# ATLANTIC GEOSCIENCE CENTRE

Lithoprobe - 1986

Gulf of St. Lawrence

# Seismic Reflection Processing Report

By

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# I. FIELD RECORDING

## GENERAL INFORMATION

Date Shot : August 1986
Shot By : GSI Party 2995
Vessel : M/V Fred J. Agnich

## INSTRUMENTATION

Recording System : DFS V
Format : SEG-B Gapped
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

## 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 : TI Two Chip Dish Hydrophone
Number of Hydrophones/Group : 27
Spacing of Hydrophones : 0.93 metres
Number of Hydrophone Groups : 120
Near Group : 120
Average Near Group Offset : 164 metres
Average Cable Depth : 12 metres
Multiplicity : 30 fold

## POSITIONING SYSTEM

Primary System : Satellite / Sonar
Secondary System : Satellite / Loran

## II. DATA PROCESSED

| Line | Shotpoints | TMAX (seconds) | Kilometres |
|---|---|---|---|
| 86-1 | 101 - 4951 | 19.3 | 242.55 |
| 86-2 | 121 - 5507 | 19.3 | 269.35 |
| 86-3 | 901 - 3575 | 19.3 | 133.75 |
| 86-3A | 101 - 646 | 19.3 | 27.30 |
| 86-3AA | 101 - 1097 | 19.3 | 49.85 |
| 86-4 | 101 - 3720 | 19.3 | 181.00 |
| 86-5 | 101 - 3539 | 19.3 | 171.95 |
| 86-5AA | 101 - 2212 | 17.0 | 105.60 |
| | | | ------- |
| Total 8 Lines | | | 1181.35 |

# 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 resample from 4 ms to 8 ms.

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

4. **Spherical Divergence Corrections**
   A spherical divergence approximation of T scalar was applied.

5. **Deconvolution**
   A gapped deconvolution in shot domain was applied to attenuate surface multiples. In application a filter with ZW2 length (1.3 x two way water bottom time) and a gap of ZW (0.9 x two way water bottom time) was found to be most effective.

6. **True Amplitude Recovery**
   Amplitude recovery exponentiation was applied to compensate for the amplitude decay with depth in recording. This parameter was very thoroughly tested and a varying factor used on individual lines. It was found that on a prospect wide analysis of the exponential gain factors applied that no one factor could be used on all lines, and it was necessary to vary the gain due to rapid changes in geology.

7. **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 receiver ghosts and shallow reverberations. This filter, convolved with the wavelet, should yield a broad band zero phase wavelet.

8. **Velocity Filter (Common Shot Domain)**
   F-K filtering of coherent linear noise applied in shot domain. Dips greater than +7 ms/trace and less than -3 ms/trace are attenuated to a maximum frequency of 80 Hz.

9. **Designature Application**
   The filters designed in step 7 above are applied to each shot. The design of these filters prior to velocity filtering eliminates overwhitening of the low end of the spectrum.

10. **Velocity Filter (Common Receiver Domain)**
    The data is organized on common receiver domain and F-K velocity filtering applied, attenuating dips greater than +14 ms/trace and less than -6 ms/trace. These velocity cuts are symmetrical to those applied in the common shot domain and have the effect of attenuating coherent linear noise received from far to near offset. A maximum frequency of 80 Hz was again passed by the velocity filtering.

11. **Equalization**
    A 15 000 ms unity scalar was applied for trace balancing across each shot record.

12. **Common Depth Point Gather**
    Shot organized files are regathered to common depth point domain.

13. **Velocity Analysis**
    An analysis of near surface (0 - 7000 ms) velocities at a three kilometre interval was used to interpret NMO corrections. The scientific authority provided velocity information for the deeper section. These velocities were then merged to give a full 0 - 20 000 ms NMO function at each location.

14. **Statics**
    Steamer and shot depth statics applied to a water bottom datum.

15. **Normal Moveout Corrections**
    The velocities derived in step 13 were applied spatially according to location of analysis.

