ATLANTIC GEOSCIENCE CENTRE

LITHOPROBE EAST 1984

Seismic Reflection Processing Report

By

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I. FIELD INSTRUMENTATION

GENERAL INFORMATION

Dates Shot	:	September 23 to October 4, 1984 October 6 to October 16, 1984
Shot By	:	Geophysical Service Incorporated
Vessel	:	M/V Polar Prince

INSTRUMENTATION

Amplifier	:	Texas Instruments DFS V
Format	:	SEG-B Phase Encoded / 1600 BPI
Gain Mode	:	IFP
Field Filter	:	5.3 Hz @ 18 dB/octave 64.0 Hz @ 72 dB/octave
Number of Traces	:	120
Record Length	:	15.0 to 19.0 seconds
Sample Rate	:	4 milliseconds
Tape Polarity	:	SEG Normal

ENERGY SOURCE

Type	:	Four String Tuned Airgun Array with an added Fifth String
Volume	:	6320 cubic inches
Gun Pressure	:	2000 PSI
Timing Controller	:	Tiger II
Firing Delay	:	51.2 milliseconds
Average Operating Depth	:	12 metres

RECORDING CONFIGURATION

Shot Point Interval	:	50 metres
Group Interval	:	25 metres
No. of Hydrophones per Group	:	27
Hydrophone Interval (within group)	:	0.93 metres
Group Length	:	25 metres
Number of Groups	:	120
Fold	:	30
Near Trace	:	120
Average Near Trace Offset	:	290 metres
Average Cable Depth	:	20 metres

POSITIONING SYSTEM

Primary System	:	SPOT
Secondary System	:	Satellite with LORAN

II. DATA PROCESSED

The following lines were processed in this project:

Line	Shot Points	TMax (sec)	Kilometres
1	101 - 321	15.0	11.000
1A	456 - 804	15.0	17.400
1B	941 - 1704	15.0	38.150
2A	229 - 890	15.0	33.050
2B	988 - 3519	15.0	126.550
2D	3633 - 4799	15.0	58.300
2E	101 - 321	15.0	11.000
2F	322 - 1250	15.0	46.400
2H	2098 - 4058	15.0	98.000
3	101 - 2140	15.0	101.950
3A	2141 - 5064	15.0	162.000
	5065 - 5381	17.0	
3B	5382 - 7416	17.0	138.550
	7417 - 8153	18.0	
3C	8154 -10295	18.0	107.050
3D	296 - 1035	18.0	114.700
	1036 - 2478	19.0	
	2479 - 2590	18.0	

			1064.100 Kms

The following lines were reprocessed from 0.0 to 5.0 seconds:

Line	Shot Points	TMax (sec)	Kilometres
2A	229 - 890	5.0	33.050
2D	3633 - 4799	5.0	58.300

			91.350 Kms

III. DIGITAL PROCESSING SEQUENCE

(A) Lines 1, 1A, 1B, 2A, 2B, 2D, 2E, 2F, 2H and 3

1. Demultiplex
   This data was processed to 15.0 seconds.

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

3. Edits
   Bad traces and shot records were edited from the data as necessary.

4. True Amplitude Recovery
   Correction for spherical divergence and inelastic attenuation. The exponential gain factor used to compensate for inelastic attenuation was 6.0 dB/sec, applied from the water bottom to the water bottom plus 5.0 seconds. Spherical divergence was compensated for with a "time in seconds" X "input amplitude" correction.

5. Pre Deconvolution Mute
   Muting of first break energy. Muting was applied from 500 ms on the near trace offset, to 6000 ms on the far trace offset.

6. Velocity Filter (Common Shot Domain)
   Filtering of coherent linear noise trains from the shot domain. Dips greater than +9 msec/trace and less than -4 msec/trace were attenuated to a maximum frequency of 62.5 Hz.

7. Designature
   A deconvolution technique to remove the source signature, system response, short period reverberations, and receiver ghosts. Standard marine wavelet mode was used, with one inverse filter design / and application per shot.

