o h	Layer 3 V_o h	Layer 4 V_o h	Layer 5 V_o h	Layer 6 V_o h
44	-76° 0.00'	177° 13.38'	466	*1.90	3.08	5.59			
	2	1		0.09	0.90				
45	-75° 59.99'	175° 28.62'	569	*1.90	2.67	+3.27	+4.04	6.08	
	2	193		0.42	0.32	0.50	0.92		
46	-76° 0.06'	173° 53.82'	533	*1.90	2.57	+3.34	+3.79	+4.34	6.14
	2	369		0.36	0.36	0.66	0.74	3.98	
47	-75° 59.99'	172° 15.06'	600	*1.90	3.03	+3.66	+4.17	5.61	
	2	558		0.32	0.59	0.58	1.36		
48	-76° 0.18'	170° 35.16'	690	1.93	2.76	3.50	3.99	6.56	
	2	728		0.14	0.51	0.44	0.89		
50	-75° 36.18'	173° 20.52'	503	*1.90	2.87	+3.80	+4.25	5.18	6.82
	3	57		0.29	0.67	0.88	2.64	2.43	
51	-76° 7.02'	173° 19.86'	630	*1.90	3.12	+3.78	+4.32	+5.29	6.29
	3	286		0.29	0.88	0.85	3.19	0.99	
52	-76° 25.08'	173° 20.46'	578	*1.90	3.09	+3.46	+3.89	+4.28	5.39
	3	445		0.43	0.44	0.47	0.53	4.36	
53	-75° 24.66'	165° 11.82'	451	2.36	4.51				
	5	3		0.78					
54	-75° 0.36'	165° 29.70'	1103	*1.90	3.61	4.85	5.01	6.65	
	5	201		0.21	0.77	0.80	5.46		
55	-75° 23.46'	176° 30.30'	361	*1.90	3.28	3.85	5.87		
	4	5		0.59	0.50	1.14			
56	-75° 17.58'	174° 54.90'	293	*1.90	2.11	+2.75	+3.55	+4.36	7.12
	4	191		0.40	0.29	0.36	0.73	2.78	
57	-75° 13.02'	173° 25.62'	480	*1.90	3.24	+3.81	4.98	6.81	
	4	355		0.35	0.44	0.53	1.38		
59	-75° 0.48'	171° 23.94'	577	*1.90	2.75	3.21	3.82	4.10	
	4	591		0.08	0.33	0.47	2.34		
60	-75° 10.60'	-175° 15.00'	317	*1.80	2.88	+3.49	+4.23	5.82	
	6	2		0.82	0.41	0.77	2.53		
61	-74° 45.40'	-175° 15.60'	279	*1.80	3.10	+3.65	4.25		
	6	201		0.92	0.49	0.70			
62	-74° 18.80'	-175° 14.60'	433	*1.80	3.05	+4.02	+4.72	6.49	
	6	401		0.64	0.57	1.94	2.71		
63	-73° 45.20'	-175° 14.20'	395	*1.80	3.27	4.01	5.15	5.51	6.35
	6	651		0.66	0.50	1.75	1.55	1.96	

V_o is the observed velocity (no dip correction).
* indicates assumed surface layer velocity.
+ indicates velocity is one of at least two (including the velocity of the layer above) that represent a single layer with a gradient.
h is the layer thickness in km.

TABLE 5: Seismic refraction solutions for sonobuoy deployed in the Ross Sea from the R.V. *OGS Explora* in 1989. Modified from Cochrane et al. (in press).

