ATLANTIC GEOSCIENCE CENTRE

Lithoprobe East 1985

South Grand Banks

Seismic Reflection Processing Report

By

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I. FIELD RECORDING

GENERAL INFORMATION

Date Shot	: March, 1985
Shot By	: Geophysical Service Inc.
Vessel	: M/V Polar Prince

INSTRUMENTATION

Recording System	: Texas Instruments DFS V
Format	: SEG-B Phase Encoded / 1600 BPI
Gain Mode	: IFP
Field Filter	: 5.3 Hz @ 18 dB/octave 64 Hz @ 72 dB/octave
Number of Traces	: 120
Record Length	: 20 seconds
Sample Rate	: 4 milliseconds
Tape Polarity	: Normal SEG Convention

ENERGY SOURCE

Type	: Airgun Array
Volume	: 7780 cubic inches
Pressure	: 2000 PSI
Timing Controller	: TIGER II
Firing Delay	: 51.2 milliseconds
Average Operating Depth	: 12 metres

RECORDING GEOMETRY

Shotpoint Interval	: 50 metres
Group Interval	: 25 metres
Type of Hydrophone	: Texas Instruments Acceleration Cancelling
Number of Hydrophones/Group	: 27
Spacing of Hydrophones	: 0.926 metres
Number of Hydrophones/Group	: 120
Near Group	: 120
Average Near Group Offset	: 247 metres
Average Cable Depth	: 20 metres
Multiplicity	: 30 Fold

POSITIONING SYSTEM

Primary System	: Loran
Secondary System	: Satellite

II. DATA PROCESSED

Line	Shotpoints	TMAX (sec)	Kilometres
85-1	101 - 6649	20.0	327.450
85-2	101 - 861	20.0	38.050
85-2A	953 - 1525	20.0	28.650
85-2B	1688 - 4192	20.0	125.250
85-2C	4355 - 6615	20.0	113.050

Total : 5 Lines			632.450

III. DIGITAL PROCESSING SEQUENCE

1. **Demultiplex**
   SEG-B field tapes demultiplexed and output in TIPEX (Texas Instruments Petroleum Exploration) format.

2. **Resample**
   Minimum phase anti-alias resampling from 4 ms to 8 ms.

3. **Edits**
   Bad traces and shot records edited as necessary from field monitors and shot record displays.

4. **True Amplitude Recovery**
   Amplitude recovery exponentiation of 7 dB/s applied from 0 to 3.5 seconds. Spherical divergence approximation of T scaler was also applied.

5. **Pre-Deconvolution Mute**
   Muting of first break and refractive energy. Mute applied from 100 ms (near offset) to 3500 ms (far offset) with reference to surface.

6. **Designature Design**
   A wavelet has been statistically derived from each shot record and a filter designed from each wavelet to remove the signature of the source, its ghost, instrument response, the common portion of the receiver ghosts and shallow reverberations. This filter, convolved with the wavelet, should yield a broad band zero phase wavelet.

7. **Velocity Filter (Common Shot Domain)**
   F-K filtering of coherent linear noise applied in shot domain. Dips greater than +9 ms/trace and less than -6 ms/ trace are attenuated to a maximum frequency of 62.5 Hz.

8. **Designature Application**
   The filter designed in step 6 above is applied to each shot. Designing this filter prior to velocity filtering eliminates over-whitening of the low end of the spectrum.

9. **Pre-Stack Deconvolution**
   A gapped deconvolution in shot domain to attenuate surface and short period multiples. The following schedule of deconvolution was applied across the survey area:

Line	Deconvolution Applied (No. of filters x filter length; gap)	Range of Application (Shotpoints)
85-1	1 x 400 ms; 40 ms	101 - 6649
85-2	1 x 400 ms; 40 ms	101 - 861
85-2A	1 x 400 ms; 40 ms	953 - 1313
85-2A	1 x ZW2 ; ZW	1314 - 1525
85-2B	1 x ZW2 ; ZW	1688 - 2467
85-2B	None Applied	2468 - 4192
85-2C	None Applied	4355 - 6615

Autocorrelation start and end times:

Near Offset = 200 ms / 16000 ms
Far Offset = 3200 ms / 16000 ms
Datum = water bottom

Note : Deconvolution with length ZW1 = 0.3 x two way water bottom time.
ZW2 = 1.3 x two way water bottom time.
Gap ZW = 0.9 x two way water bottom time.