   Note: In this processing, both the filter design and application of that filter was done after the velocity filtering.

8. Trace to Trace Equalization
   9000 ms design gates were used, and the scaler computed such that the square root of the average power within the gate is equal to 1000.

9. Deconvolution
A gapped deconvolution was applied to the shot records to further attenuate any surface or short period multiples. One filter with a length equal to 1.3 X two way water time was designed, with a gap of 0.9 X two way water time (for a total length = 2.2 X two way time ms). The autocorrelation gate length was 6000 ms starting at 500 ms for the near trace, and at 6000 ms for the far trace, referenced to the surface. 1.0% additive white noise was used.

10. Velocity Analysis
Five function continuous velocity analysis at specified locations. This analysis consists of stacking the data with each of the five space invariant velocity functions, and comparing the resulting stack sections. The velocity functions and the analysis locations were chosen by the client.

11. Static Corrections
Datum statics were applied to correct shots and receivers to surface positions.

12. Normal Moveout Corrections
Using stacking velocities derived from the analysis described in step 10.

13. Trace Mute
Trace muting was done from 500 ms on the near trace to full fold at 6000 ms on the far trace. The ramp length was 48 ms and was referenced to surface.

14. CDP Stack
30 fold (3000%) diversity power stack with true amplitude recovery scaling. The diversity stack scaling gate length was 200 ms.

15. Deconvolution
A gapped deconvolution was applied to the stacked data for further multiple attenuation. One filter with a live length equal to 1.3 X the two way water time was designed, with a gap of 0.9 X the two way water time (for a total length = 2.2 X two way time ms). The autocorrelation gate length was 6000 ms starting at 500 ms, referenced to the surface, and 1.0% additive white noise was used.

16. Time/Space Variant Filtering
The following filters were applied:

Corner frequencies (Hz)		Full-On Times (Space Variant)
0/5	35/45	Approx. the two way time to the geologic basement.
0/5	20/25	Two way basement time plus 2000 ms.

17. Time/Space Variant Scaling
A SQRTTVS scaler was designed, using 2 X 200 ms, 1 X 500 ms, and 14 X 1000 ms design gates, started 10 ms above the water bottom.

The above was followed by a FLATTVS scalar designed from 2 X 500 ms, 1 X 1000 ms, and 1 X 13000 ms design gates, started 10 ms above the water bottom. The scalars are applied by linear interpolation from the gate centres.

Note: SQRTTVS scalars are designed and applied to each gate so that the square root of the average power in each gate is equal to the quadratic root of the average input power, times the square root of 1000.

FLATTVS scalars are designed and applied to each gate so that the square root of the average power in each gate is equal to 1000.

18. Running Mix
A seven on one running mix, with each trace weighted equally, was applied to the data. There was a moveup of two traces between mixes resulting in a 2 to 1 decimation of the data.

19. Display on Film
Displayed with a vertical scale of 2.5 cm per second, and a horizontal scale of 20 traces per cm.

20. Wave Equation Migration
Kirchoff dip-controlled, F/K domain migration. Energy dispersion was invoked for dips greater than 30 degrees. The input to migration was the post stack deconvolved traces conditioned as follows:

- Time domain noise suppression on 300 ms gates, smashing 3 adjacent traces.

21. Time/Space Variant Filtering
The following filters were applied:

Corner frequencies (Hz)		Full-On Times (Space Variant)
0/5	35/45	Approx. the two way time to the geologic basement.
0/5	20/25	Two way basement time plus 2000 ms.

22. Time/Space Variant Scaling
A SQRTTVS scalar was designed, using 2 X 200 ms, 1 X 500 ms, and 14 X 1000 ms design gates, started 10 ms above the water bottom.

The above was followed by a FLATTVS scalar designed from 2 X 500 ms, 1 X 1000 ms, and 1 X 13000 ms design gates, started 10 ms above the water bottom. The scalars are applied by linear interpolation from the gate centres.

