ATLANTIC GEOSCIENCE CENTRE

Lithoprobe East 1985

Northeast Newfoundland

Seismic Reflection Processing Report

By

Geophysical Service Incorporated
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I. FIELD RECORDING

GENERAL INFORMATION

Date Shot	:	September 1985
Shot By	:	Geophysical Service Inc. Party 2995
Vessel	:	M/V Fred J. Agnich

INSTRUMENTATION

Recording System	:	Trace Sequential Recording
Format	:	SEG-D
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	:	13 metres

RECORDING GEOMETRY

Shotpoint Interval	:	50 metres
Group Interval	:	25 metres
Type of Hydrophone	:	Texas Instruments 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	:	210 metres
Average Cable Depth	:	13 metres
Multiplicity	:	30 Fold

POSITIONING SYSTEM

Primary System	:	SPOT
Secondary System	:	ARGO

II. DATA PROCESSED

Line	Shotpoints	TMAX (sec)	Kilometres
85-3	102 - 957	20.0	42.800
85-3A	102 - 2633	20.0	126.600
85-3B	2734 - 7473	20.0	237.000
85-3C	7587 -10438	20.0	142.600
85-3D	715 - 1910	20.0	59.800
85-4	102 - 5349	20.0	262.400
85-4A	5447 - 8361	18.0	145.750

Total : 7 Lines			1016.950

III. DIGITAL PROCESSING SEQUENCE

1. **Demultiplex**
   SEG-D field tapes translated to processing 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. Two mutes were applied in sequence to account for rapidly varying water depths. The first is a linear mute referenced to surface and designed for shallow water areas, retaining appropriate fold near surface to resolve water bottom reflections. This mute would be inadequate at deeper water locations. The second mute is referenced to two way water bottom time and designed to "float" deeper in time with increase of water depth. Again, this mute retains near traces to resolve water bottom reflections. It is not effective in shallow water and does not mute any data until two way water bottom times approach 500 milliseconds.

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 short period 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 on individual shot records. Dips of greater than +9 ms/trace and less than -6 ms/trace are attenuated for "flat" or "up dip" water bottom data to a maximum frequency of 62.5 Hz.

   Dips of greater than +9 ms/trace and less than -9 ms/trace are attenuated for "down dip" water bottom data to a maximum frequency of 62.5 Hz.

   This strategy helped to maintain true water bottom reflections while removing as much linear noise as possible.

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. **Velocity Analysis**
Velscan process, incorporating nine consecutive 30 fold depth points at three kilometre intervals, used to interpret multiple velocities for use in F-K multiple rejection.

10. **Demultiple**
An F-K multiple rejection method where the data is common depth point gathered and "move out" corrections made with interpreted multiple velocities. These traces are then F-K transformed and a velocity "cut" made to reject multiple energy while preserving primary data. The next step is to inverse transform the traces and apply the velocity to "move in" the data having primary information intact and multiple energy removed.

Demultiple was applied on areas with water depths greater than 200 metres as follows:

Line	Water Depth Range (m)	Demult Applied
85-3	70 - 76	None
85-3A	78 - 255	SP 1604 - 2633
85-3B	249 - 1150	SP 2734 - 7473
85-3C	382 - 3860	SP 7587 -10438
85-3D	3838 - 4229	SP 715 - 1910
85-4	302 - 4178	SP 102 - 5349
85-4A	67 - 580	SP 5447 - 5712

11. **Pre-Stack Deconvolution**
A predictive deconvolution designed to attenuate surface and interbed multiples. The following schedule of deconvolution was applied across the survey area:

Line	Deconvolution Applied (No. of filters x filter length; gap)	
85-3	1 x ZW2; 48 ms	
85-3A	1 x ZW2; 48 ms	
85-3B	1 x ZW2; 48 ms	
85-3C	1 x ZW2; 48 ms	SP 7587 - 8186
	1 x ZW2; ZW	SP 8187 - 9386
	1 x ZW1; ZW	SP 9387 -10438
85-3D	1 x ZW1; ZW	
85-4	1 x ZW1; ZW	
85-4A	1 x ZW2; 48 ms	

Autocorrelation start and end times according to water depths:

0 to 1500 metres:	near offset 54 ms / 5554 ms far offset 3284 ms / 8784 ms referenced to surface
Greater than 1500 metres:	near offset -12 ms / 5488 ms far offset 1252 ms / 6752 ms referenced to 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 individual trace header.