16. **Common Depth Point Stack**
    A 30 fold common depth point stack utilizing Diversity Power Stack was used. Diversity Power Stack, based on power, scales down the stronger contributors in a common depth point set and may provide a better signal-to-noise ratio, especially where the total trace power is dominated by noise. A recovery scalar, SQTF (square root - fold), was performed in the process. This operation is equivalent to 1/SQRT(n x m) where n is the time variant true fold and m is the maximum fold.

## 17. Deconvolution

A post-stack gapped deconvolution designed to remove multiple energy was spatially varied across the project. The following schedule was used:

| Line | Deconvolution Applied (no. of filters x filter length; gap) | Range (shotpoints) |
|---|---|---|
| 86-1 | 2 x 3500 ms; ZW | 2300 - 3500 |
| 86-1 | 1 x 600 ms; ZW | 101 - 4951 |
| 86-2 | 1 x 750 ms; 72 ms | 200 - 2200 |
| 86-2 | 1 x 600 ms; ZW | 121 - 5507 |
| 86-3 | 1 x 600 ms; ZW | 901 - 3575 |
| 86-3A | 1 x 600 ms; ZW | 101 - 646 |
| 86-3AA | 1 x 600 ms; ZW | 101 - 1097 |
| 86-4 | 1 x 600 ms; ZW | 101 - 3270 |
| 86-5 | 1 x 600 ms; ZW | 101 - 3539 |
| 86-5AA | 1 x 600 ms; ZW | 101 - 2212 |

Note: a) A gap of ZW is equal to the two way water bottom time x 0.9.

b) Where a line has two deconvolution operations implied, they are, in fact, two consecutive operations run independently of each other in the order described.

## 18. Time Variant Filter

A bandpass filter technique varying in time and space with reference to the water bottom.

3, 11, 30, 40 applied from water bottom to water bottom + 1000 ms.
0, 8, 20, 30 applied from water bottom to water bottom + 3000 ms.

## 19. Time Variant Scaling

Two independent scalars, applied in a consecutive manner, were used:

a) SQRTTVS (Square Root - time variant scaling): Gate length of 200 ms applied from water bottom to 19.3 seconds.

b) FLATTVS (Unity Scaling): Gate lengths of 500 ms, 750 ms, 1000 ms and 21 000 ms applied from water bottom.

Note: Definition of scalars - refer to section IV 5) of this report.

20. **Running Mix**
    An evenly weighted mix of five consecutive traces outputting the centre trace. Move-up is one trace.

21. **Display**
    Two displays, generated in decimated form, output at 25 metre and 50 metre depth point intervals and a time scale of 2.5 cm/second.

22. **F-K Migration**
    Deconvolved stack traces input from step 17 (above) were migrated using diplimited F-K migration of 50 degrees.

23. **Time Variant Filter**
    As per step 18.

24. **Time Variant Scaling**
    As per step 19.

25. **Running Mix**
    As per step 20.

26. **Display**
    As per step 21.

# IV. TESTING

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

a) Line 1; shotpoints 4500 to 4700
b) Line 2; shotpoints 200 to 400
c) Line 2; shotpoints 3000 to 3300
d) Line 2; shotpoints 4550 to 4750
e) Line 3; shotpoints 900 to 1100
f) Line 4; shotpoints 2300 to 2600
g) Line 5; shotpoints 1650 to 1850
h) Line 5; shotpoints 2950 to 3150
i) Line 5AA; shotpoints 500 to 700
j) Line 5AA; shotpoints 1950 to 2150

The tests applied to each location were as follows:

## 1. True Amplitude Recovery - Deconvolution

The application of spherical divergence and exponential gain may be applied in either of two ways. The spherical divergence and exponential gain may be applied before any other processing or, the spherical divergence may be applied first, then a deconvolution process may be applied, and then the exponential gain may be applied. These different procedures were tested and it was found that the second method was more effective in producing a well modulated record, since the multiple energy was suppressed before the application of the exponential gain. A number of deconvolution operators were tested on test location 6. It was decided that an operator of ZW2 length (1.3 times the two way water time) and gap of ZW (0.9 times the two way water time) would be most useful at this stage in the processing, since water bottom times would be varying throughout the project.