Water bottom values are stored in each trace header.

10. **Brute Stack Display**
A single, time variant velocity function from surface to twenty seconds is used to stack each line. This velocity function is designed to best fit the known geologic boundaries. Displays of these stack data are then output using every fourth common depth point.

11. **Velocity Analysis**
Velscan process, incorporating nine consecutive 30 fold depth points at three kilometre intervals, used to interpret normal moveout corrections in shallow section from surface to seven seconds.

12. **Iso-Velocity Knee-Link Displays**
Interpreted velocities from step 11 are input to a velocity contouring program to plot iso-velocities and velocity inflection points at the same scale as the brute stacks in step 10. These plots are then interpreted and an interval velocity model built to conform with expected geologic interface in the deep section. The intent of this process is is to correctly place deep horizons in time where normal moveout is nonexistent and therefore more conventional velocity routines are disabled.

13. **Multi-Velocity Displays (Multivels)**
Five stack panels are generated, V1 through V5, where V3 uses the interval velocity information interpreted from steps 10, 11 and 12 and converts these velocities into time/velocity pairs from surface to twenty seconds. The four remaining panels are then calculated using a +/- delta t technique to "fan" velocities, two slower and two faster, from the interpreted centre velocity. These plots are then interpreted by the client for continuity with depth and accuracy with respect to the geologic model. A final velocity model is built at three kilometre intervals on each line and used for moveout correction prior to the stack process.

14. **Common Depth Point Gather**
The data is reorganized from shot to common depth point domain.

15. **Equalization**
Thirty fold common depth point gathers equalized over an eighteen second gate with reference to the water bottom.

16. **Static Corrections**
Cable and shot corrected to surface.

17. **Normal Moveout Corrections**
The velocity models generated in steps 10 through 13 for each line are used for final NMO corrections.

18. **Trace Mute**
Full fold achieved at 3.5 seconds.

19. **Common Depth Point Stack**
Thirty fold diversity power stack was utilized. Diversity-scaled stack, based on power, scales down the stronger contributors (traces) in a common depth point set and may provide better signal-to-noise ratio, especially where total trace power is dominated by noise.

A recovery scaler, SQTF (Square Root - Fold), was performed in the process. This operation is equivalent to 1/SQRT[nxm] where n is the time variant true fold and m is the maximum fold.

20. **Post Stack Deconvolution**

A gapped deconvolution designed to attenuate long period multiples. The following schedule of deconvolution was applied across the survey area:

Line	Deconvolution Applied (No. of filters x filter length; gap)	Range (Shotpoints)	White Noise
85-1	1 x 400 ms; ZW	101 - 6649	1.0%
85-2	1 x 400 ms; ZW	101 - 861	1.0%
85-2A	1 x 400 ms; ZW	953 - 1525	1.0%
85-2B	1 x 400 ms; ZW	1688 - 1900	1.0%
85-2B	1 x ZW2 ; ZW	1901 - 2465	1.0%
85-2B	1 x 4000 ; ZW	2466 - 3600	1.0%
85-2B	1 x 4000 ; ZW	3601 - 4192	1.0%
85-2B	1 x 4000 ; ZW	3601 - 4192	1.0%
85-2C	2 x 4000 ; ZW	4355 - 6615	1.0%/10.0%

Note :

a) ZW gap is equal to 0.9 x two way water bottom time.
b) ZW2 filter length is equal to 1.3 x two way water bottom time.
c) 1 x 4000 ms; gap = ZW deconvolution from shotpoint 3601 - 4192 on 85-2B are two consecutive deconvolution operations performed independent of each other.