Sonobuoy No.	Lat. Line no.	Long. Shotpoint	Water depth (m)	Layer 1 V_c h D	Layer 2 V_c h D	Layer 3 V_c h D	Layer 4 V_c h D	Layer 5 V_c h D	Layer 6 V_c h D	Layer 7 V_c h D	Layer 8 V_c h D	Layer 9 V_c h D
61	-74° 37.60'	168° 14.30'	580	1.93	3.24	3.87	+4.25					
	14	1113		0.44	0.60	0.39						
				-1.2	1.3	0.6	-0.1					
62	-73° 58.40'	171° 30.40'	493	*1.90	1.99	2.49	2.73	4.22	5.97			
	15	443		0.35	0.10	0.15	0.15	0.98				
				0.	0.	0.	0.	0.	0.			
63	-74° 30.90'	171° 30.20'	428	*1.90	2.36	2.68	5.80					
	16	1675		0.21	0.12	0.52						
				0.	0.	0.	0.					
64	-75° 27.90'	174° 0.00'	297	*1.90	2.29	2.90						
	18	738		0.41	0.38							
				0.	0.	0.						
65	-75° 16.50'	172° 12.40'	522	*1.90	2.03	2.57	+3.10	+3.79	+4.09	4.73		
	19	1098		0.12	0.18	0.28	0.42	0.32	1.21			
				-0.1	0.3	0.2	0.7	0.5	-0.3	1.4		
66	-75° 17.20'	170° 0.80'	370	*1.90	2.26	2.44	+3.31	+3.77	4.32			
	19	2363		0.26	0.27	0.16	0.30	0.41				
				0.0	-0.7	0.	0.	0.	0.			
67	-75° 27.90'	173° 20.00'	442	*1.90	2.46	2.74	+3.35	+3.66	+4.19	4.73	5.96	7.45
	0	2984		0.42	0.09	0.37	0.30	0.51	0.84	1.73	1.40	
				0.	0.	0.	0.	0.	0.	0.	0.	0.
68	-75° 23.00'	175° 15.00'	319	*1.90	2.41	3.42	+4.06	4.78	6.70			
	26	153		0.47	0.37	0.82	0.61	1.55				
				0.	-0.6	0.2	0.2	-0.8	0.			
69	-73° 31.60'	178° 35.70'	334	*1.90	2.19	2.59	5.45	6.80				
	27	2268		0.20	0.41	0.27	1.85					
				0.	0.5	-1.3	-0.9	0.				
70	-73° 34.90'	-177° 23.30'	1014	1.87	5.39							
	27	4798		0.62								
				0.	0.							
71	-74° 22.60'	-178° 57.90'	303	2.01	2.26	4.26	6.16					
	29	2258		0.80	0.13	0.51						
				0.	0.	0.	0.					
72	-76° 22.40'	-176° 5.30'	580	1.93	2.57	3.20	3.79	5.43				
	30	1688		0.34	1.01	0.67	2.50					
				0.	0.	0.	0.	0.				
74	-77° 26.80'	-174° 0.10'	544	*1.90	2.22	2.79	+3.38	+3.92	+4.37	4.77		
	33	113		0.24	0.79	0.44	0.49	0.55	0.61			
				0.	0.	0.8	0.	0.	0.	0.		
75	-77° 27.00'	-178° 30.00'	525	2.22	+2.37	5.84						
	33	2399		0.06	0.39							
				0.	0.	0.						
76	-77° 26.80'	-178° 30.40'	660	1.83	5.40							
	34	390		0.29								
				0.	0.							
77	-77° 7.20'	-178° 41.30'	638	*1.90	2.27	2.65	2.67	5.86				
	34	1143		0.21	0.15	0.21	0.13					
				0.	0.	0.	0.	0.				
78	-76° 20.00'	-179° 45.50'	371	*1.90	2.03	2.98	4.24	7.60				
	35	492		0.13	0.60	0.78	3.21					
				0.	0.	0.	0.	0.				
79	-76° 17.30'	177° 0. '	443	*1.90	2.70	3.03	3.32	3.54	5.68	6.46	8.60	
	36	203		0.47	0.18	0.32	0.11	0.56	1.38	0.83		
				0.	0.	0.	0.	0.	0.	0.	0.	
80	-75° 26.10'	177° 0.20'	404	*1.90	2.46	3.89	4.46					
	36	2108		0.45	0.52	1.10						
				0.	0.	0.	0.					
81	-73° 43.40'	176° 58.50'	372	2.15	2.62	3.54	4.65					
	36	1858		0.01	0.50	0.42						
				0.	0.	0.	0.					

V_c is the dip-corrected velocity.
* indicates assumed velocity.
+ indicates velocity is one of at least two (including the velocity of the layer above) that represent a single layer with a gradient.
h is the layer thickness in km.
D is the layer dip in degrees (- indicates increasing depth along shotline).

TABLE 6: Preliminary seismic refraction solutions for sonobuoy measurements made in the Ross Sea in 1990 aboard the R.V. OGS Explora (Note: these are preliminary solutions currently being checked, revised, and corrected for dipping layers and structures.)