The following tests were run on each location:
(Three shots were displayed on each.)

(1) No TAR Panel

(2) Spherical Divergence (Deconvolution)
Exponential Gain 3 dB/sec 0 to 4.0 sec

(3) Spherical Divergence (Deconvolution)
Exponential Gain 3 dB/sec 0 to 6.0 sec

(4) Spherical Divergence (Deconvolution)
Exponential Gain 3 dB/sec 0 to 8.0 sec

(5) Spherical Divergence (Deconvolution)
Exponential Gain 4 dB/sec 0 to 6.0 sec

(6) Spherical Divergence (Deconvolution)
Exponential Gain 5 dB/sec 0 to 6.0 sec

(On all the above tests the deconvolution used was one operator of ZW2 length and gap of ZW.)

As a means of testing the results of method two (split TAR) as opposed to the conventional true amplitude recovery method, the following tests were run:

(1) Spherical Divergence (Deconvolution)
Exponential Gain 3 dB/sec 0 to 6.0 sec
(2) Spherical Divergence
Exponential Gain 3 dB/sec 0 to 6.0 sec
(Deconvolution)
(3) Spherical Divergence
Exponential Gain 3 dB/sec 0 to 6.0 sec

The following decisions were made:

The application of spherical divergence, followed by deconvolution, followed by application exponential gain, was to be used on all lines. The deconvolution used was ZW2 length and gap of ZW. The exponential gain for each location was as follows:

Location 1
3.0 dB/sec from 0 to 6.0 sec

Location 2
3.5 dB/sec from 0 to 5.0 sec

Location 3
3.5 dB/sec from 0 to 5.0 sec

Location 4
3.5 dB/sec from 0 to 5.0 sec

Location 5
3.0 dB/sec from 0 to 7.5 sec

Location 6
3.0 dB/sec from 0 to 9.0 sec

Location 7
3.0 dB/sec from 0 to 9.0 sec

Location 8
4.0 dB/sec from 0 to 5.5 sec

Location 9
4.0 dB/sec from 0 to 5.5 sec

Location 10
4.0 dB/sec from 0 to 5.0 sec

Additional tests were run on test locations 6 and 7 and also on locations 8 and 9, to verify the gain factors which were chosen.

## 2. Velocity Filter

In order to test the effectiveness of velocity filtering for the removal of coherent linear noise trains in both the shot and receiver domains, the following tests were evaluated:

a) Shot Domain Velocity Filter using +12 ms/trace and -5 ms/trace
b) Shot Domain Velocity Filter using +9 ms/trace and -4 ms/trace
c) Shot Domain Velocity Filter using +7 ms/trace and -3 ms/trace

Each of the above tests were then run with symmetric common receiver (CRP) velocity filter as follows:

a) CRP Velocity Filter using +24 ms/trace and -10 ms/trace
b) CRP Velocity Filter using +18 ms/trace and - 8 ms/trace
c) CRP Velocity Filter using +14 ms/trace and - 6 ms/trace

During this stage of processing, designature, in offset dependent mode, was applied. The actual estimate of the filter is prior to shot domain velocity filtering with the application after, but before CRP velocity filtering.

The conclusion reached on the test panels was that with the significant amount of noise present while collection was taking place it would be necessary to use the harshest cuts tested, in this case a combination of shot and common receiver using the cuts tested in panel C. The noise that was to be removed was traced to interference generated by traffic in the congested shipping lanes of the St. Lawrence. It was also found that a small percentage of the noise could be attributed to both noise returning to the cable from broadside reflectors, and crab pots of local fishermen dragging on the cable. These cases were minor, however, when compared to the noise being generated by ship traffic.

## 3. Deconvolution

Several forms of deconvolution before stack were tested for their multiple attenuation capability. They were then run with and without a deconvolution after stack to test which would be most beneficial in improving the interpretability of the data set. These tests were run until all combinations and multiple passes were exhausted and the decision made that the most effective approach was to run deconvolution post-stack. This method and position in the processing sequence gave the best results for both multiple attenuation and final wavelet collapse.

