New Zealand South Island GeopHysical Transect (SIGHT): Marine Active-Source Seismic Component – A Processing Summary

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ABSTRACT

In February and March 1996, thirteen multiple channel marine seismic lines were shot across New Zealand's South Island. These surveys were carried out as part of a joint US-NZ investigation of continental deformation at convergent plate boundaries, known as the South Island GeopHysical Transection (SIGHT) project. The lines were processed at GNS and Victoria University with the aim of providing new information on the deep structure of the Pacific/Australian plate boundary. Processing histories, and key publications resulting from this processing, are detailed in this report.

KEYWORDS

South Island Geophysical Transect, SIGHT, multiple channel, seismic, Pacific/Australian Plate Boundary, Deep

SUMMARY

This report documents the objectives and processing history of the multiple channel seismic lines shot across New Zealand's South Island in the South Island GeopHysical Transect (SIGHT) Project.

This project formed a major part of a multidisciplinary, joint US-New Zealand investigation of continental deformation at convergent plate boundaries. SIGHT was co-funded by the New Zealand Foundation for Research Science and Technology (FRST) and the USA National Science Foundation (NSF).

The Alpine Fault zone of the South Island of New Zealand marks the Pacific/Australian plate boundary, where oblique convergence of two thin continental crustal blocks has built the Southern Alps. A comprehensive range of geophysical measurements were undertaken in 1995/9 to derive a three dimensional structural model for the South Island orogen. These measurements include active source and passive seismology, magneto-telluric and electrical studies, petrophysics and gravity measurements (Davey et al. 1997). The principal field activities were an integrated onshore and onshore-offshore wide-angle seismic refraction experiment, combined with a marine MCS component on two main transects across the central part of the South Island. These transects cross the Southern Alps where the orogen is unaffected by neighbouring tectonic regimes.

The objective of this survey was to provide new information on the deep structure of the Pacific/Australian plate boundary. The survey was not designed for detailed study of near surface sedimentary records.

Multiple channel seismic data was shot by the R/V Maurice Ewing during cruise EW-9601, from 10 February 1996 to 6 March 1996. Over 41,000 shots were fired from a 20-gun tuned airgun source into a wide array of seismic receivers distributed on three major transects and several cross-lines, displayed in Figure 1.

The resulting data sets make up 13 individual seismic lines.