Sonobuoy No.	Lat. Line no.	Long. Shotpoint	Water depth (m)	Layer 1 V_o h	Layer 2 V_o h	Layer 3 V_o h	Layer 4 V_o h	Layer 5 V_o h	Layer 6 V_o h	Layer7 V_o h
87	-74° 53.00'	165° 28.90'	782	*1.80	2.52	3.38	3.89	4.36		
	58	880		0.47	0.36	0.36	0.51			
88	-74° 58.03'	164° 42.41'	920	*1.80	2.58	2.92	3.66	5.67		
	59	430		0.27	0.21	0.25	0.09			
89	-75° 3.99'	168° 6.69'	316	*1.80	2.02	2.64	3.32	4.21	4.95	
	61	370		0.41	0.27	0.43	0.49	1.26		
90	-75° 2.60'	164° 55.41'	929	*1.80	2.37	3.54	4.67			
	61	1400		0.28	0.30	0.91				
91	-75° 22.13'	166° 39.24'	476	*1.80	2.37	2.82	4.66	5.54		
	62	755		0.41	0.07	0.98	2.13			
92	-75° 54.50'	166° 20.96'	507	*1.80	2.18	2.95	3.45	3.97	4.47	4.92
	62	3205		0.41	0.25	0.40	0.46	0.71	0.90	
93	-76° 3.17'	164° 55.34'	883	*1.80	1.84	3.56	4.49	5.17		
	63	1578		0.98	0.04	0.82	0.78			
94	-75° 55.82'	163° 47.61'	730	*1.80	2.25	3.05	3.71	3.99	4.31	
	64	220		0.39	0.06	0.35	0.43	0.70		
95	-75° 50.64'	164° 40.45'	773	*1.80	2.82	4.41				
	65	2024		0.88	0.25					
96	-75° 55.11'	163° 43.12'	697	*1.80	3.55	4.39	5.09			
	66	1025		0.41	0.68	1.51				
97	-75° 56.23'	163° 57.51'	714	*1.80	2.26	3.20	3.81	4.65	6.28	
	67	738		0.34	0.23	0.27	1.16	3.14		
98	-75° 55.36'	164° 12.68'	681	*1.80	2.53	2.98	3.42	3.77	4.31	4.67
	68	630		0.43	0.19	0.31	0.34	0.51	0.72	
99	-76° 59.67'	164° 46.89'	440	*1.80	3.17	3.71	4.20	4.95	5.59	
	69	1400		0.74	0.37	0.67	1.21	2.86		
100	-77° 1.49'	166° 0.50'	833	*1.80	2.95	3.83	4.53			
	69	2590		0.95	0.59	0.89				
101	-77° 8.68'	166° 17.88'	936	*1.80	2.27	4.21	4.93			
	70	807		0.36	0.75	1.34				
102	-77° 35.59'	164° 33.76'	263	*1.80	2.15	3.33	4.19			
	71	950		0.29	0.20	1.58				
103	-76° 57.02'	164° 24.48'	387	*1.80	3.10	3.76				
	72	673		0.31	0.66					
104	-77° 4.70'	166° 20.39'	933	*1.80	2.00	2.80	3.39	3.89	4.45	5.31
	74	345		0.63	0.25	0.41	0.39	0.61	1.81	
105	-76° 53.05'	164° 57.31'	574	*1.80	2.71	3.60	4.44			
	75	1525		0.56	0.43	0.82				
106	-76° 31.94'	166° 15.67'	630	*1.80	2.13	2.92	3.78	4.49	5.06	
	74	1810		0.41	0.17	0.48	1.07	1.09		
107	-70° 17.23'	166° 17.08'	604	*1.80	2.13	3.04	3.96	5.37		
	74	2910		0.36	0.33	0.58	2.05			
108	-75° 1.65'	167° 45.08'	419	*1.80	2.08	2.71	4.09	4.70	6.46	
	77	4884		0.37	0.29	0.66	1.04	3.14		
109	-74° 51.00'	166° 11.27'	1080	*1.80	2.03	2.77	3.52	4.29		
	78	1669		0.44	0.17	0.66	0.68			
110	-75° 3.74'	169° 14.25'	370	*1.80	2.14	2.44	3.36	3.92	4.39	
	79	3200		0.34	0.38	0.33	0.36	0.45		
111	-74° 47.73'	170° 25.45'	300	*1.80	1.96	2.52	4.84	5.77		
	80	1396		0.49	0.00	0.64	1.20			
112	-74° 33.72'	169° 8.70'	537	*1.80	2.13	3.16	3.81	5.41	6.14	
	81	160		0.29	0.37	0.46	1.37	0.98		
113	-63° 0.70'	166° 51.19'	2357	*1.80	4.91	5.50	6.95			
	82	3100		0.61	0.27	1.57				

V_o is the observed velocity (no dip correction).
* indicates assumed surface layer velocity.
h is the layer thickness in km.