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SEISMIC STRUCTURE OF THE CONTINENTAL MARGINS AND OCEAN BASINS OF SOUTHEASTERN CANADA

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ABSTRACT

The results obtained from seven crustal refraction lines and 23 expendable sonobuoys are described. Six of the crustal refraction lines are parallel to the continental margin off Nova Scotia or the southern Grand Banks. The refraction data from the former area may limit the continent-ocean transition to a zone of 75 km or less while the data from the later area suggests a transition zone of 36 km or less. One crustal refraction line with typical oceanic structure was obtained in the Newfoundland Basin. The results from the expendable sonobuoy wide angle reflections and refractions are grouped according to area. The 14 sonobuoys launched over the Sohm Abyssal Plain measured three ranges of velocities, 1. 7 to 2. 2 km/sec, 2. 2 to 2. 7 km/sec, and 2. 7 to 3. 7 km/sec. Six expendable sonobuoys launched in the vicinity of the Newfoundland fracture zone measured two distinct groups of velocities, 1. 94 to 2. 14 km/sec and 3. 70 to 3. 95 km/sec. Three other expendable sonobuoys were launched and are discussed separately.

RESUME

Les auteurs décrivent les résultats obtenus à partir de sept lignes de réfraction dans la croûte et de 23 bouées acoustiques non récupérables. Six des lignes de réfraction dans la croût sont parallèles à la marge continentale située au nord de la Nouvelle-Ecosse ou au sud des Grands bancs. Selon les données de réfraction dans la première région, il semble que la transition entre le continent et l'océan soit limitée à une zone de 75 km ou moins, tandis que selon les données tirées de l'autre région, la transition serait constituée d'une zone de 36 km ou moins. On a obtenu une ligne de réfraction dans la croûte possédant une structure océanique type dans le bassin de Terre-Neuve. Les résultats obtenus provenant des réflexions et des réfractions à grands angles des bouées acoustiques lancées, au-dessus de la plaine abyssale de Sohm ont mesuré trois classes de vitesses de propagation: 1. 7 à 2. 2 km/s, 2. 2 à 2. 7 km/s et 2. 7 à 3. 7 km/s. Les six bouées acoustiques non récupérables lancées aux environs de la zone de fracture de Terre-Neuve ont établi deux classes distincts de vitesses: 1. 94 à 2. 14 km/s et 3. 70 à 3. 95 km/s. On a lancé trois autres bouées acoustiques non récupérables, et les résultats sont étudiés séparément.

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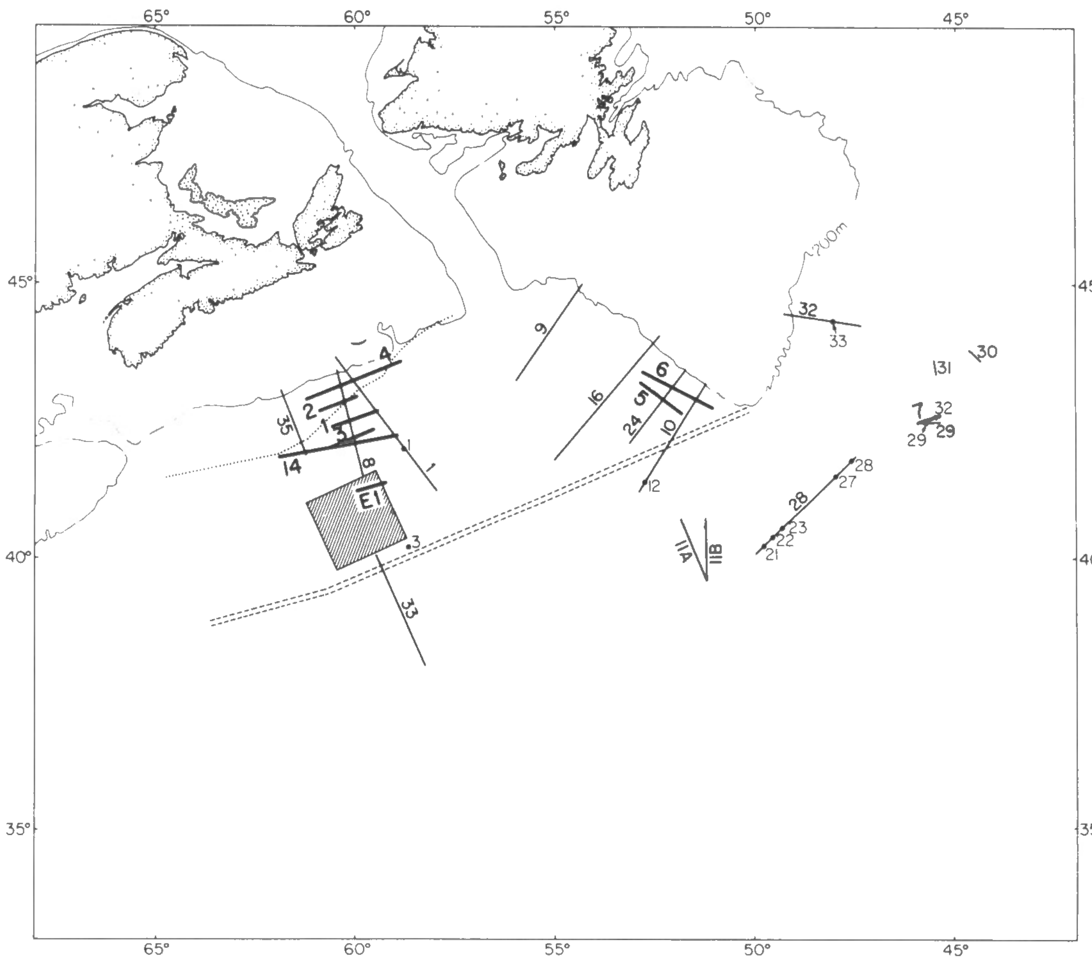

Figure 1. Index map. The heavy numbered lines are seismic refraction lines, the numbered solid lines represent lines of seismic reflection, gravity and magnetic coverage, the light numbers indicate expendable sonobuoy positions, the shaded box is the magnetic quiet zone survey area, and the two dashed lines represent the rough-smooth magnetic zone boundary.

SEISMIC STRUCTURE OF THE CONTINENTAL MARGINS AND OCEAN BASINS
OF SOUTHEASTERN CANADA

INTRODUCTION

During the summers of 1972 and 1973, seven crustal refraction profiles were established seaward of the continental shelf of Nova Scotia south of Sable Island, seaward of the southern margin of the Grand Banks, and in the Newfoundland Basin (Fig. 1). These studies were part of a program to investigate the nature of the deep crustal structure at the continent-ocean transition off eastern Canada.

Expendable sonobuoy wide angle reflection and refraction lines were also obtained to define the velocities and layering of the sedimentary strata and velocity of oceanic basement. Gravity and magnetic field measurements were carried out along the refraction lines. The gravity measurements were made to aid in the determination of depths to the Mohorovicic discontinuity. The magnetic field measurements were to give additional information on the character of basement. This paper describes the data reduction and some of the results of the work carried out on C.S.S. HUDSON (Cruises 72-021, 73-011).