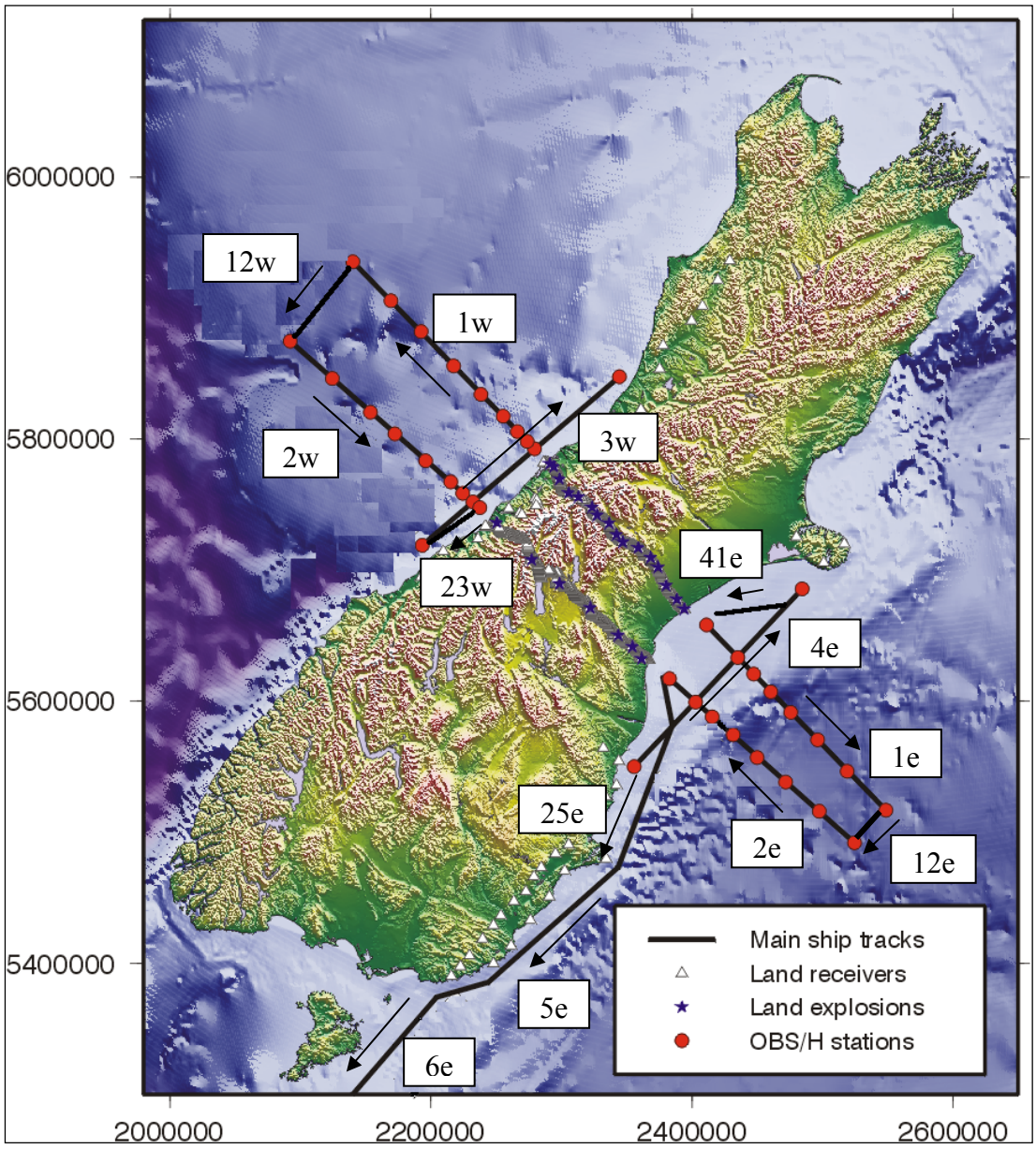

Figure 1. 13 seismic lines were shot. Lines 1w, 12w, 2w, 3w, and 23w were shot to the North West of New Zealand's South Island in the Tasman Sea. Lines 1e, 12e, 2e, 25e, 4e, 41e, 25e, 5e, and 6e were shot to the South East in the Pacific Ocean. The grid references refer to the New Zealand Map Grid.

SCIENTIFIC OBJECTIVES

SIGHT forms a major part of a joint US-New Zealand investigation aimed at improving our understanding of continental deformation at convergent plate boundaries. Mountain belts are the highly visible products of continental collisions and contain unique clues about the rheological properties of continental lithosphere and the processes by which it deforms. Within mountain belts, compression, overthrusting, and erosion often combine to expose large sections of high-grade metamorphic rocks and associated faults. Collisional mountain belts are usually paired with, and mechanically linked to, large asymmetric foreland basins that contain much of the world's hydrocarbons.

On the South Island of New Zealand, along the Pacific/Australian plate boundary, youthful oblique convergence of two thin continental crustal blocks – the submerged Lord Howe Rise to the west and the Chatham Rise/Campbell Plateau to the east – has resulted in a relatively narrow (~80 km wide) zone of active mountain building, the Southern Alps. The plate boundary has recently been forced into a condition of transpression through plate boundary reorganization processes. The South Island thus offers a natural laboratory for the study of partitioning between convergence and translation. In the central Southern Alps of New Zealand, there is also the apparent paradox that the greatest present uplift and deformation is associated with relatively low seismicity. Finally, the narrowness of the South Island provides a unique opportunity to use marine onshore/offshore seismic techniques to provide a detailed image of the boundary from both sides.

The active-source seismic survey was designed to provide fundamental knowledge on deformation in a transpressional continental orogen by identifying potential strain markers in the lithosphere on both sides of the plate boundary. By tracing these strain markers – such as the Moho, lower-crustal laminations, and crustal shear zones – the hope was to constrain whether, and at what levels of the lithosphere, strain is accommodated by brittle faulting or plastic flow. The specific goals of the survey were to obtain wide-angle onshore/offshore, marine multichannel seismic, and OBH/S wide-angle data along three profiles, two profiles across the orogen and one profile across undeformed rocks that form the orogen. The data acquired will constrain models of continental collision by providing information on:

- Crustal thickness across the orogen
- Seismic velocity structure through the crust and upper mantle
- Structure and inferred deformation under the upthrust Southern Alps
- Change in structure across the plate boundary
- Seismic structure of the relatively undeformed crust on either side of the orogen

ACQUISITION

Survey Description

Thirteen Seismic lines were acquired by the R/V Maurice Ewing during the EW-9601 survey, from 10 February 1996 to 6 March 1996, as detailed in the cruise report

Details of the stacked lines processed from EW-9601 are given in Table 1.

Line	Length (km)	Shooting Direction	First SP[1]	Last SP	First CDP	Last CDP	Trace Length (s)	Date Shot
1e	210.688	South-East	2397099	2812549	100	16718	16	26.02.96
1w	202.125	North-West	95824	501799	100	16339	16	13.02.96
12e	37.587	South-West	2897099	2972274	148	3155	16	27.02.96
12w	94.812	South-West	532599	722224	100	7685	16	14.02.96
2e	191.288	North-West	2974049	3356624	130	15433	16	28.02.96
2w	186.250	South-East	743299	1116749	100	15036	16	15.02.96
23w	94.812	South-West	1125699	1254674	100	5259	16	16.02.96
25e	159.050	South	3357299	3675399	136	12860	16	29.02.96
3w	210.312	North-West	1266799	1688174	100	16955	16	16.02.96
4e	181.675	North-East	1732199	2096299	101	14664	16	25.02.96
41e	73.125	West	2253099	2400774	100	6007	16	26.02.96
5e	139.725	South-West	3674499	3954699	100	11308	16	29.02.96
6e	153.250	South-West	4001099	4309574	100	12439	16	01.03.96

Table 1. A summary of basic details about the seismic lines

Acquisition Parameters

The acquisition parameters were as follows:

Source Parameters

Source Type	Airgun Array
SP Interval	50 metres
Airgun Tow Depth	8 metres

Streamer Parameters

Number of Groups	104 (for west coast lines) 152 (for east coast lines)
Group Spacing	25 metres
Source-Streamer Offset	25.9 metres
Cable Length	2600 metres (for west coast lines) 3800 metres (for east coast lines)
Cable Tow depth	8 metres

Recording Parameters

Recording System	DFS-V
Recording Media	3480 cartridges
Recording Format	SEGY
Sample Interval	4 milliseconds
Recording Length	16000 milliseconds

[1] Shot Points have been given corrected values to ensure that each CDP has a distinct SP assigned to it

PROCESSING SEQUENCE

All processing was completed at GNS, with the exception of line 2w which was processed by T. Harrison as part of his Master's Thesis at Victoria University of Wellington, New Zealand.