The deconvolution approaches taken were as follows:

| | No. of filters x length of filter; gap | White Noise (%) | Before and/or After Stack |
|---|---|---|---|
| a) | 1 x 300; gap = 48 ms | 0.1 | Before/After |
| b) | 1 x 400; gap = 48 ms | 0.1 | Before/After |
| c) | 1 x 400; gap = ZW | 0.1 | Before/After |
| d) | 1 x 500; gap = 48 ms | 0.1 | Before/After |
| e) | 1 x 500; gap = 48 ms | 1.0 | Before/After |
| f) | 1 x 500; gap = 72 ms | 0.1 | Before/After |
| g) | 1 x 500; gap = ZW | 0.1 | Before/After |
| h) | 1 x 600; gap = 48 ms | 0.1 | Before/After |
| i) | 1 x 600; gap = 72 ms | 0.1 | Before/After |
| j) | 1 x 600; gap = ZW | 0.1 | Before/After |
| k) | 2 x 600; gap = 48 ms | 0.1 | After |
| l) | 1 x 750; gap = 48 ms | 0.1 | Before/After |
| m) | 1 x 750; gap = 48 ms | 0.1 | Before/After |
| n) | 1 x 750; gap = 72 ms | 0.1 | Before/After |
| o) | 2 x 750; gap = 48 ms | 0.1 | After |
| p) | 1 x ZW1; gap = ZW | 0.1 | Before After |
| q) | 1 x ZW2; gap = ZW | 0.1 | Before/After |
| r) | 1 x 1750; gap = 48 ms | 0.1 | Before/After |
| s) | 1 x 1750; gap = 72 ms | 0.1 | After |
| t) | 1 x 1750; gap = ZW | 0.1 | After |
| u) | 2 x 1750; gap = 48 ms | 0.1 | After |
| v) | 2 x 1750; gap = ZW | 0.1 | After |
| w) | 1 x 1200; gap = ZW | 0.1 | After |
| x) | 1 x 2000; gap = 48 ms | 0.1 | After |
| y) | 1 x 2000; gap = ZW | 0.1 | After |
| z) | 1 x 3200; gap = 60 ms | 0.1 | After |
| i) | 1 x 3500; gap = 48 ms | 0.1 | After |
| ii) | 1 x 3500; gap = ZW | 0.1 | After |
| iii) | 1 x 3500; gap = ZW | 5.0 | After |
| iv) | 2 x 3500; gap = 48 ms | 0.1 | After |
| v) | 2 x 3500; gap = ZW | 0.1 | After |
| vi) | 1 x 4000; gap = ZW | 0.1 | After |
| vii) | 1 x 4000; gap = ZW | 1.0 | After |

The locations for the above tests were:

Line 1; shotpoints 1050 to 1350
Line 1; shotpoints 2566 to 2968
Line 3; shotpoints 1470 to 2070
Line 4; shotpoints 600 to 1000
Line 5; shotpoints 2100 to 2450

Note: Not all deconvolution parameters tested were run on all locations, but varying combinations of short pre-stack and medium to long length post-stack were run on each range of shotpoints.

The decisions reached after exhaustive testing are reflected in the final processing parameters chosen and listed in the previous section of this report.

## 4. Time Variant Filter

Time variant filtering was tested on the following locations:

a) Line 1; shotpoints 4500 to 4700
b) Line 2; shotpoints 200 to 400
c) Line 2; shotpoints 3000 to 3300
d) Line 2; shotpoints 4550 to 4750
e) Line 3; shotpoints 900 to 1100
f) Line 4; shotpoints 2300 to 2600
g) Line 5; shotpoints 1650 to 1850
h) Line 5; shotpoints 2950 to 3150
i) Line 5AA; shotpoints 500 to 700
j) Line 5AA; shotpoints 1950 to 2150

Deconvolved stack traces with whole trace equalization applied were used at each test location. The bandpass filters applied were as follows:

i) None
ii) 0, 0, 8, 12
iii) 3, 7, 12, 18
iv) 3, 7, 17, 23
v) 3, 7, 21, 29
vi) 3, 7, 25, 35
vii) 3, 7, 30, 40
viii) 3, 7, 35, 45
ix) 8, 12, 17, 23
x) 17, 23, 25, 35
xi) 25, 35, 35, 45
xii) 35, 45, 45, 55
xiii) 8, 12, 75, 85
xiv) 10, 15, 65, 75
xv) 12, 18, 65, 75
xvi) 14, 20, 65, 75

Each of the filter panels used a datum of surface and were applied at zero milliseconds.