All autocorrelation gate times from above deconvolution schedule are 500 ms start and 16000 ms end with reference to the water bottom. In the case of line 85-2C there has been a 25% overlap in autocorrelation gates between the two filters and a 50% overlap in filter application.

21. **Time/Space Variant Filter**

A bandpass filter technique, varied in both time and space, was applied as follows:

Frequencies (Hz)	
2, 8, 35, 45	applied from water bottom to 1000 ms above the Avalon Unconformity.
0, 6, 25, 35	applied at the Avalon Unconformity plus 1000 ms.

22. **Time Variant Scaling**
Two consecutive scalers were applied with reference to the water bottom. The first, SQRTTVS (square root time variant scaling), was applied in two 200 ms gates and then 1000 ms gates to maximum time for each line. The next scaler, FLATTVS (flat time variant scaling), was applied using two 1000 ms gates followed by a 15000 ms gate.

SQRTTVS operation : A scaler is applied such that square root of the average output power in each gate is equal to:

$\sqrt{1000} \times \sqrt[4]{P}$ where P is the average input power.

FLATTVS operation : A scaler is applied such that the square root of the average power in each gate is equal to 1000 millivolt level.

23. **Running Mix**
A seven on one equally weighted running mix with a move-up rate of one trace was applied to all lines prior to display. This was used to attenuate random noise removal and to help enhance continuity of deep reflectors.

24. **Display**
Two displays were generated in decimated form. The first was displayed at 25 metre depth point interval (every second trace) and the next displayed at 50 metre depth point interval (every fourth trace). The time scale for each of the two sections was 2.5 cm/second.

25. **Migration**
F-K migration was performed on the deconvolved stack traces output from step 20 in the processing sequence. Energy dispersion was invoked for dips greater than 50 degrees.

26. **Time/Space Variant Filter**
As/step 21.

27. **Time Variant Scaling**
As/step 22.

28. **Running Mix**
As/step 23.

29. **Post Stack Velocity Filter (DIPCON)**
Dipcon was applied on lines 85-2B and 85-2C, shotpoints 2050 to 4187 and 4355 to 6615, respectively. Dipcon is a post stack velocity filter process designed, in this case, to reject residual, dipping multiple energy and control wavefronting post-migration. The result is to enhance deep reflector continuity.

30. **Display**
As/step 24.

IV. TESTING

A very comprehensive test sequence was developed for use on five test zones across the survey area. These test zones were:

Location Line		Shot Points	Description
1)	85-1;	SPN's 2100 - 2300	Shallow water depths - Shallow basement
2)	85-1;	SPN's 5100 - 5300	Shallow water depths - Horseshoe Basin
3)	85-2B;	SPN's 2260 - 2460	Medium water - Continental shelf
4)	85-2B;	SPN's 3100 - 3300	Deep water - Continental shelf
5)	85-2C;	SPN's 5300 - 5500	Deep water - Oceanic crust

The tests applied to each location were as follows:

1. **True Amplitude Recovery**
   Amplitude recovery exponentiation was tested and displayed in shot record format using 6 dB/second, 7 dB/second and 8 db/second with start time equal to water bottom and each value tested to 3.0 and 3.5 second end times. The chosen value for all areas was 7 dB/second from water bottom to 3.5 seconds. A spherical divergence approximation was applied to all test panels.

2. **Noise Analysis - Shot Record Displays**
   Selected shots, at a 50 shot point interval, on each test location were displayed. Each location was then transformed to F-K domain and displayed showing relative dB levels of energy from zero to eighty hertz. These T-X and F-K displays are then interpreted for linear noise trains which are measured for apparent velocity and suitability for rejection by velocity filter.

3. **Velocity Filter**
   Shot domain velocity filtering cuts of 7,-4 / 9,-6 / 11,-6 / and 15,-6 milliseconds/trace were displayed in shot record format in order to gauge the removal of linear noise from the data.