The final processing sequence for lines 1e, 2e, 25e, 4e, 41e, 5e and 6e was:

01 **Reformat to in-house format:** 4ms sample rate
02 **Insert missing shots and channels**
03 **Source-Streamer static correction:** -11ms
04 **Trace edit:** Selected channels muted
05 **1-3-1 normalised runmix within shots**
06 **True amplitude recovery:** V^2T Spherical Divergence function
07 **Automatic and manual despike**
08 **Swell noise suppression:** 1-4-80-90 Hz band-pass filter
09 **Gap Deconvolution[2]:** 128ms Gap, 500ms Operator, 0.1% White Noise
10 **Gap Deconvolution:** 28ms Gap, 200ms Operator, 0.1% White Noise
11 **Time varying band-pass filter:** 3-10-60-70 Hz, 0-2000 ms
3-6-50-65 Hz, 2500-4500 ms
3-6-40-55 Hz, 5000-6000 ms
3-6-30-45 Hz, 7000-8000 ms
3-6-20-35 Hz, 9000-16000 ms
12 **2-window trace balance**
13 **Sort to 38 fold CDP's**
14 **Front mute:** 20ms taper
15 **NMO correction with 100%[3] stretch mute**
16 **38 fold normalised stack**
17 **Automatic despike on selected spikes**
18 **High pass frequency filter:** above 4-6 Hz
19 **Gap Deconvolution[4]:** 90ms Gap, 200ms Operator
20 **Time varying band-pass filter[5]:** 3-10-50-60 Hz, 0-2000 ms
3-6-40-55 Hz, 2500-3000 ms
3-6-30-45 Hz, 4000-5000 ms
3-6-20-35 Hz, 6000-16000 ms
21 **Gap Deconvolution[6]:** 128ms Gap, 500ms Operator
22 **Time varying band-pass filter:** 3-10-50-60 Hz, 0-2000 ms
3-6-40-55 Hz, 2500-3000 ms
3-6-30-45 Hz, 4000-5000 ms
3-6-20-35 Hz, 6000-16000 ms

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2 Line 41e: 23ms Gap, 200ms Operator, 0.1% white noise
3 Stretch mute: 100% for line 1e, 30% for line 2e, 80% for line 5e
4 Line 1e, 5e: 90ms Gap, 200ms Operator; line 2e: 28ms Gap, 200ms Operator; line 25e, 4e, 41e, 6e: 80ms Gap, 500ms Operator
5 Time varying filter for line 4e, 5e: 3-10-55-62 Hz, 0-1500 ms
3-7-45-60 Hz, 2000-3000 ms
3-6-40-55 Hz, 3500-4500 ms
3-6-35-47 Hz, 5000-6500 ms
3-6-30-45 Hz, 7000-8000 ms
3-6-20-35 Hz, 9000-16000 ms
6 Line 1e, 5e: 128ms Gap, 500ms Operator; line 2e, 25e, 6e: 116ms Gap, 500ms Operator; line 4e, 41e: steps 21, 22 not applied.

23 **Resample to 8ms:** with anti-alias filter
24 **2:1 Trace Sum**
25 **Finite Difference Migration**
26 **Output to SEG-Y and Display**

The final processing sequence for lines 1w, 12e, 12w, 23w and 3w was:

01 **Reformat to in-house format:** 4ms sample rate
02 **Insert missing shots and channels**
03 **Source-Streamer static correction:** -11ms
04 **Trace edit:** Selected channels muted
05 **1-3-1 normalised runmix within shots**
06 **True amplitude recovery:** V^2T Spherical Divergence function
07 **Automatic and manual despike**
08 **Swell noise suppression:** 1-4-80-90 Hz band-pass filter
09 **Gap Deconvolution:** 128ms Gap, 500ms Operator, 0.1% White Noise
10 **Gap Deconvolution:** 28ms Gap, 200ms Operator, 0.1% White Noise
11 **Time varying band-pass filter:** 3-10-60-70 Hz, 0-2000 ms
3-6-50-65 Hz, 2500-4500 ms
3-6-40-55 Hz, 5000-6000 ms
3-6-30-45 Hz, 7000-8000 ms
3-6-20-35 Hz, 9000-16000 ms
12 **2-window trace balance**
13 **Sort to 26 fold CDP's**
14 **Front mute:** 20ms taper
15 **NMO correction with 100%[7] stretch mute**
16 **26 fold normalised stack**
17 **Automatic despike on selected spikes**
18 **High pass frequency filter:** above 4-6 Hz
19 **Gap Deconvolution[8]:** 40ms Gap, 200ms Operator
20 **Time varying band-pass filter:** 3-10-50-60 Hz, 0-2000 ms
3-6-40-55 Hz, 2500-3000 ms
3-6-30-45 Hz, 4000-5000 ms
3-6-20-35 Hz, 6000-16000 ms
21 **Gap Deconvolution[9]:** 90ms Gap, 500ms Operator
22 **Time varying band-pass filter:** 3-10-50-60 Hz, 0-2000 ms
3-6-40-55 Hz, 2500-3000 ms
3-6-30-45 Hz, 4000-5000 ms
3-6-20-35 Hz, 6000-16000 ms
23 **Resample to 8ms:** with anti-alias filter
24 **2:1 Trace Sum**
25 **Finite Difference Migration**
26 **Output to SEG-Y and Display**