23. Display on Film
Displayed with a vertical scale of 2.5 cm per second, and a horizontal scale of 20 traces per cm.

(B) Line 3A - Note: Much of this sequence is the same as for Lines 1 through 3, described previously, so only the changes are elaborated on here.

1. Demultiplex

2. Resample

3. Edits

4. True Amplitude Recovery

5. Pre Deconvolution Mute

6. Velocity Filter (Common Shot Domain)

7. Designature

8. Trace to Trace Equalization

9. Deconvolution
   A gapped deconvolution was applied to the shot records to further attenuate any surface or short period multiples. One filter with a length equal to 1.3 X two way water time was designed, with a gap of 0.9 X two way water time (for a total length = 2.2 X two way time ms). The autocorrelation gate length was 6000 ms starting at 500 ms for the near trace, and at 6000 ms for the far trace, referenced to the surface. 1.0% additive white noise was used.

   Note: On this line, the deconvolution was applied only to shot points 2141 to 5152.

10. Velocity Analysis
    30 fold, seven function velscans were run on nine consecutive depth points, every 3.0 kilometres, to determine demultiple velocities.

11. Demultiple
    An F/K multiple attenuation process which uses differential moveout to discriminate against certain multiple velocities. In this case the velocity functions determined in step 10 were used to attenuate the simple water bottom and pegleg multiples.

    Note: On this line, the demultiple was applied only to shot points 4231 to 5381.

12. Velocity Analysis
    Five function continuous velocity analysis to determine stacking velocities.

13. Static Corrections

14. Normal Moveout Corrections
    Using stacking velocities derived from the analysis described in step 12.

15. Trace Mute

16. CDP Stack

17. Deconvolution

18. Time/Space Variant Filtering

19. Time/Space Variant Scaling

20. Running Mix

21. Display on Film

22. Wave Equation Migration

23. Time/Space Variant Filtering

24. Time/Space Variant Scaling

25. Display on Film

(C) Lines 3B, 3C and 3D - Note: Much of this sequence is the same as for lines 1 through 3, described previously, so only changes are elaborated on here.

1. Demultiplex

Line 3B:	Shot points 5382 - 7387 processed to 17.0 seconds
	Shot points 7388 - 8152 processed to 18.0 seconds
Line 3C:	Processed to 18.0 seconds
Line 3D:	Shot points 296 - 1006 processed to 18.0 seconds
	Shot points 1007 - 2478 processed to 19.0 seconds
	Shot points 2479 - 2590 processed to 18.0 seconds

2. Resample

3. Edits

4. True Amplitude Recovery

5. Pre Deconvolution Mute

6. Velocity Filter (Common Shot Domain)

7. Designature

8. Trace to Trace Equalization

9. Velocity Analysis
   30 fold, seven function velscans were run on nine consecutive depth points, every 3.0 kilometres, to determine demultiple velocities.

10. Demultiple
    An F/K multiple attenuation process which uses differential moveout to discriminate against certain multiple velocities. In this case the velocity functions determined in step 10 were used to attenuate the simple water bottom and pegleg multiples.

11. Velocity Analysis
    Five function continuous velocity analysis to determine stacking velocities.

12. Static Corrections

13. Normal Moveout Corrections
    Using stacking velocities derived from the analysis described in step 12.

14. Trace Mute

15. CDP Stack

16. Deconvolution
A gapped deconvolution was applied to the stack data for further multiple attenuation.

Lines 3B and 3C : One filter with a live length equal to 1.3 X the two way water time was designed, with a gap of 0.9 X the two way water time (total length = 2.2 X two way time ms).

Line 3D : One filter design with a live length equal to 0.3 X the two way water time, and a gap equal to 0.9 X the two way water time (total = 1.2 x two way time).

Whole trace autocorrelation gates and one percent additive white noise was used.