## 5. Time Variant Scaling

Several time variant scaling approaches were taken to best modulate the data with respect to the balance between very shallow and very deep data. The following scalars, with an explanation of each, were tested:

i) FLATTVS; 200 ms gates
ii) SQRTTVS; 50 ms gates followed by
FLATTVS; 200 ms gates
iii) SQRTTVS; 100 ms gates followed by
FLATTVS; 500 ms gates
iv) SLOWDGCS; 100 ms gates
v) EQ; 18000 ms gates
vi) SQRTTVS; 100 ms gates followed by
FLATTVS; 200, 500, 1000, 1000, 1000, 7000 ms gates
vii) SQRTTVS; 200 ms gates
viii) SQRTTVS; 200 ms gates followed by
EQ; 18000 ms gates
ix) SQRTTVS; 200 ms gates followed by
FLATTVS; 500, 750, 1000, 15000 ms gates
x) AMPSQR; 1500 ms gates
xi) AMPSQR; 1500 ms gates followed by
EQ; 18000 ms gates

<u>Definitions</u>:

SQRTTVS - scalar designed for each specific gate such that the square root of the average power in each gate is equal to $\sqrt{1000} \times \sqrt[4]{P}$, where P is the average input power.

FLATTVS - scalar designed for each specific gate such that the average absolute amplitude in each gate is set equal to 1000.

EQ - scalar designed such that the single design gates' average absolute amplitude is set equal to 1000.

AMPSQR - scalar designed such that the output trace amplitude values will be the square of the input amplitudes but with the same sign.

SLOWDCGS - Defines slow digital gain control scaling and is equivalent to 128 ms AGC.

## 6. Running Mix

Mix tests incorporated the use of 3 on 1, 5 on 1 and 7 on 1 running mixes. These were all produced with even weighting for each trace with the centre trace being output.

## 7. Display

Several panels of final stacked data were output in a) wiggle trace with variable density, and b) variable density only. These tests were examined to determine the best form of presenting continuity at depth.

In the variable density tests, differing amounts of trace bias were attempted. These were -10, +10, +20 and +30 bias.

## V. PROCESSING PERSONNEL

| Name | Country of Citizenship | Man Months on Project |
|---|---|---|
| Neil Baker | Canadian | 2.30 |
| William Bilozer | Canadian | 0.05 |
| Claudia Bowman | Canadian | 2.55 |
| Dot Hale | Canadian | 1.75 |
| Joan Likuski | Canadian | 1.85 |
| Al Rempel | Canadian | 0.50 |
| | | ---- |
| | | 9.00 |

## VI. CONCLUSIONS

The Gulf of St. Lawrence has long been known as an extremely difficult area in which to process seismic data. As previously noted, interference from heavy traffic in the shipping lanes and the presence of many sources of reflection in the water layer have, in the past, been cause for diminished returns on seismic sections. A hard water bottom with very little sedimentary deposits accounts for only small reflection returns in recording. Refractive energy, in most cases, have masked most returning signal in the shallow section. That signal that does return is, in turn covered by multiple energy that is 2 to 4 times greater in amplitude.

The advantages gained in a Lithoprobe study are the use of extremely powerful airgun arrays for signal penetration and a very small amount of sacrifice in near surface continuity to allow noise and multiple rejection methods to work aggressively in the attenuation of undesired energy.

This project can be viewed, from a processing standpoint, as having been most thoroughly tested and very successful. The quality of the final data set is as good, or better, than any data previously collected in the area. Continuity at depth, being the major focus of processing, is maintained and interpretable across the project area.

Respectfully submitted by Geophysical Service Incorporated.

**Neil Baker**
**Supervisor**

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