[7] Stretch mute: 35% for line 1w, 30% for line 12e, 100% for line 12w and 23w, 70% for line 3w
[8] Line 1w, 3w: 40ms Gap, 200ms Operator; line 12e, 12w, 23w: 80ms Gap, 500ms Operator
[9] Line 1w: 90ms Gap, 500ms Operator; line 12e, 12w, 23w: steps 21, 22 not applied; line 3w: 128ms Gap, 500ms Operator

The final processing sequence for line 2w was:

01 **Reformat to in-house format:** 4ms sample rate
02 **Swell noise suppression:** 0-4-80-90 Hz band-pass filter
03 **Source-Streamer static correction:** -10.7ms
04 **Trace edit:** Selected channels muted
05 **Automatic and manual despike**
06 **True amplitude recovery:** V^2T Spherical Divergence function
07 **1-3-1 normalised runmix within shots**
08 **Time varying band-pass filter**
09 **Gap Deconvolution:** 28ms Gap, 600ms Operator
10 **Gap Deconvolution:** 48ms Gap, 1000ms Operator
11 **2-window trace balance**
12 **Sort to 26 fold CDP's**
13 **NMO correction**
14 **26 fold normalised stack**
15 **Time varying band-pass filter**
16 **Gap Deconvolution:** 200ms Gap, 400ms Operator
17 **Gap Deconvolution:** 32ms Gap, 248ms Operator
18 **Automatic despike on selected spikes**
19 **2:1 Trace Sum**
20 **Coherency filter:** with frequency domain running mix, 35ms/trace
21 **Front mute:** 20ms taper
22 **Resample to 8ms:** with anti-alias filter
23 **Finite Difference Migration**
24 **Output to SEG-Y and Display**

RESULTS

The migrated sections for each of the lines are displayed in appendices A1 to A13.

FINAL PRODUCTS

The final products were archived onto CD-ROM and are now available from:

Institute of Geological and Nuclear Sciences
PO Box 30 368
Lower Hutt 6315
New Zealand

Please note that a charge will be made for the copying and delivery of these products.

Data Set	CD Number
Stack and Migration – lines 1e and 1w	CO2107
Stack and Migration – lines 12e, 12w and 2e SIGHT: Marine Active – Source Seismic Component – A Processing Summary	CO2108
Stack and Migration – lines 2w, 23w and 25e	CO2109
Stack and Migration – lines 3w and 4e	CO2110
Stack and Migration – lines 41e, 5e and 6e	CO2111

USEFUL REFERENCES

Mortimer, N., Davey, F.J., Melhuish, A., Yu, J., and Godfrey, N.J., 2002, Geological interpretation of a deep seismic reflection profile across the Eastern Province and Median Batholith, New Zealand: crustal architecture of an extended Phanerozoic convergent orogen, *N.Z. J. Geol & Geophys., 45*, 349-363.

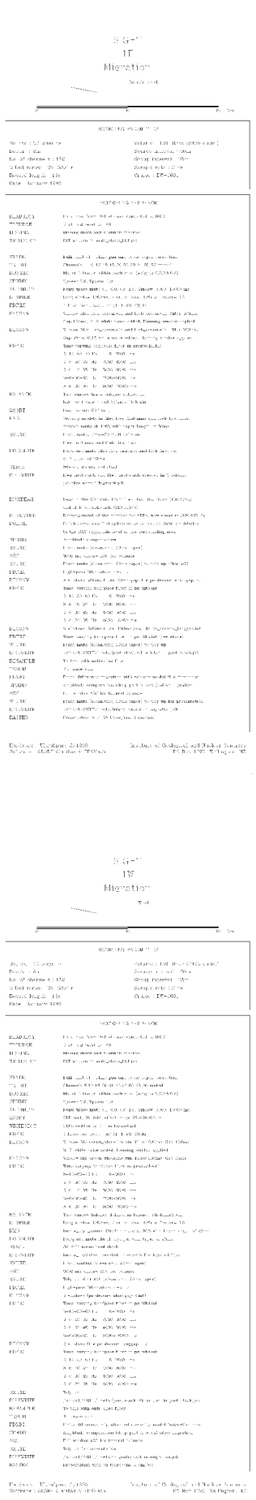
Godfrey, N.J., Davey, F., Stern, T.A., and Okaya, D., 2001, Crustal structure and thermal anomalies of the Dunedin Region, South Island, New Zealand, *J. Geophys. Res., 106*, 30,835-30,848.