17. Time/Space Variant Filtering

18. Time/Space Variant Scaling

19. Running Mix

20. Display on Film

21. Wave Equation Migration
Kirchoff dip-controlled, F/K domain migration, energy dispersion was invoked for dips greater than 30 degrees. The input to migration was the post stack deconvolved traces conditioned as follows:

- Time domain noise suppression on 300 msec gates, smashing 3 adjacent traces.
- 300 msec gate SQRTTVS scaling.

22. Time/Space Variant Filtering

23. Time/Space Variant Scaling

24. Display on Film

(D) Reprocessing Lines 2A and 2D

1. Demultiplex
   This data was processed to 5.0 seconds.

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

3. Edits
   Bad traces and shot records were edited from the data as necessary.

4. True Amplitude Recovery
   Correction for spherical divergence and inelastic attenuation. The exponential gain factor used was 3.0 dB/second, applied from the water bottom to water bottom plus 5.0 seconds.

5. Pre Deconvolution Mute
   Muting of the first break energy. Muting was applied from 300 ms on the near trace offset, to 4200 ms on the far trace offset.

6. Designature
   A deconvolution technique to remove the source signature, system response, short period reverberations, and receiver ghosts. Standard marine wavelet mode was used, with one inverse filter design / and application per shot.

7. Velocity Analysis
   30 fold, seven function velscans were run on nine consecutive depth points, every 3.0 kilometres, to determine demultiple velocities.

8. Demultiple
   An F/K multiple attenuation process which used differential moveout to discriminate against certain multiple velocities. In this case the velocity functions determined above were used to attenuate the simple water bottom multiples and their pegs.

9. Normal Moveout Corrections
   Using velocities determined from the original processing.

10. Velocity Filter (Common Shot)
    Filtering of coherent linear noise trains from the NMO-corrected shot records. Dips greater than +7 msec/trace and less than -4 msec/trace were attenuated to a maximum frequency of 62.5 Hz.

11. Trace to Trace Equalization
    5000 ms design gates were used, and the scalar computed such that the square root of the average power within the gate is equal to 1000.

12. Static Corrections
Datum statics were applied to correct shots and receivers to surface positions.

13. Trace Mute
Trace muting was done from 250 ms on the near trace to full fold at 4000 ms on the far trace. The ramp length was 48 ms and was referenced to surface.

14. CDP Stack
30 fold (3000%) straight stack (equal weights) with true amplitude recovery scaling.

15. Transmission Compensation
The gap option was used and a shallow non-reverbatory horizon was tracked. A design gate length of 3500 ms, additive noise of 20 percent, and a 17 trace power spectral averaging was used on this data.

16. Time/Space Variant Filtering
The following filter was applied:

Corner frequencies (Hz)		Full-On Times
3/8	35/45	0 ms

17. Time/Space Variant Scaling
A FLATTVS scalar was designed from 1000 ms gates, starting at 100 ms, referenced to the surface. The scalars were applied by linear interpolation from the gate centres.

18. Display on Film
Displayed with a vertical scale of 5.0 cm per second, and a horizontal scale of 20 traces per cm.

IV. TESTING

There were two basic test locations. First, in a shallow water area, Line 2B shot points 2188 to 2287 and secondly, in a deeper water environment, Line 3D shot points 420 to 620.

1. Noise Analysis
   Power/Phase spectra and F/K contour displays of shot records.

   These were run on raw field records to check data quality and the bandwidth of the field data, as well as helping to choose velocity filter and designature test parameters.

   They were also run on the shot records after velocity filtering and designature to check and qualify the results.

2. True Amplitude Recovery Tests
   Run to choose an optimum exponential decay exponent and the cut-off time. Values tested were:

Exponential Decay Factor (dB/sec)	End Time (msec)
4.0	5000
6.0	3000
6.0	5000

   All the above were started at the water bottom, with the end times being relative to the water bottom.

   6.0 dB/sec with an end time of 5000 msec was used in production.

3. Velocity Filter/Pre Stack Trace Mix
   Velocity cuts of (+9, -4) and (+12, -4) msec/trace to a maximum frequency of 62.5 Hz in the shot domain were tested.