12. **Equalization**
Thirty fold common depth point gathers were equalized over a 15 000 ms gate with reference to water bottom.

13. **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.

14. **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.

15. **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.

16. **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.

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

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

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

20. **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.

21. **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
85-3	1 x 400; ZW	102 - 957	0.1%
85-3A	1 x 400; ZW	102 - 2633	0.1%
85-3B	1 x 400; ZW	2734 - 3141	0.1%
	1 x ZW2; ZW	3142 - 4983	0.1%
	1 x 400; ZW	4984 - 7473	0.1%
85-3C	1 x 400; ZW	7587 - 7996	0.1%
	1 x ZW2; ZW	7997 - 9482	0.1%
	1 x 4000; ZW	9483 - 2852	1.0%
85-3D	1 x 4000; ZW	715 - 1910	1.0%
85-4	1 x 4000; 64	102 - 3322	1.0%
	1 x ZW2; ZW	3323 - 5198	1.0%
	1 x 400; ZW	5199 - 5248	0.1%
85-4A	1 x ZW2; ZW	5447 - 5492	0.1%
	1 x 400; ZW	5493 - 8361	0.1%

Autocorrelation start and end times:

Start = -30 ms
End = 15 000 ms
Referenced to water bottom

22. **Time Variant Filter**
A time variant bandpass filter was applied as follows:

Frequency	Time (Referenced to Water Bottom)
0,5 / 45,55	0 ms
0,5 / 35,45	5000 ms

23. **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 15 000 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.

24. **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.

25. **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.

26. **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.

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

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

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

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

IV. TESTING

Test Locations

Loc #	Line	Shot Points	Area
1	85-3A	1000 - 1200	Shallow water - Hibernia
2	85-3B	3700 - 3900	75 m water depth - Flemish Pass Slope
3	85-3B	2900 - 3100	Slope
4	85-3B	6600 - 6800	300 m water depth - Flemish Cap
5	85-3C	8700 - 8900	2000 m water depth - Slope
6	85-3C	10000 -10200	3600 m water depth
7	85-4A	8100 - 8300	Shallow - Grand Banks
8	85-4A	6100 - 6300	Shallow - Carson Subbasin Shelf
9	85-4	3900 - 4100	2000 m water depth - Slope
10	85-4	102 - 302	3000 - 4000 m water depth

1. True Amplitude Recovery

This process was used to choose optimum exponential decay exponent and cut-off time for inelastic attenuation compensation. Locations 1, 2, 4, 6, and 9 were tested with the following TAR's applied, referenced to water bottom.

Exponential Decay Factor (dB)	End Time (seconds)
6.0	3.0
6.0	3.5
6.0	4.0
7.0	3.0
7.0	3.5
7.0	4.0
8.0	3.0
8.0	3.5
8.0	4.0

2. F/K Analysis

Location 1
Shot domain velocity filtering cuts of 11, -6 and 15, -6 ms/trace.

Location 2 through 10
Shot domain velocity filtering cuts of 7, -4 / 9, -6 / 11, -6 / 15, -6 ms/trace.

3. Shot Domain Velocity Filtering

Location 1 through 10
Shot record displays with velfilt cuts of 7, -4 / 9, -6 / 11, -6, / 15, -6 ms/trace. Autocorrelation displays were also generated.

4. Velocity Analysis

Test locations 1 through 10
Two velscans were generated for each location.
Processing sequence was as follows:

a) True Amplitude Recovery
   6 dB/sec 0 to 3.5 seconds Spherical Divergence applied
b) Pre-Deconvolution Ramp
   Start/end 0/3300 Ramp Length 48 milliseconds
c) Velocity Filtering
   Cuts 9, -6
d) Designature
   Standard Marine Mode
e) Whole Trace Equalization Scaling
f) Velocity Analysis
g) Brute Stack
h) Display
   Every fourth trace

5. Pre-Stack Deconvolution / Demultiple

Decon testing in combination with demult on locations 4, 5, and 9. Shallow locations 1 and 8 had only decon before stack testing. Decons applied:

# of Filters x Filter Length; Gap

1) 1 x ZW1; ZW
2) 1 x ZW2; ZW
3) 1 x ZW2; 32 ms
4) 1 x ZW2; 48 ms
5) 1 x ZW2; 64 ms
6) 2 x ZW2; 48 ms SEPRMS 50, 100
7) 2 x ZW2; 48 ms

Note: SEPRMS = Autocorr. gate % overlap, filter application % overlap

Autocorrelation start/end times in milliseconds:

Locations 1, 4 and 8: 54/8784 for decons 1 through 5
54/10784 for decons 6 and 7
referenced to surface

Locations 5 and 9: -30/6830 for decons 1 through 5
-30/7830 for decons 6 and 7
referenced to water bottom

Displays generated were as follows:

Shot records and autocorrelations
Filtered/unfiltered stack
Autocorrelation of stack

Locations 4, 5 and 9 demultiple/decon before stack

Processing sequence as follows:

DBS --> Demult --> Stack --> Display
(Note: DBS = Deconvolution Before Stack)

Demult --> DBS --> Stack --> Display

Demult --> Stack --> Display

Deconvolution used was: 1 x ZW2 Gap 48 ms White Noise 1.001
Autocorr. start/end times -30/6830 ms

Demultiple: The negative velocity bound was 300000 m/s

The low cut frequency pass band was defined as 5 Hz
The high cut frequency pass band was defined as 62 Hz

6. Deconvolution After Stack (DAS)

Locations used were 1, 4, 8, 5, and 9

Processing sequence:

Diversity Power Stack

Filter	0,5,45,55	0 ms
	0,5,35,45	5000 ms
Scaling	SQRTTVS/Gate Length 200,200,1000 ms	
	FLATTVS/Gate Length 1000,1000,15000 ms	

Autocorrelations, raw stacks, filtered/scaled displays were generated.

Deconvolution chosen to test:

# of Filters	x	Filter Length;	Gap	Autocorr. Start/End Times
1	x	400;	32	-30/7000
1	x	400;	ZW	-30/7000
1	x	ZW2;	32	-30/7000
1	x	ZW1;	32	-30/7000
1	x	4000;	32	-30/13000
1	x	4000;	ZW	-30/13000

Datum referenced to water bottom

Two additional deconvolutions were generated on locations 4, 5, and 9:

# of Filters	x	Filter Length;	Gap	Autocorr. Start/End Times
1	x	ZW2;	ZW	-30/13000
1	x	ZW1;	ZW	-30/13000

Datum referenced to water bottom

Two displays were output: Every trace
Every second trace

7. Post-Stack Time/Space Variant Filter

Seven filters were examined. In each case the filter was non-normalized, non-smoothed 200 millisecond band pass.

Frequencies examined:

	Hertz	Time (ms)
1)	0,0,8,12	0
2)	8,12,17,23	0
3)	17,23,27,33	0
4)	27,33,45,55	0
5)	35,45,52,62	0
6)	0,0,20,30	7000
	0,0,15,25	9000
7)	2,10,40,50	0
	2,10,30,40	200
	2,10,25,35	1000
	2,10,20,30	6000

8. Time/Space Variant Scaling

The scaling decision was made from prior scaling tests on the South Grand Banks area, Atlantic Geoscience Centre 1985.

9. Post-Stack Mix

The following mix tests were generated:

1) 7 on 1 moveup 2
2) 5 on 1 moveup 2
3) 9 on 1 moveup 2
4) 5 on 1 moveup 4
5) 7 on 1 moveup 4
6) 9 on 1 moveup 4

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	1.75
William Bilozer	Canada	0.05
Claudia Bowman	Canada	2.00
Dot Hale	Canada	2.00
Tad Iwamoto	Canada	0.15
Peter Jeffrey	Canada	0.75
Al Rempel	Canada	0.50