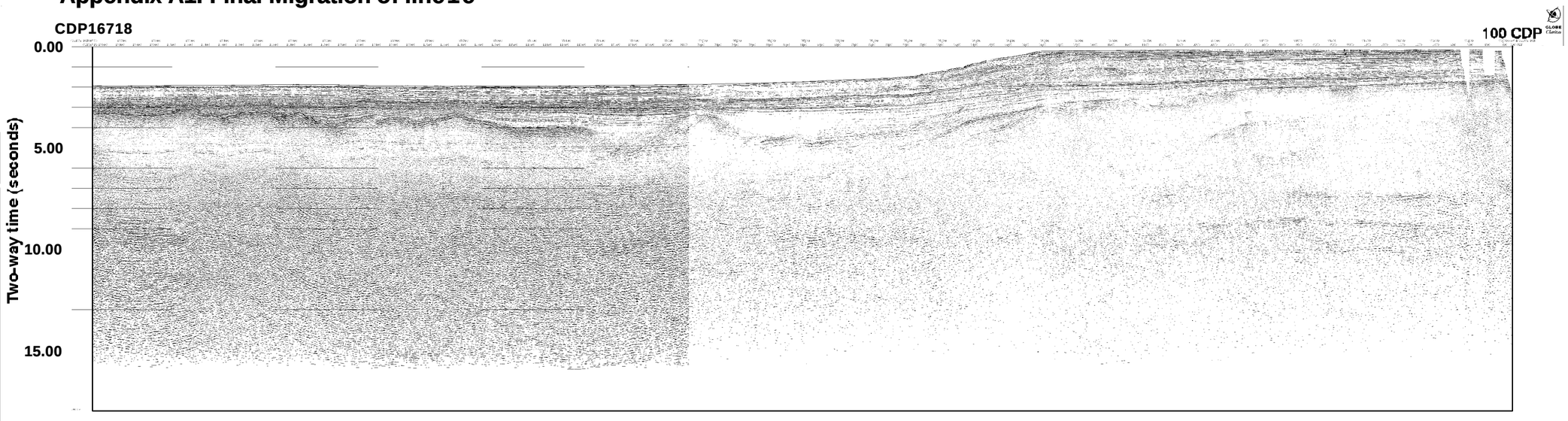
Davey, F.J., Henyey, T., Holbrook, W.S., Okaya, D., Stern, T.A., Melhuish, A., Henrys, S., Eberhart-Phillips, D., McEvilly, T., Urhammer, R., Anderson, H., Wu, F., Jiracek, G., Wannamaker, P., Caldwell, G., and Christensen, N., 1998, Preliminary results from a geophysical study across a modern, continent-continent collisional plate boundary - the Southern Alps, New Zealand, *Tectonophysics*, *288*, 221-235.

Harrison, T., 1999, Multichannel Seismic and Flexural Analysis of the Westland Sedimentary Basin, South Island, New Zealand, *Master's Thesis, University of Victoria, Wellington, New Zealand*

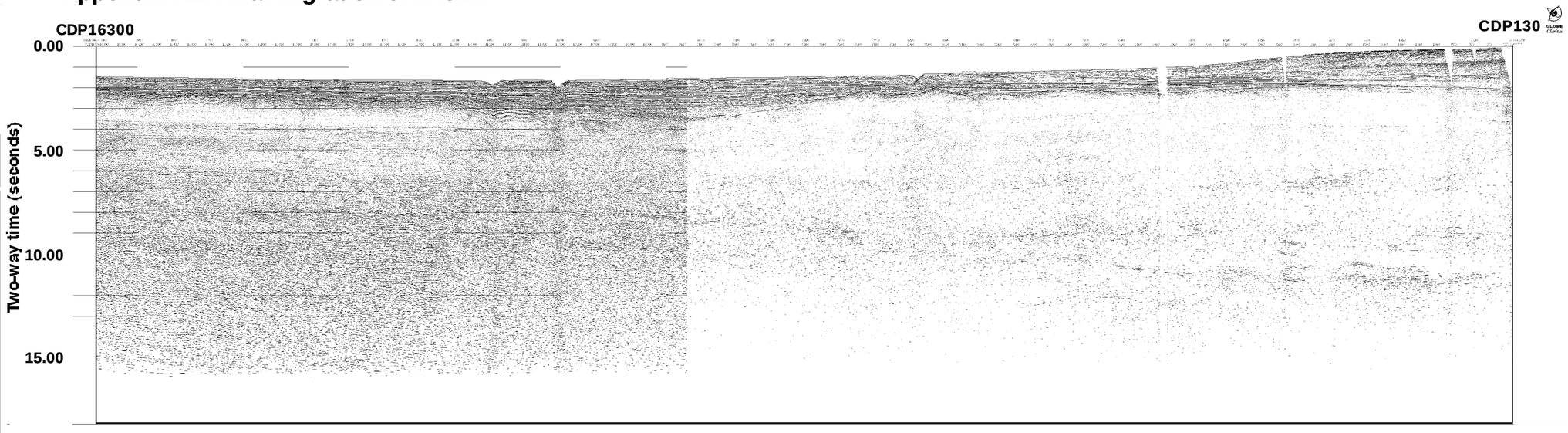
Holbrook, W.S., Davey, F.J. Cruise Report: South Island GeopHysical Transect, Cruise EW-9601A, Feb-Mar 1996.