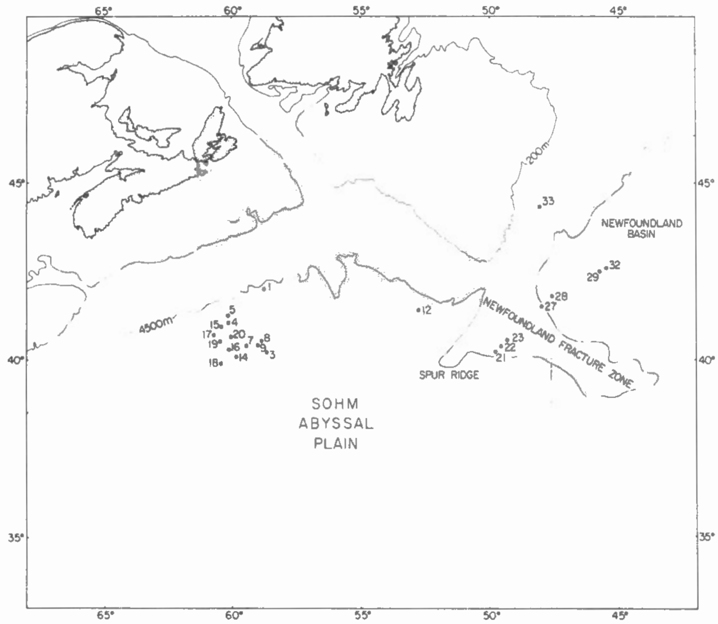

Figure 2. Location of expendable sonobuoys.

EXPERIMENTAL METHOD

Of the seven refraction lines obtained, six were parallel and close to the continental margin. The refraction lines have accompanying seismic reflection information along lines 1, 3, 4, and 7. The refraction lines adjacent to the continental margins are crossed by reflection lines 8 and 24, which run approximately perpendicular to the Shelf break. The purpose of the accompanying reflection lines was to allow measured refractors to be related to rock types or to particular reflectors. There are gravity and magnetic field measurements to accompany all reflection lines.

The lines were accurately positioned with the aid of Loran-C in the range-range mode in conjunction with satellite navigation. This system gave locations to within 300 m.

Crustal seismic refraction lines were shot using single ship sonobuoy techniques to obtain reversed profiles. The buoys used were telemetering sonobuoys manufactured by G. and E. Bradley Ltd. They were free floating to reduce flow noise at the hydrophones. The sonobuoys also contained tape recorders programmed to switch on and off at a predetermined interval. This system removes the limitations imposed by a radio transmission link (Keen and Barrett, 1972). Buoy drift and locations related to the experimental procedures are presented in Table 1. The sound sources used were a 1,000-cubic-inch (16,386-cubic-cm) air gun and explosive charges with weights of up to 1,300 pounds (590 kg). The air gun was fired at a repetition rate of 30 seconds, which allowed wide angle reflection as well as refractions to be obtained for the sedimentary layers and for oceanic layer 2. The explosive charges enabled the deeper crustal structure to be delineated.

The time-distance plots include results from the explosive and air gun data. If a velocity was observed at only one end of the line, it was assumed that its absence was due to the complexity of the time-distance plot which often makes it difficult to resolve two lines whose velocities are within 1 km/sec. Therefore, when a layer was observed at only one end, the same layer was assumed to be present at the other end and the same apparent velocity and intercepts were used in the calculations. Often, the lowest velocity corresponding to unconsolidated sediments was not recorded. When this happened, a 2.0- to 2.3-km/sec layer was assumed. Occasionally mantle velocities were not measured. In this case, a line whose slope corresponded to an assumed mantle velocity was drawn through the last point on the line representing the highest velocity measured. This gave a minimum depth to the M discontinuity.

Two types of expendable sonobuoys were used: Aquatronics 68-B and Seismic Engineering Ltd. sonobuoys. The equipment and techniques involved have been described by Keen and Barrett (1972), and by Le Pichon et al. (1968). A total of 23 expendable sonobuoys were launched (Fig. 2) successfully. They were used along seismic reflection profiles, and

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Table 1.

Mechanics of shooting the refraction lines

Line No.	First Shot	Last Shot	Buoy No.	Buoy Laid	Buoy Up	Total Drift (km)	Drift Rate (km/hr)	Air Gun Begin	Air Gun End
1	42°24.0'N 60°36.8'W	42°41.7'N 59°28.8'W	2	42°04.7'N 60°37.5'W	41°58.8'N 60°40.8'W	12			
			3	42°27.2'N 60°37.0'W	42°19.2'N 60°34.5'W	8.0	.6	42°33.8'N 59°59.5'W	42°19.4'N 60°34.5'W
			6	42°28.8'N 60°30.2'W	42°21.4'N 60°27.0'W	7.6	.52	42°33.8'N 59°59.5'W	42°19.4'N 60°34.5'W
2	42°40.8'N 60°53.0'W	42°57.7'N 59°56.0'W	6	42°57.7'N 59°56.0'W	42°59.9'N 59°57.3'W	3.8	.28	42°57.7'N 59°56.0'W	42°50.4'N 60°27.0'W
			5	42°40.8'N 60°53.0'W	42°38.6'N 60°57.3'W	7.1	.47	42°40.8'N 60°53.0'W	42°56.6'N 59°55.2'W
3	42°06.0'N 60°24.4'W	42°20.0'N 59°34.9'W	5	42°07.2'N 60°25.2'W	42°03.8'N 60°18.6'W	10.8	.75	42°04.6'N 60°83.4'W	42°12.4'N 60°04.8'W
			6	42°06.0'N 60°24.8'W	42°20.9'N 59°31.3'W	2.4	.30		
4	42°58.5'N 61°15.1'W	43°30.8'N 59°13.9'W	1	42°54.3'N 61°25.2'W	42°54.3'N 61°04.9'W	15.1	.50	42°54.6'N 61°21.7'W	42°59.6'N 61°03.6'W
			3	42°55.7'N 61°20.0'W	42°55.1'N 61°03.9'W	11.8	.45	42°55.5'N 61°19.5'W	42°59.6'N 61°03.6'W
			5	43°33.2'N 59°10.8'W	43°36.0'N 58°43.3'W	20.2	.62	43°11.7'N 60°26.2'W	43°25.7'N 59°33.5'W
			6	43°31.1'N 59°16.7'W	43°35.2'N 58°43.5'W	24.4	.65	43°11.7'N 60°26.2'W	43°25.7'N 59°33.5'W
5	42°41.3'N 51°52.2'W	43°11.5'N 52°49.0'W	1	43°15.2'N 52°56.1'W	43°13.5'N 52°53.1'W	4.0	.29	43°14.8'N 52°55.2'W	43°07.7'N 52°43.0'W
			2	43°13.6'N 52°53.9'W	43°17.3'N 52°51.8'W	4.0	.24	43°15.2'N 52°56.1'W	43°03.7'N 52°35.8'W
			3	42°40.5'N 51°52.0'W	42°84.7'N 51°39.1'W	11.2	.76	42°46.6'N 52°09.9'W	42°35.2'N 51°39.2'W
6	43°33.3'N 52°48.3'W	42°57.3'N 51°43.4'W	1	43°54.5'N 51°34.8'W	42°39.9'N 51°26.7'W	15.7	.68	42°53.6'N 51°34.4'W	43°04.6'N 51°52.2'W
			3	42°55.4'N 51°37.0'W	42°39.0'N 51°25.6'W	18.4	.88	42°53.6'N 51°34.4'W	43°04.6'N 51°52.2'W
			5	43°34.0'N 52°49.3'W	43°19.2'N 53°08.9'W	20.6	.77	43°18.7'N 52°19.0'W	43°21.2'N 53°07.2'W
			6	43°35.7'N 52°52.1'W	43°14.8'N 53°01.2'W	21.9	.86	43°17.2'N 56°16.9'W	43°26.2'N 53°07.2'W
7	42°30.5'N 45°59.8'W	42°35.0'N 45°19.9'W	3	42°33.2'N 45°20.4'W	42°45.3'N 45°28.0'W	11.7	1.0	42°32.5'N 45°13.4'W	42°30.5'N 45°53.4'W
			6	42°30.7'N 46°00.3'W	42°45.3'N 45°59.5'W	13.1	1.2	42°30.3'N 45°50.7'W	42°31.6'N 45°18.8'W