		7.20

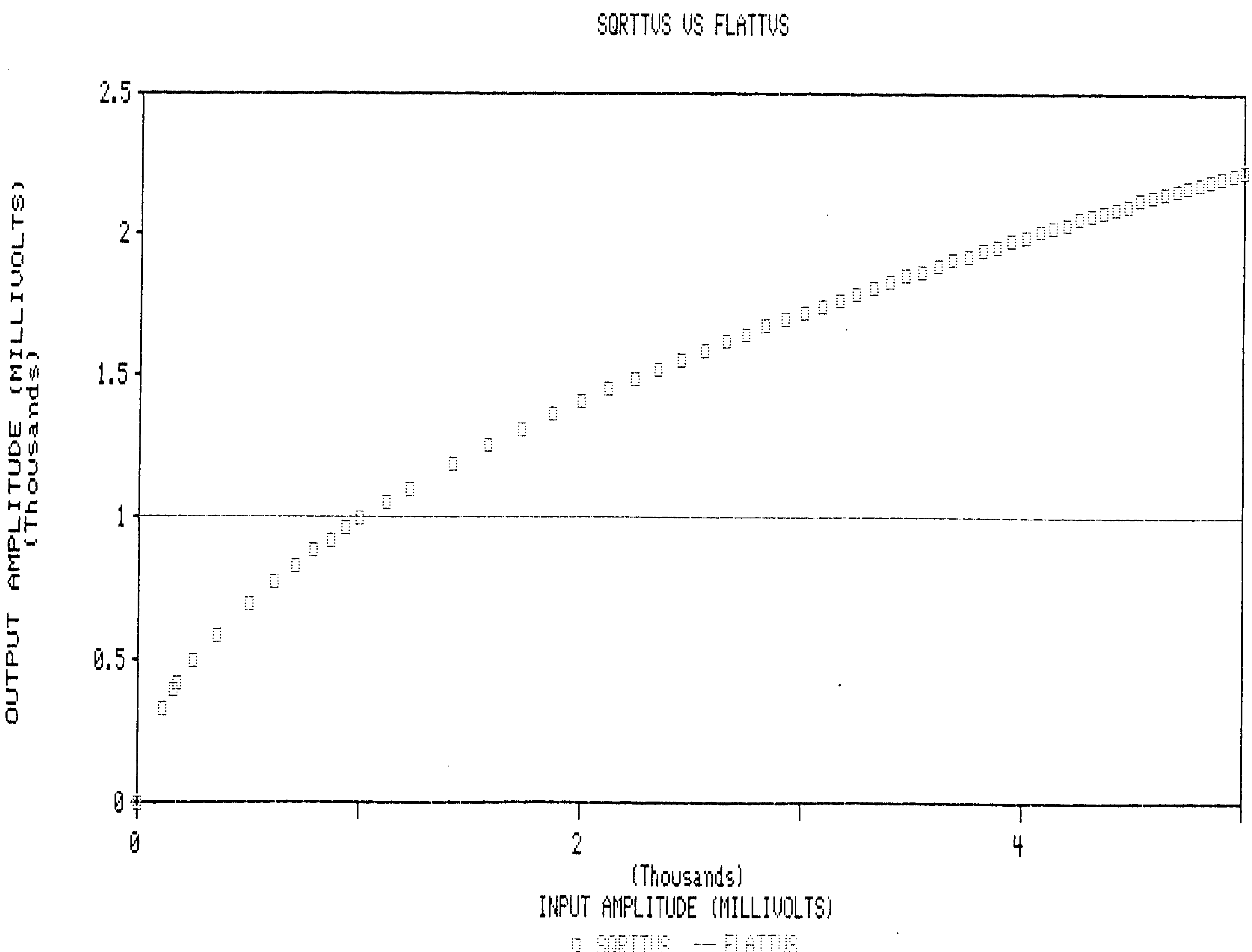
VI. DISCUSSION

Data quality across the project area was very good. Again, as in past projects, multiple rejection was the major thrust in testing and final processing. This project was very successful in this endeavor and only minor residual multiple left in processing.

Respectfully submitted by Geophysical Service Incorporated.

Neil Baker
Party Chief

NB/lsc


SQRTTVS VS FLATTVS
OUTPUT AMPLITUDE (MILLIVOLTS)
(Thousands)
2.5
2
1.5
1
0.5
0
0
2
4
(Thousands)
INPUT AMPLITUDE (MILLIVOLTS)
SQRTTVS — FLATTVS