Appendix A1. Final Migration of line1e

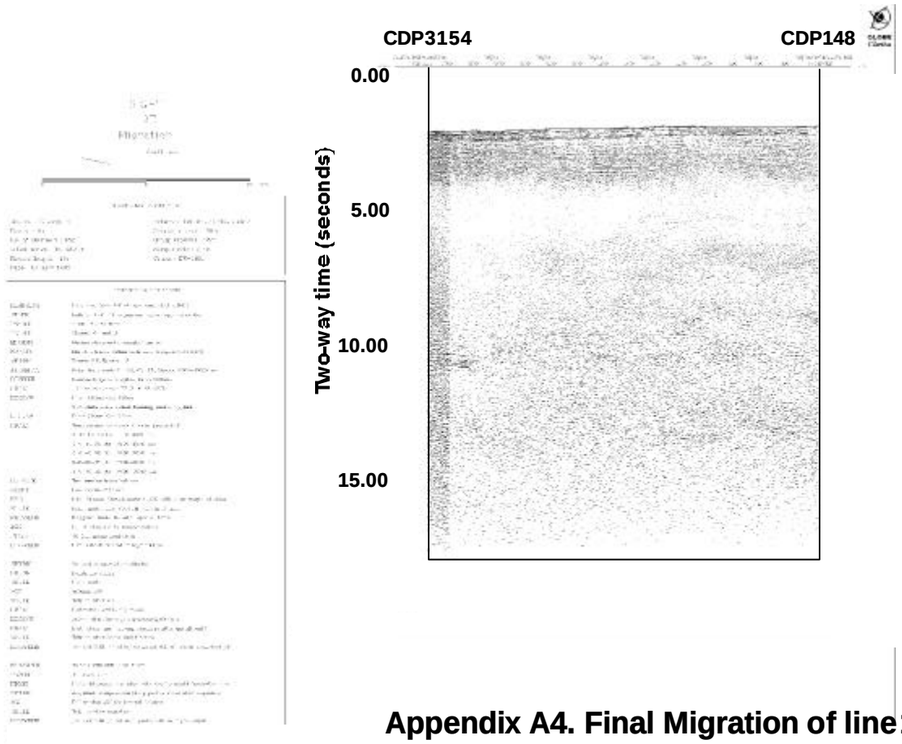




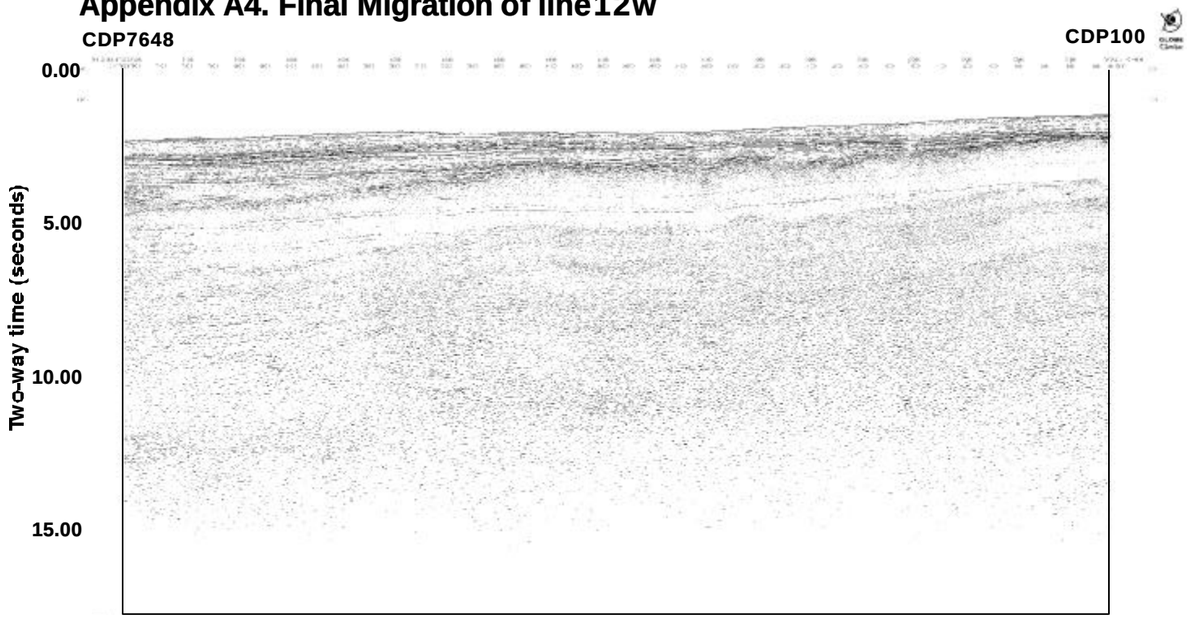
Appendix A2. Final Migration of line1w



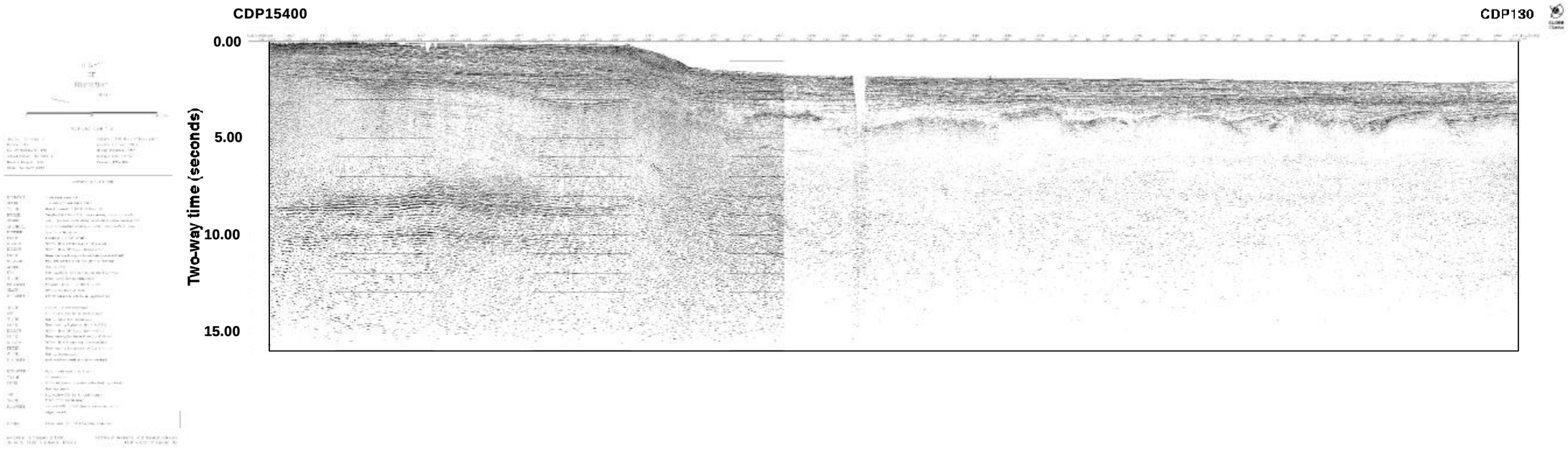