occasionally along crustal refraction profiles. Sedimentary and basement velocities and thicknesses were determined over a horizontal distance of about 30 km. Reflection and refraction information were obtained from the expendable sonobuoys. Wide angle reflection arrivals were interpreted in a manner similar to Le Pichon et al. (1968) except that greater attention was given to the refraction arrivals.

When the direct wave was not observed beyond one kilometre on the wide angle reflection record, distances were calculated from the Loran-C fixes or from bottom reflections at wide angles. Occasionally the Loran-C navigational data were not accurate enough for measurements of these short distances, and so bottom reflection travel times were read from high frequency playbacks and distances were calculated taking into account the gradient of the sea floor estimated from the sounding records. The horizontal and vertical sound velocities used were 1.5 km/sec. The horizontal velocity was known to be close to 1.5 km/sec from observations made on long refraction lines. The vertical velocity was assumed because velocities from Matthew's Tables produced discrepancies in ranges when compared with ranges obtained from Loran-C.

Because of the considerable topographic relief on oceanic basement, "true" velocities of this layer seldom can be extracted from the refraction data alone. In this case, both the wide angle reflection and refraction times were used to calculate the true velocities.

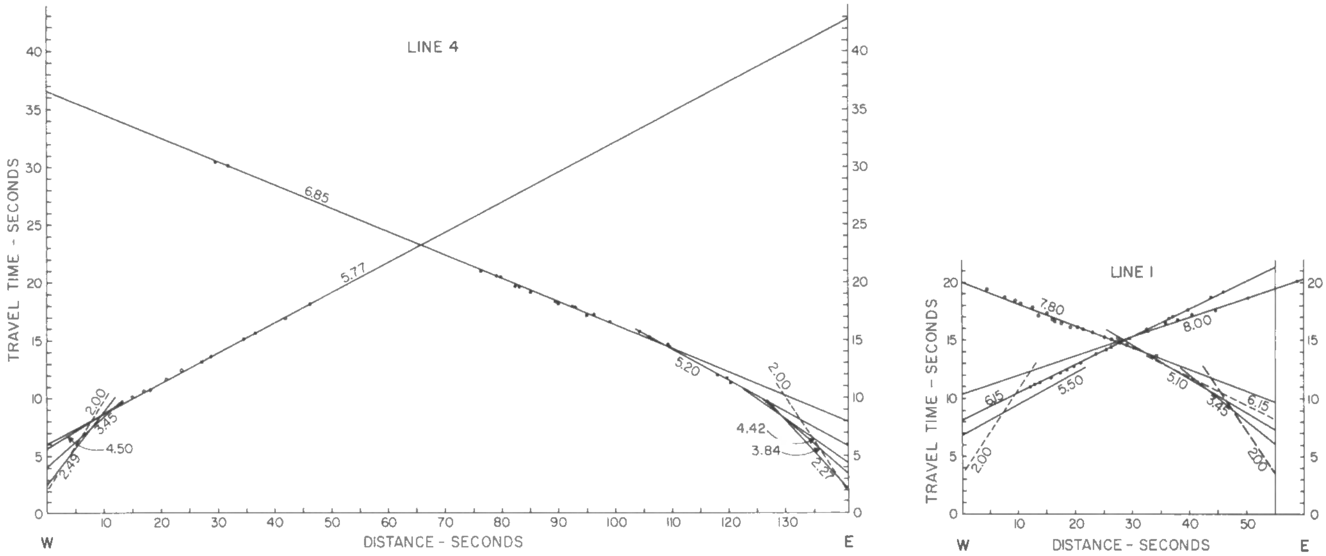


Figure 3. Time-distance plot, lines 1, 4. The solid lines with superimposed filled and hollow circles represent velocities measured by means of explosives, the solid lines are velocities interpreted from expendable sonobuoy wide angle reflections and refractions, and the dashed lines represent assumed velocities.

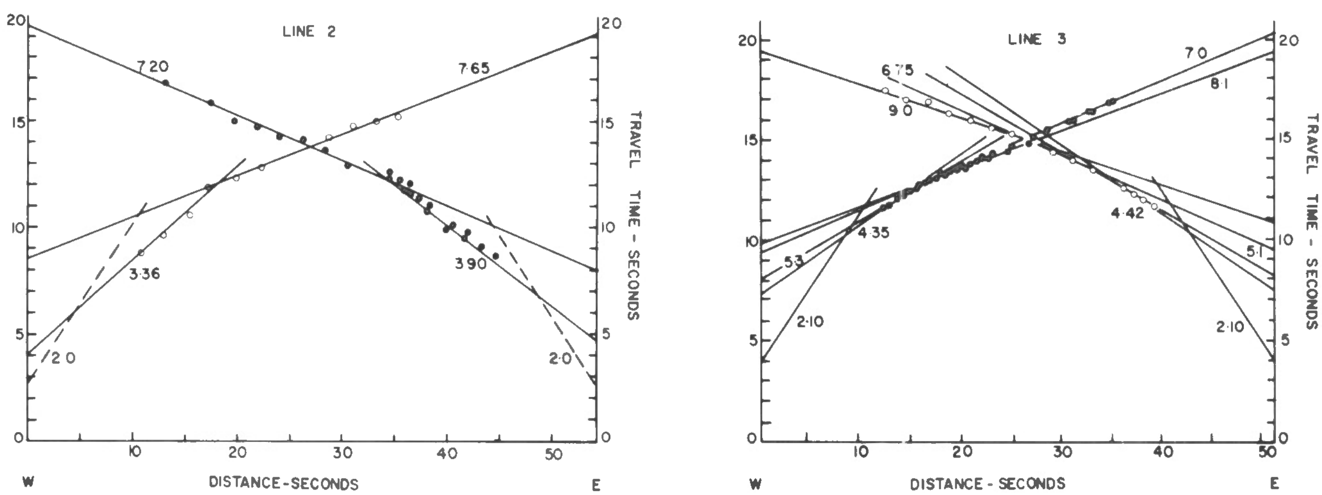


Figure 4. Time-distance plot, lines 2, 3. The solid lines with superimposed filled and hollow circles represent velocities measured by means of explosives, the solid lines are velocities interpreted from expendable sonobuoy wide angle reflections and refractions, and the dashed lines represent assumed velocities.