   Velocity filter on NMO-corrected shots, cuts of (+4, -4) was also tested (after NMO you can use more severe cuts, and thus also get more background noise suppression), and finally a test was run with the (+12, -4) velfilt being followed by NMO correction and the second velocity filter, (+4, -4) cuts, being applied.

   As an alternative to the F/K domain velocity filter for a coherent linear noise suppression, a pre stack, shot domain trace mix was also tested.

   This was a 5 trace running mix, moveup = 1, with the traces being mixed weighted 1:2:3:2:1, applied after NMO in the shot domain.

The process chosen for production was a velocity filter with cuts of (+9, -4) msec/trace. This gave the best noise suppression, while making sure no valid structural dips were being attenuated.

4. Designature
Standard marine designature was tested versus offset dependent designature (this breaks the shot into 4 groups of offsets to design and apply the operator) to determine if higher noise levels on the near traces were affecting the Desig design.

Designature before or after the velocity filtering was also looked at.

The result of these tests was to go with the normal sequence of standard designature being both designed and applied after the velocity filter for production.

5. Pre stack shot domain filter test
A pre stack filter test was run to determine if the signal energy was confined to a narrow bandpass, especially deeper in the data. The following filters were tested:

Filter	Corner Frequencies
1	0, 0, 3, 7
2	3, 7, 8, 12
3	8, 12, 13, 17
4	13, 17, 18, 22
5	18, 22, 23, 27
6	0, 0, 8, 12
7	23, 27, 28, 32
8	8, 12, 17, 23
9	17, 23, 26, 34
10	26, 34, 36, 44
11	36, 44, 46, 54
12	0, 0, 26, 34

The result of this test was inconclusive and no pre stack filtering was done in production.

6. Outside Trace Mute
Due to the presence of a very high velocity, 4000 - 5000 m/sec, refraction at surface, the outside trace mute was varied during the testing.

The trace mute used in production was from 500 msec at the near offset to 6000 msec at the far offset.

7. Demultiple
Demult was tested on the shallow water location, shot points 2188 - 2287 Line 2B and on a deep water location, Line 3D.

Single pass demult (velocity function for simple water bottom multiples) versus two pass demult (first pass velocity for simple water bottom multiples, second pass velocity for pegleg multiples) was tested. No inside trace mute was used.

It was concluded that demult was not effective in the shallow water location and that only the simple water bottom multiples were being attenuated in the deep water location. Thus a single pass demultiple was run in production on the parts of the prospect where the two way water bottom reflection time was >/= 500 msec.

8. Pre Stack Deconvolution
The following predictive "decons" were tested:

a) 1 filter, length = ZW1*, Gap = ZW*
b) 1 filter, length = ZW2, Gap = ZW
c) 1 filter, length = 80 msec, Gap = 60 msec
d) 1 filter, length = 240 msec, Gap = 60 msec

All the above had a 1% white noise level and the autocorrelation gates started just below the pre deconvolution mute.

ZW decons use the two way water bottom time stored in the trace headers to spatially vary the operator length and gap to follow the water bottom.

* ZW : 0.9 X two way water bottom arrival time
ZW1 : 1.2 X two way water bottom arrival time
ZW2 : 2.2 X two way water bottom arrival time

The gap = ZW, 1 X ZW2 operator decon was chosen for use in production.

9. Stack Tests
Diversity power stack and a weighted stack were tested versus straight stack. The diversity power stack looks at the average power of all traces contributing to the stack within a specified window (200 msec in this case), and then scales down any anomalously high amplitudes to that value.

The weighted stack scales down traces within the gather, based on offsets. The scalars used in this case were "Hanning" scalars that scale down the near traces.

The best result was the diversity stack and this was used in production.

10. Post Stack Deconvolution
The following "decons" were tested:
(on Line 2B)

a) Gap = 250 msec, Operator Length = 400 msec
b) Gap = 60 msec, Operator Length = 80
c) Gap = 60 msec, Operator Length = 120
d) Gap = 60 msec, Operator Length = 240
e) Gap = ZW msec, Operator Length = ZW1
f) Gap = ZW msec, Operator Length = ZW2

All the above had a 1% white noise level, and were tested with and without Decon before stack on the input. Tests (e) and (f) were repeated on Line 3D.