Appendix A3. Final Migration of line12e



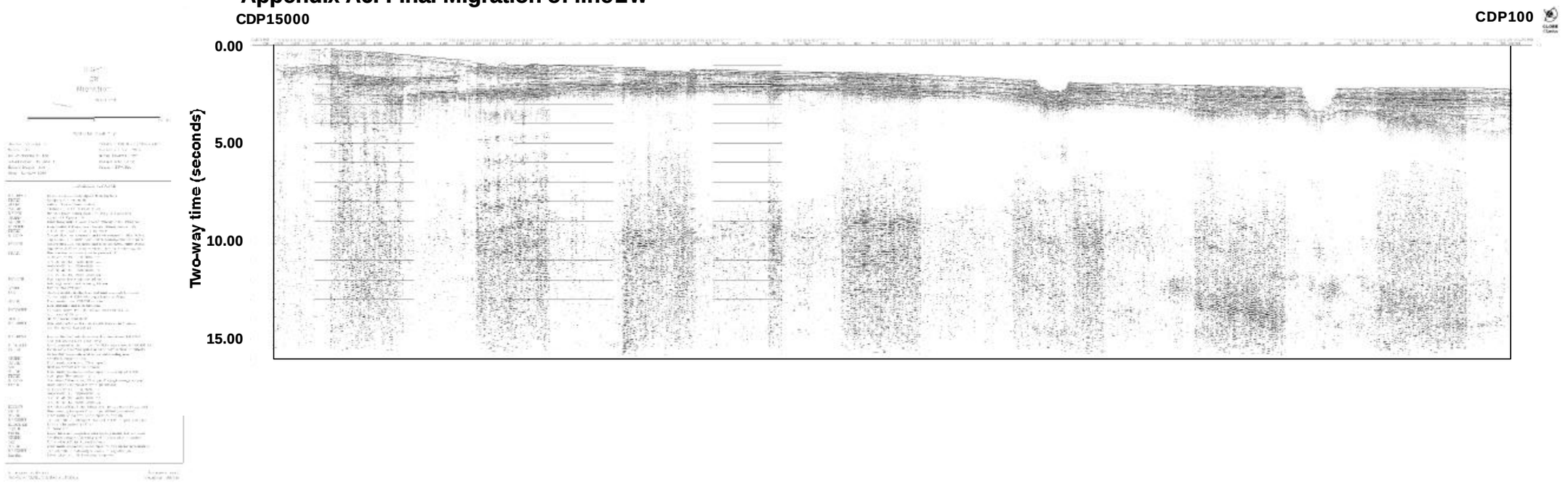
Appendix A4. Final Migration of line12w



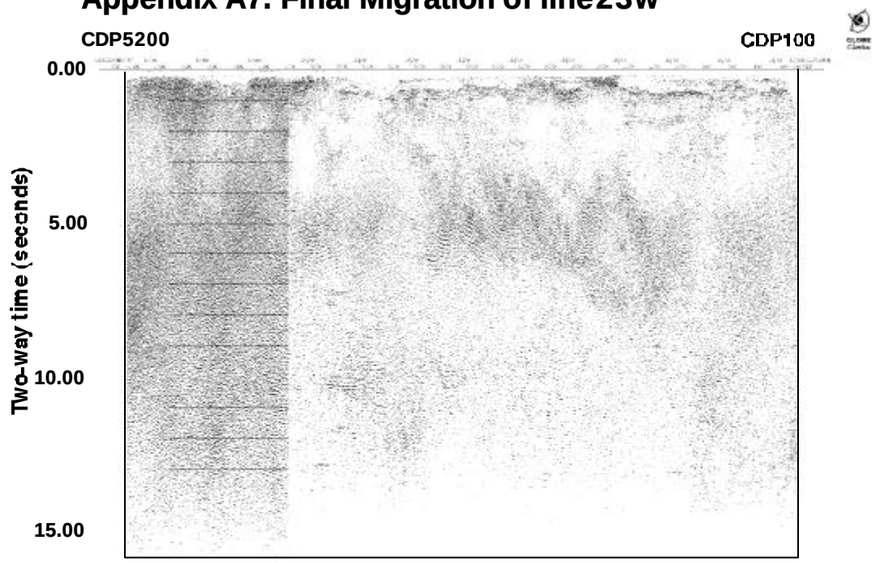
Appendix A5. Final Migration of line2e



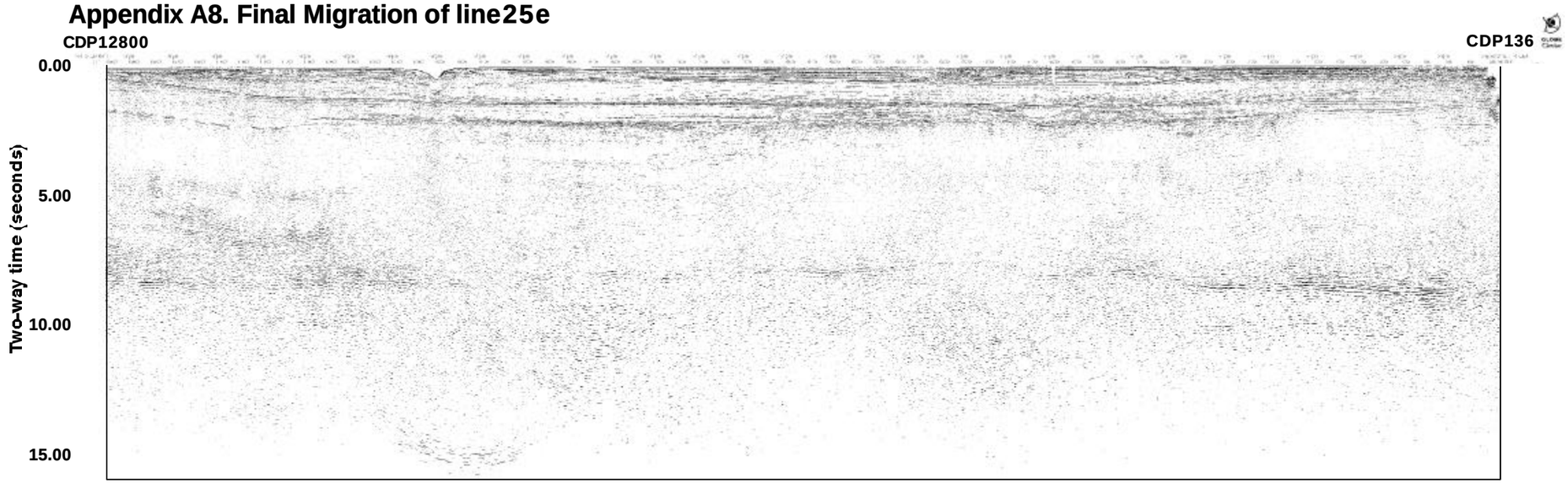