Table 2.

Summary of velocities

Profile No.	Sedimentary (km/sec)				Basement (km/sec)	Sub-basement (km/sec)	Mantle (km/sec)
1	2.00*	3.45			5.29	6.12	7.85
2	2.00*	3.61				7.38	8.04*
3	2.10	4.38			5.19	6.87	8.48
4	2.00*	2.66	3.65	4.46	5.47	6.81	8.00*
5	2.00*	2.89	4.18		5.85		7.94
6	2.00	2.54	3.32	3.94		6.49	7.97*
7	2.33				5.38	6.54	7.78

*Assumed velocity

Table 3.

LINE 1

Explosive Line

West			East		
Velocity (km/sec)	Intercept (sec)	Reversal (sec)	Velocity (km/sec)	Intercept (sec)	Reversal (sec)
5.50*	6.80	21.2	5.10	7.30	23.5
6.15	8.10				
8.00	10.30	19.60	7.80	9.60	20.00

*Air gun measurement

Table 4.

LINE 2

Explosive Line

West			East		
Velocity (km/sec)	Intercept (sec)	Reversal (sec)	Velocity (km/sec)	Intercept (sec)	Reversal (sec)
3.30	4.02	Poor-irrelevant	3.97	4.65	Poor-irrelevant
7.80	8.50	19.40	7.35	8.00	19.25

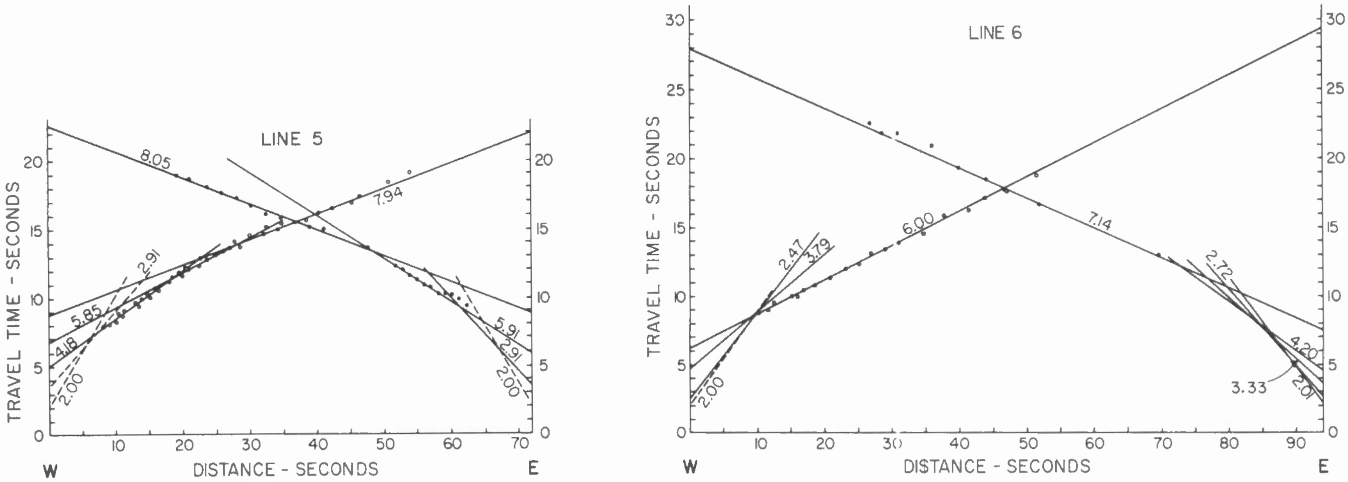


Figure 5. Time-distance plot, lines 5, 6. The solid lines with superimposed filled and hollow circles represent velocities measured by means of explosives, the solid lines are velocities interpreted from expendable sonobuoy wide angle reflections and refractions, and the dashed lines represent assumed velocities.

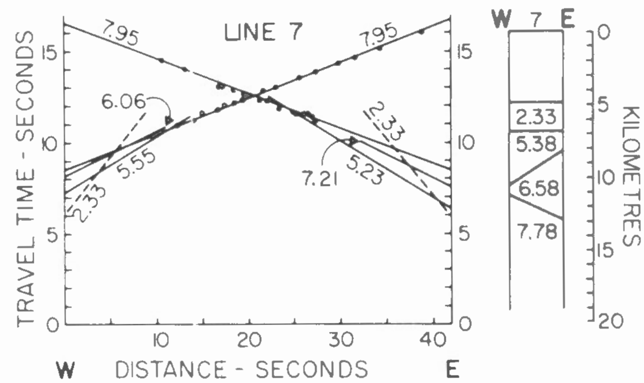


Figure 6. Time distance plot, line 7. The solid lines with superimposed filled and hollow circles represent velocities measured by means of explosives, the solid lines are velocities interpreted from expendable sonobuoy wide angle reflections and refractions, and the dashed lines represent assumed velocities. The column to the right of the time-distance plot contains the reversed velocities from the time-distance plot drawn so that depth and thickness of the layers can be read directly in kilometers.

Location of Refraction Lines and Velocities

This section describes the location of the refraction lines, the velocities, both measured and assumed. The time-distance plots corresponding to the refraction lines are given in the figures (Figs. 3, 4, 5, and 6).

A summary of the measurements is given in Table 2.

PROFILE 1

Profile 1 is located 113 km from the shelf off Nova Scotia south of Sable Island (Fig. 7).

Two velocities at each end of the line were measured using explosives (Table 3). The 5.10 km/sec layer on the east end of the line was reversed with a 5.50 km/sec refractor measured on the air gun records. One other velocity was measured on the air gun records, a 3.45 km/sec layer with an intercept of 6.00 sec on the east end. This velocity was assumed for the west end. A 2.00 km/sec layer was assumed for the unconsolidated sediments.

PROFILE 2

This line is located 75 km from the Scotian Shelf south of Sable Island. On each end of the line a high and a low velocity were measured using explosives (Table 4). The low velocity in the east is confirmed by air gun data. A 2.10 km/sec layer was assumed for the unconsolidated sediments to obtain the correct water depth. No 5 km/sec layer was observed. Up to 3 km of a 5 km/sec layer could be present if it is assumed that its refracted arrivals were not observed because they were masked by first arrivals. However, it was not observed as a second arrival on the air gun line. Also if a 5 km/sec layer, 3 km thick, was included it should have been observed on the seismic reflection profile. Therefore, the reflection results suggest that if layer 2 is present beneath line 2, it must be thin, i.e., 1.5 km or less. When a velocity typical of the upper mantle was assumed (8.04 km/sec), a minimum depth to M of 17 km was calculated.

PROFILE 3

Profile 3 is located 153 km from the Scotian Shelf south of Sable Island.

Recordings obtained from explosives show four velocities on each end of the line (Table 5). Good reversals were obtained for each set of velocities. Air gun results are available for the west end only (Table 6). They give good support for the velocities measured by the explosives. The results given in the tables will be described briefly. Velocities of the sedimentary layers of 2.10 km/sec and 4.38 km/sec were measured. A layer 2 velocity of 5.19 km/sec and a layer 3 velocity of 6.87 km/sec were observed. Layer

Table 5.