A Gap = ZW, 1 X ZW2 decon after stack was used on the entire prospect. (Except the deep part of Line 3D where the operator length had to be shortened.)

11. Dip Filter
Post stack dip filtering to attenuate linear noise was tested as follows:

a) Keep zone of -4 msec/trace to +4 msec/trace
Reject dips of +6 msec/trace (+/- 10%)

b) Keep zone of -5 msec/trace to +5 msec/trace
Reject dips of +6 msec/trace (+/- 10%)

The position of dip filter in the sequence before or after deconvolution, was also tested.

Dip filtering was not used in production.

12. Post Stack Filter Test
The following filter panels were run:

Filter	Corner Frequencies
1	0, 0, 8, 12
2	3, 7, 13, 17
3	8, 12, 18, 22
4	13, 17, 23, 27
5	18, 22, 28, 32
6	23, 27, 33, 27
7	28, 32, 38, 42
8	38, 42, 48, 52
9	0, 0, 18, 22
10	3, 7, 18, 22
11	3, 7, 28, 32
12	3, 7, 38, 42
13	0, 0, 28, 32
14	13, 17, 28, 32

The filter chosen for production was:

0, 5, 35, 45 at water bottom
0, 5, 20, 45 at sedimentary basement

for line 3, and:

0, 0, 20, 30 at 7000 msec
0, 0, 15, 25 at 9000 msec

for lines 1 and 2.

13. Scaling Test
The following scaling tests were run:

a) 3000 msec gates, Type = FLATTVS
b) 5000 msec gates, Type = FLATTVS
c) 1000 msec gates, Type = SQRTTVS
d) 3000 msec gates, Type = SQRTTVS
e) 5000 msec gates, Type = SQRTTVS

All the above had a start time = water bottom + 100 msec.

These tests were run on both lines 2B and 3D, but it was found that the deep water lines, which have a thick sedimentary section, needed different scaling, so the following additional test was run on line 3D.

-200, 200, 500, 1000 msec gates starting at 10 msec before the water bottom, Type = SQRTTVS, followed by 500, 500, 1000, 13000 msec FLATTVS gates.

This scaling was used in production for line 3, while the 1000 msec gate SQRTTVS scaling was used for lines 1 and 2.

14. Running Mix/Decimation Test
The following running mix, equally weighted, tests were run:

a) 5:1 mix, output every 2nd trace
b) 5:1 mix, output every 4th trace
c) 7:1 mix, output every 2nd trace
d) 7:1 mix, output every 4th trace
e) 9:1 mix, output every 2nd trace
f) 9:1 mix, output every 4th trace

The 7:1 mix outputting every 2nd trace was chosen for production. This was chosen over dip filtering as a means of attenuating linear noise.

V. GENERAL DISCUSSION

The overall data quality of this prospect was good, though there were a couple of unresolved issues. The main processing problem was caused by strong first and second order surface multiples. Demultiple and/or deconvolution was fairly successful in attenuating the first order multiples, but the second order multiples remained.

However, except for the part of line 3D covering the slope off the continental margin, we were able to attenuate the multiples to a point where the zone of interest was resolved fairly well. A second problem was the high refractor velocity which necessitated a severe outside trace mute - such that the water bottom reflection was lost on the shallow lines. This was a trade-off to improve the deeper part of the section, in the main zone of interest.

The third problem was a lack of continuity in the events of interest, however this is most likely due to the nature of the reflector and not necessarily related to either the acquisition or processing.

Overall section quality could be considered fair to good, especially keeping in mind the zone of interest where, hopefully, some issues were resolved and possibly some new ones were raised.

Respectfully Submitted by Geophysical Service Incorporated

Denis Conne
Party Chief

DC/lsc