4. **Pre-Stack Deconvolution / Demultiple**
Several deconvolution operators were tested on each location as follows:

Location 1	-	a) 1 x ZW1;	gap = ZW
		b) 1 x ZW2;	gap = ZW
		c) 1 x 400 ms;	gap = ZW
Location 2	-	a) 1 x ZW2;	gap = ZW
		b) 1 x 400 ms;	gap = 40 ms
Location 3	-	a) 1 x ZW2;	gap = ZW
		b) 1 x ZW2;	gap = 40 ms
Location 4	-	No Deconvolution Pre-Stack Testing	
Location 5	-	No Deconvolution Pre-Stack Testing	

The above deconvolution operators were tested with and without demultiple (locations 4 & 5 demultiple only) to check most effective multiple rejection processing.

* Note : Filter with length ZW1 = 0.3 x two-way water bottom time
ZW2 = 1.3 x two-way water bottom time
Gap with length ZW = 0.9 x two-way water bottom time

Water bottom values are stored in each individual trace header.

5. **Deconvolution After Stack**
All test locations 1 through 5, were tested with the following deconvolution operations:

a) 1 x ZW1; gap = ZW
b) 1 x ZW2; gap = ZW
c) 1 x 400 ms; gap = 48 ms
d) 1 x 400 ms; gap = ZW
e) 1 x 4000 ms; gap = ZW (locations 4 & 5 only)
f) 1 x 4000 ms; gap = 48 ms (locations 4 & 5 only)
g) 1 x 4000 ms; gap = 64 ms (locations 4 & 5 only)

6. Time Variant Filter

Seven time invariant and time variant panels were displayed as follows:

	Hertz	Time (ms)
a)	0, 0, 8,12	0
b)	8,12,17,23	0
c)	17,23,27,33	0
d)	27,33,45,55	0
e)	35,45,52,62	0
f)	0, 0,20,30	7000
	0, 0,15,25	9000
g)	2,10,40,50	0
	2,10,30,40	200
	2,10,25,35	1000
	2,10,20,30	6000

7. Time Variant Scaling

The following scaling panels were produced:

a) 500 ms FLATTVS
b) 1000 ms FLATTVS
c) 1500 ms FLATTVS
d) 200 ms SQRTTVS
e) 500 ms SQRTTVS
f) 200 ms SQRTTVS followed by 1000 FLATTVS
g) 200 ms SQRTTVS followed by 20000 ms Equalization

Note : SQRTTVS (square root time variant scaling - A scaler is applied such that the square root of the average output power in each gate is equal to:

$\sqrt{1000} \times \sqrt[4]{P}$ where P is the average input power.

FLATTVS (Flat time variant scaling) - A scaler is applied such that the square root of the average power in each gate is equal to 1000 millivolt level.

Equalization : Same as FLATTVS but only one gate length may be applied.

8. Post Stack Mix

Several mix combinations were selected for testing:

a) 5 on 1 running mix equally weighted
b) 7 on 1 running mix equally weighted
c) 9 on 1 running mix equally weighted
d) 7 on 1 decimated mix equally weighted

V. PROCESSING PERSONNEL

The following employees of Geophysical Service Incorporated contributed to the processing of this project:

NAME	COUNTRY OF CITIZENSHIP	MAN-MONTHS ON PROJECT
Neil Baker	Canada	1.00
Debra Belsey	Canada	0.02
William Bilozer	Canada	0.03
Claudia Bowman	Canada	1.00
Denis Conne	Canada	0.10
Peter Evdokimoff	Canada	0.75
Dot Hale	Canada	1.25
Peter Jeffrey	Canada	1.00
Sally McCraven	U.S.A.	0.75
Al Rempel	Canada	0.20

		6.10

VI. DISCUSSION

On a whole data quality was very good, although in some areas multiple interference was a problem. These areas, typically due to sloping water bottoms, are a continuing problem in data processing. Some relief was possible by the use of dipfiltering after stack, allowing deeper primary reflections a greater degree of continuity.

A very major time consuming problem was the necessity for software updates in order to handle twenty second record length and long line lengths in processing. All software modifications were installed prior to completion of the survey.

Respectfully submitted by Geophysical Service Incorporated.

Neil Baker
Party Chief

NB/lsc