LINE 3

Explosive Line

West			East		
Velocity (km/sec)	Intercept (sec)	Reversal (sec)	Velocity (km/sec)	Intercept (sec)	Reversal (sec)
4.35	7.30	25.10	4.42	7.52	25.00
5.30	8.02	23.00	5.10	8.26	22.60
7.00	9.35	20.25	6.75	9.48	20.95
8.10	9.80	19.35	9.00	10.90	19.40

Table 6.

LINE 3

Air Gun Line

East		
Velocity (km/sec)	Intercept (sec)	Comments
2.10	4.00	second arrivals only
4.08	7.25	
5.85	8.76	velocity could be lower
7.95	10.01	velocity could be higher

Table 8.

LINE 4

Air Gun Line

West		East	
Velocity (km/sec)	Intercept (sec)	Velocity (km/sec)	Intercept (sec)
2.49	2.40	2.77	2.20
3.45	4.00	3.84	3.40
4.50	5.60	4.42	4.30

Table 7.

LINE 4

Explosive Line

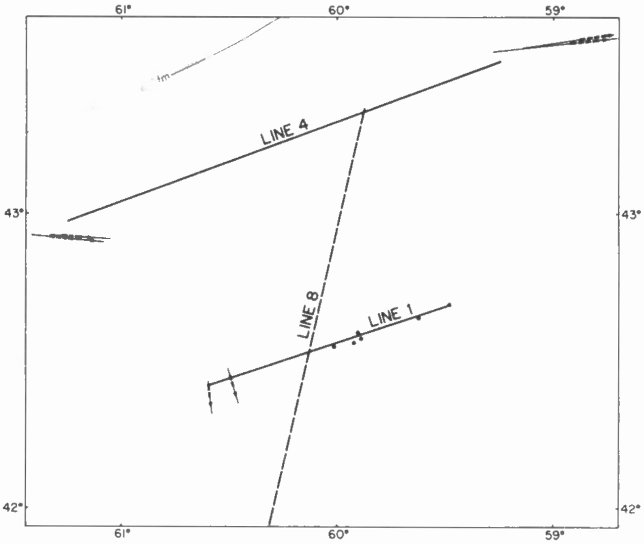
West			East		
Velocity (km/sec)	Intercept (sec)	Reversal (sec)	Velocity (km/sec)	Intersept (sec)	Reversal (sec)
5.77	6.00	42.80	5.20	5.73	44.30
			6.83	7.80	

Table 9.

LINE 5

Explosive Line

West			East		
Velocity (km/sec)	Intercept (sec)	Reversal (sec)	Velocity (km/sec)	Intercept (sec)	Reversal (sec)
4.18	4.86				
5.85	6.77	25.75	5.91	7.03	25.79
7.94	8.67	22.65	8.05	9.02	22.81



gure 7. Lines 1, 4 and 8. The heavy solid lines describe the ship's path when using the explosives, the solid lines with dashed portions and arrows indicate the sonobuoy position during the firing of the explosives. The long dashes give the accompanying seismic reflection line coverage. The light solid line gives the position of the edge of the continental shelf. The large dots indicate additional large shots that were fired a year later.

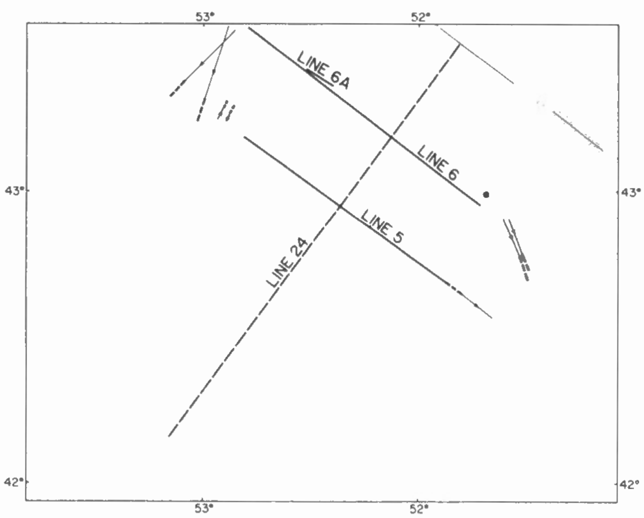


Figure 8. Lines 5, 6 and 24. The heavy solid lines describe the ship's path while shooting the explosives, the solid lines with dashed portions and arrows indicate the sonobuoy's drift and direction, and the dashed portion of the line is the sonobuoy's position during the firing of the explosives. The long dashes give the accompanying seismic reflection line coverage. The light solid line gives the position of the edge of the continental shelf.

3 is only 0.5 km thick on the east end of the line. The M discontinuity was measured at a depth of 13 km. When the refraction results are compared to the reflection horizons it is necessary to assign some of the 5.19 km/sec layer to the sedimentary horizons to get the correct two-way travel time to basement.

PROFILE 4

This line was shot 38 km from the edge of the Scotian Shelf south of Sable Island (Fig. 7).

Three refractors were measured using explosives (Table 7). The 5.2 km/sec layer on the east end was not as well defined as the other velocities. The 6.83 km/sec velocity was measured only on one end and it was treated as an unreversed measurement.

Three velocities on each end of the line were measured from refractors evident on the wide angle reflection records (Table 8).

Because mantle velocities were not observed, an 8.0 km/sec layer was assumed and a 28 km minimum depth to M discontinuity was calculated.

PROFILE 5

This line is located 76 km from the shelf on the southern margin of the Grand Banks (Fig. 8).

Three velocities on the west end and two velocities on the east end were measured utilizing the data obtained from explosives (Table 9). The quality of the arrivals from layer 2 and the mantle were excellent. The 4.18 km/sec velocity measured on the west end was treated as unreversed. Wide angle reflection data produced only one velocity - a 2.91 km/sec layer on the east end with an intercept of 3.70 sec. This was also treated as an unreversed measurement.

The magnetic expression along profile 5 gives an insight into the character of the oceanic basement (Fig. 9). There are four troughs and crests. One of the magnetic crests is coincident with an oceanic basement high seen on reflection line 24 (Fig. 10) where it crosses refraction line 5 at right angles. Because of the irregularity of the topography of oceanic basement as seen on the reflection profile and revealed by the magnetic expression, it is difficult to correlate sediment thickness and velocities from the refraction measurement to the reflection records.

A velocity of approximately 6.70 km/sec, typical of layer 3, was not observed. If a major crustal layer

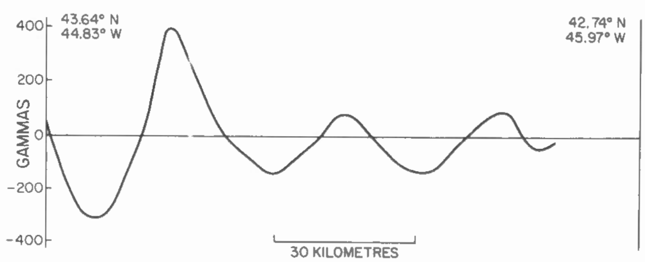


Figure 9. The magnetic anomaly measured along line 5.

Table 10.

LINE 6

Explosive Line

West			East		
Velocity (km/sec)	Intercept (sec)	Reversal (sec)	Velocity (km/sec)	Intercept (sec)	Reversal (sec)
6.00	6.20	29.30	7.14	7.50	28.00

Table 11.

LINE 6

Air Gun Line

West		East	
Velocity (km/sec)	Intercept (sec)	Velocity (km/sec)	Intercept (sec)
2.72	2.65	2.47	2.44
3.33	3.60	3.79	4.75
4.20	4.60		

Table 12.

LINE 7

Explosive Line

West			East		
Velocity (km/sec)	Intercept (sec)	Reversal (sec)	Velocity (km/sec)	Intercept (sec)	Reversal (sec)
7.95	8.50	16.6	7.95	8.53	16.5

Table 13.

LINE 7

Air Gun Line

West			East		
Velocity (km/sec)	Intercept (sec)	Reversal (sec)	Velocity (km/sec)	Intercept (sec)	Reversal (sec)
5.23	7.23		5.55	7.23	
6.06	8.10	18.60	7.12	7.60	18.4

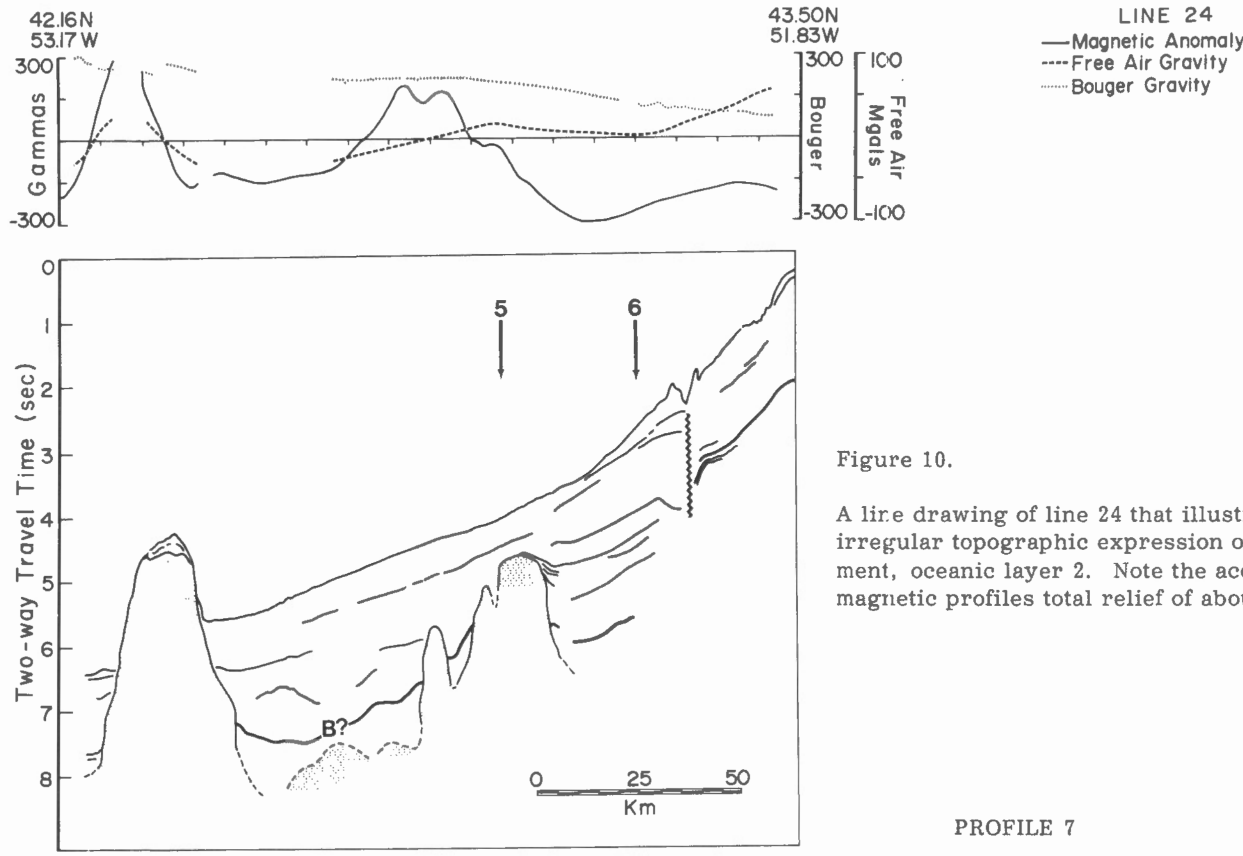


Figure 10.

A line drawing of line 24 that illustrates the irregular topographic expression of basement, oceanic layer 2. Note the accompanying magnetic profiles total relief of about 600.

was not measured it was assumed that it had been missed as a first arrival. A typical velocity for the layer of 6.7 km/sec was taken and the maximum thickness that could have been missed was calculated to be 2.7 km at a depth of 14 km.

PROFILE 6

This line is located 43 km from the shelf on the southern margin of the Grand Banks (Fig. 8).

Using explosives, only one velocity was measured at each end of the line (Table 10). The reversal times were measured over a distance of 138 km and the true velocity was calculated to be 6.49 km/sec. A velocity corresponding to layer 2 was not observed.

Using wide angle reflections and refraction arrivals from sonobuoy records, five velocities were measured (Table 11). When the measured velocities and thicknesses were converted into two-way vertical travel time and compared to reflection line 24, sedimentary horizons were visible.

If a layer 2 velocity of 5.76 km/sec is assumed, a maximum thickness of 2.3 km could be present at a depth of 11 km. Velocities typical of the mantle were not recorded so a velocity of 8.0 km/sec was assumed. Minimum depth to the M discontinuity was calculated to be 26 km.

PROFILE 7

This line is located in the Newfoundland Basin (Fig. 11). A reflection profile was also obtained adjacent to the refraction line. Arrivals from explosives shot along this line yielded one well reversed velocity typical of the mantle (Table 12). Expendable sonobuoys launched along the line measured a velocity typical of layer 2 (Table 13). The layer 2 velocity had its intercepts adjusted for irregular topographic expression of basement on the reflection record. This was the only line where such an adjustment was possible because it was the only line with complete seismic reflection coverage.

The technique of firing the air gun to the buoys resulted in detection of refractors at each end of the line with velocities of 6.06 km/sec and 7.12 km/sec and comparable reversal times within 0.2 sec of each other in a distance of 45 sec. Sedimentary velocities were not observed and an average velocity of 2.33 km/sec was assumed. This gave a 2 km thickness for the sedimentary column, which was compatible with the reflection profile.

RESULTS FROM EXPENDABLE SONOBUOYS

The results of expendable sonobuoys launched on the Hudson 72-021 and 73-011 cruises can be divided into three groups: (a) those over the Sohm Abyssal Plain, (b) those in the vicinity of the Newfoundland Fracture zone, and (c) three expendables in other areas that will be considered separately (Table 14).

Table 14.

Expendable Sonobuoy Results

SOHM ABYSSAL PLAIN

Sonobuoy Number	Velocity (km/sec)	Thickness (km)	Remarks	Sonobuoy Number	Velocity (km/sec)	Thickness (km)	Remarks
1	1.50	4.70	water	3	1.50	5.08	water
	2.11	2.03	reflector		2.15	0.75	reflector
	3.22	1.67	reflector		2.75	2.00	refractor
	4.32	1.83	refractor		4.95		refractor
	5.36		refractor				
4	1.50	4.88	water	5	1.50	4.83	water
	2.00	2.45	reflector		2.00	1.74	assumed
	3.90	2.12	reflector		2.17	0.41	assumed
	6.50		refractor		4.00	1.64	refractor
					4.70	2.35	refractor
					6.25		refractor
7	1.50	5.03	water	8	1.50	5.14	water
	2.00	0.86	assumed		2.00	1.22	assumed
	2.34	2.22	assumed		2.65	0.95	assumed
	5.60		refractor		4.56		refractor
9	1.50	5.05	water	14	1.50	5.06	water
	2.18	0.92	reflector		1.70	1.06	reflector
	2.56	1.79	reflector		3.13	1.00	reflector
	3.85		refractor				
15	1.50	4.91	water	16	1.50	4.97	water
	1.83	0.83	reflector		1.92	0.69	reflector
	2.19	0.82	assumed		2.38	1.18	assumed
	3.51	1.57	reflector		3.71	1.62	refractor
	4.83		refractor		5.73		refractor
17	1.50	4.89	water	18	1.50	5.03	water
	2.02	1.70	reflector		2.02	0.50	reflector
	3.45	2.13	assumed		2.30	1.62	assumed
	5.75		refractor		3.84	1.07	reflector
					5.80		refractor
19	1.50	4.93	water	20	1.50	4.93	water
	2.28	1.92	reflector		2.17	2.08	reflector
	4.10	1.74	refractor		3.50	0.24	refractor
	5.75		refractor		4.85		refractor
12	1.50	5.04	water	21	1.50	5.25	water
	2.41	2.11	reflector		2.20	1.08	assumed
	3.87	2.46	assumed		3.75	0.53	reflector
	5.87		refractor		5.43		refractor
22	1.50	4.57	water	23	1.50	4.02	water
	2.09	1.44	reflector		1.94	1.24	reflector
	3.95	0.84	reflector		3.70	1.49	assumed
	4.96		refractor		5.67		refractor
27	1.50	3.74	water	28	1.50	Incomplete, lack of data	
	2.14	0.99	reflector		2.14		
	3.80	0.88	assumed		5.36		
	4.95		refractor				
NEWFOUNDLAND BASIN AREA							
29	1.50	4.71	water	32	1.50	4.74	water
	2.12	1.48	reflector		3.02	3.09	reflector
	3.60	1.53	assumed		5.55		refractor
	5.23		refractor				
EASTERN MARGIN OF THE GRAND BANKS							
33	1.50	3.79	water				
	1.64	0.66	reflector				
	2.60	1.28	reflector				
	3.48	2.23	reflector				
	5.82		refractor				

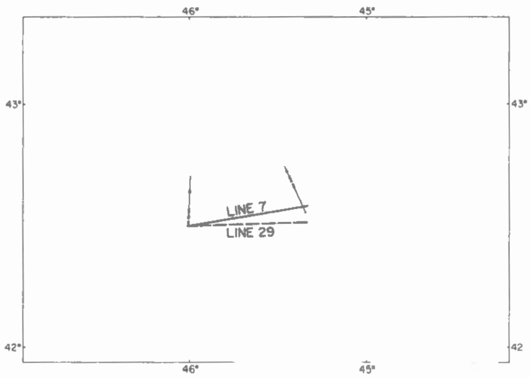


Figure 11. Lines 7 and 29. The heavy solid lines describe the ship's path while shooting the explosives, the solid lines with dashed portions and arrows indicate the sonobuoy drift and direction, the dashed portion of the line is the sonobuoy position during the firing of the explosives. The long dashes give accompanying seismic reflection line coverage.

From the Sohm Abyssal Plain three horizons were identified on the vertically incident reflection profiles. Horizons A, β, and B correspond to those described by Ewing and Ewing (1968). The velocities measured from the area fall into three groups. A consistent velocity for the deeper sediments of about 3.68 km/sec was measured. It is in the range of 2.7 to 3.7 km/sec, which Houtz et al. (1968) measured and called consolidated sediments associated with reflector β. The depth to this layer corresponds to horizon β on the vertical incident reflection profiles.

Velocities within the upper sedimentary layers fell into two groups, 1.7 to 2.2 km/sec and 2.2 to 2.7 km/sec. The group from 2.2 to 2.7 km/sec correlated with Horizon A on the vertically incident reflection profiles. Houtz et al. (1968) recognized a range of sedimentary velocities from 1.7 to 2.9 km/sec that were also correlated with Horizon A on vertically incident reflection profiles. The sediments with velocities of 1.7 to 2.2 km/sec were found on the records immediately below bottom. These are similar to a group of velocities (1.6 to 2.2 km/sec) that Houtz et al. (1968) observed, and which they correlated with near surface sediments. The velocities of the two shallower sedimentary layers are not as clearly defined as the deeper sedimentary velocities because often only an average velocity can be determined from the wide angle reflection profiles. The average velocity of basement in the Sohm Abyssal Plain is 5.24 km/sec.

The vertically incident reflection profile over the Newfoundland Fracture Zone does not have layering like that seen in the Sohm Abyssal Plain. Horizons A, β, and B were not visible. In fact, the sedimentary horizons north and south of the basement and topographic high that define the fracture zone have different characteristics. North of the fracture zone contorted layering is evident while south of the fracture zone reflectors

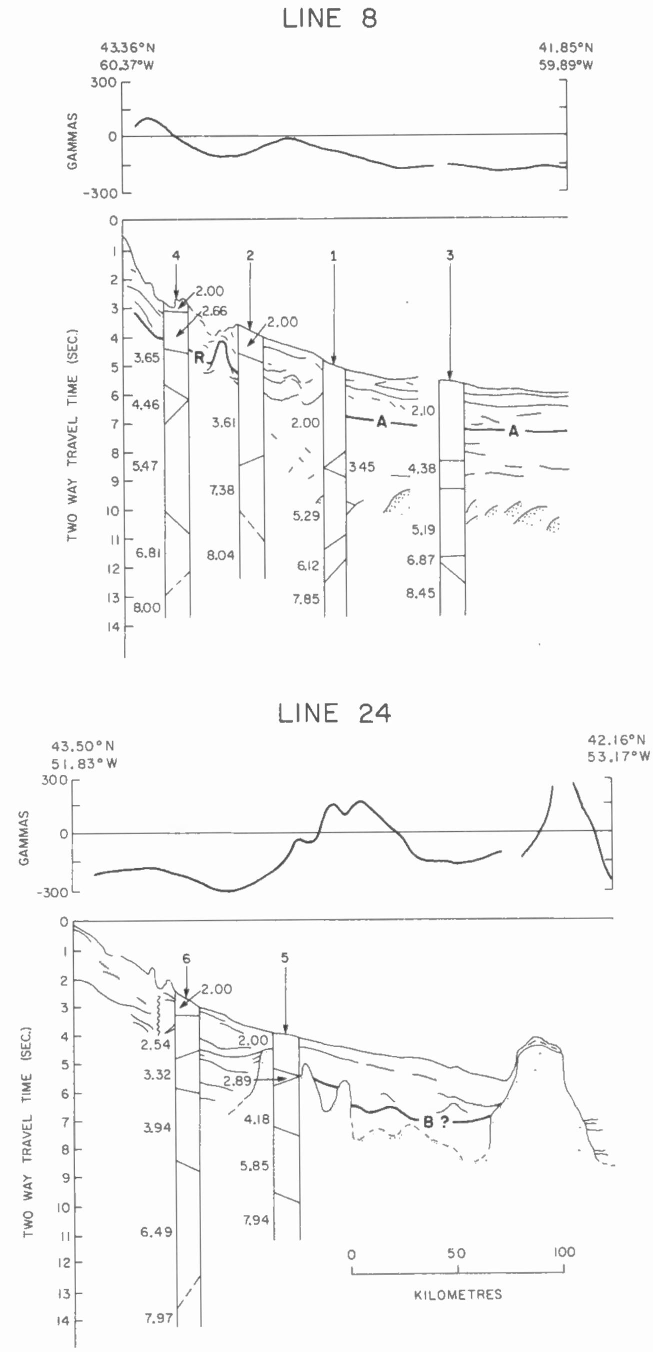


Figure 12. Seismic reflection, refraction and magnetic measurements from off the Scotian Shelf and from off the southern margin of the Grand Banks. Superimposed on line drawings of seismic reflection profiles are columns with the seismic refraction results. The numbers with arrows indicate the line numbers and positions of the seismic refraction measurements.

within the sediments are less frequent. However, in the north and south no differences can be distinguished in the velocity measurements. In this area only two groups of velocities were measured. The low range is between 1.94 to 2.14 km/sec and the high range is between 3.70 and 3.95 km/sec. The 1.7 to 2.9 km/sec layer of the Abyssal Plain group is not found here. The average basement velocity in the Newfoundland Fracture Zone area is 5.37 km/sec.

Of the three other expendable sonobuoys, two were launched in the Newfoundland Basin. Both gave good determinations of basement velocities. However, only one average measurement was obtained for the sedimentary layers.

The final expendable sonobuoy was launched on the eastern margin of the Grand Banks. Three sedimentary velocities were recorded as wide angle reflections and oceanic basement velocity was recorded as a refractor.

DISCUSSION

There are obvious contrasts when the results of refraction, reflection and magnetic measurements off the Continental Shelf of Nova Scotia and off the southern margin of the Grand Banks are assembled (Fig. 12). The data may indicate features peculiar to the way in which the formation of these margins took place in each area.

The magnetic slope anomaly parallels the entire continental margin of eastern North America south of the Grand Banks (Taylor et al., 1968; Emery et al., 1970). Several models have been proposed to explain the existence of the slope anomaly. One such model employs a 30 km wide intrusive dyke (Taylor et al., 1968); another model explains the anomaly as an "edge effect" in which a thick magnetic continental crust abuts a thin magnetic oceanic crust (Keen, 1969); a third model is based on a reversely magnetized oceanic layer 2 in the magnetic quiet zone next to normally magnetized oceanic material in the crust beneath the slope anomaly (Emery et al., 1970). We favour the "edge effect" model. A similarly shaped double-peaked magnetic anomaly is observed on the southern margin of the Grand Banks on lines 9, 10, 16, and 24 (Fig. 1). However, when line 8 south of Sable Island is compared with line 24 on the southern margin of the Grand Banks, it is noticeable that the landward crest of the magnetic anomaly is prominent on line 8 while the seaward crest is prominent on line 24. The continental basement on the Scotian Shelf has an unusually high susceptibility of about .0035 emu (Keen et al., in press). This undoubtedly contributed to the dominant landward crest of the anomaly. The seaward crest of the magnetic anomaly along line 24 is produced by a thickened layer 2 as indicated by reflection and refraction observations. Therefore, the relative prominence of the two crests of the magnetic anomalies is due to local geological variations.

When layer 2 is traced on reflection profile 24, oceanic basement is visible 65 km from the shelf break. Refraction line 5, located at the position of the last landward oceanic basement observed on line 24, indicates the presence of normal oceanic layer 2 and a total crustal thickness of 17 km. Refraction line 6 (Fig. 12) indicates a sediment thickness of 8 km underlain by a layer with a velocity of 6.49 km/sec. This is similar to previous velocity measurements on the adjacent shelf. At two locations on the Grand Banks, Press and Beckman (1954) measured continental subbasement velocities of 6.10 and 6.43 km/sec. The calculated minimum depth to M discontinuity under line 6 is 27 km. The general impression derived from the data is that refraction line 6 measured continental structure and refraction line 5 measured oceanic structure. If this is a correct conclusion, the transition between continental and oceanic material took place in a narrow zone, approximately 36 km wide.

Reconstructions of the original positions of the continents suggest that strike-slip motion would occur between Africa and the southern margin of the Grand Banks (Le Pichon et al., 1971; Keen and Keen, 1971). Off the Queen Charlotte Islands there is a known transform fault along which strike-slip motion has occurred. The width of the fault from confirmed continental material to known oceanic material, as determined from reflection records, is about 20 km (Keen and Keen, 1971). Layer 2 seaward of the transition zone in that region is block faulted. Layer 2 as seen on line 24 on the southern margin of the Grand Banks is also characterized by irregular steep-sided blocks. Thus the margins south of the Grand Banks and off the Queen Charlotte Islands exhibit similar narrow transition zones from continental to oceanic material and irregular, steep-sided topography on oceanic basement.

The Scotian margin is known to have formed by rifting between Africa and North America (Emery et al., 1970). The transition between known oceanic crust as observed on reflection line 8 and the continental shelf is 90 km or less. Therefore, the maximum width of the continent-ocean transition is 90 km. Results from refraction line 4 located 38 km from the shelf show the presence of probable continental material. A velocity of 5.47 km/sec with a thickness of 8 km was measured on line 4. This is similar to a velocity of 5.40 km/sec with a thickness of 9.2 km measured for crystalline basement on the continental shelf near Sable Island by Dainty et al. (1966). The minimum depth to the M discontinuity was calculated to be 28 km. Results from refraction line 2 between lines 1 and 4 reveal 8 km of sediment overlying a velocity of 7.38 km/sec. On this line no 5 km/sec layer was measured. However, 3 km of a velocity typical of layer 2 could be present if the refracted arrivals did not occur as first arrivals but as later arrivals. This is not a reasonable assumption. Firstly, no second arrivals were observed on the air gun lines and secondly, if layer 2 was present and thicker than 1.5 km it would have been recorded on the seismic reflection records above the water multiple. Therefore the structure beneath line 2 is not typical of oceanic or continental crust and it would appear that the transition takes place between refraction lines 1 and 4 in a zone 75 km wide or less.

In summary, when the measurements south of the Grand Banks and south of Sable Island are compared, magnetic slope anomalies are found in both areas. The most realistic interpretation of the seismic data implies that on the southern margin of the Grand Banks the transition between continental and oceanic material takes place in a zone of about 36 km or less while off the Scotian Shelf the transition takes place in a zone of about 75 km or less. The character of basement in the former area is irregular, steep-sided blocks while in the later area the topographic expression of basement is much less rugged.

These results may reflect differences in the way plate motions took place in each area. The southern margin of the Grand Banks exhibits characteristics of a fracture zone along a continental margin while the Scotian margin exhibits features that could be formed by the rifting apart of two continental masses.

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