Appendix A6. Final Migration of line2w



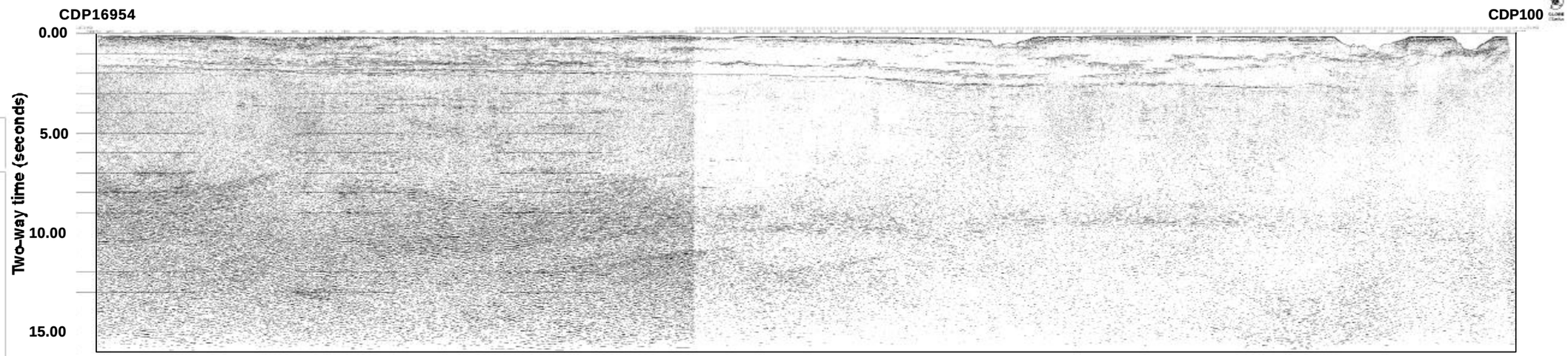
Appendix A7. Final Migration of line23w



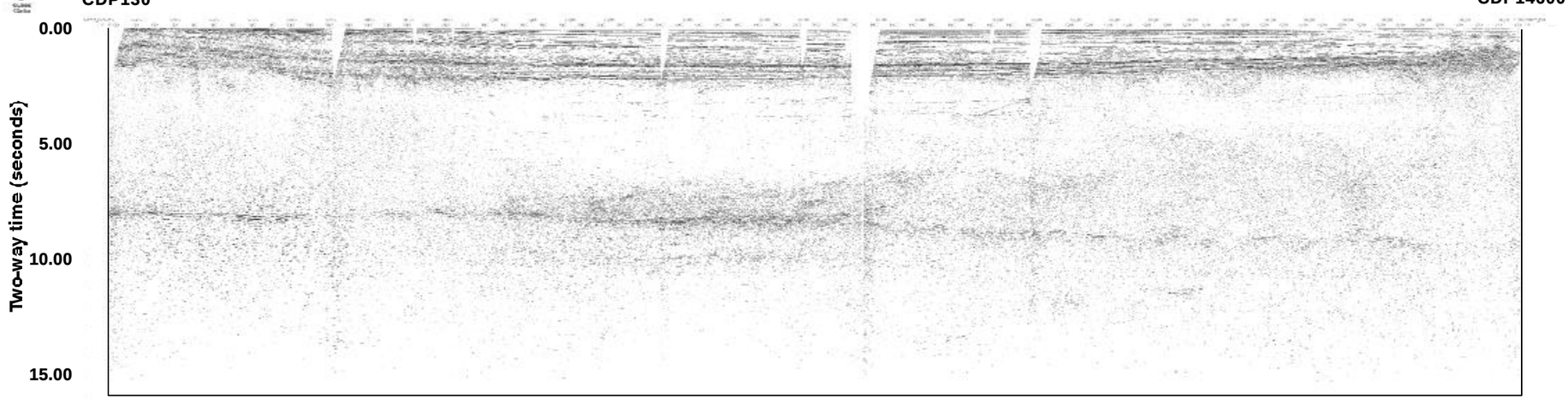
Appendix A8. Final Migration of line25e



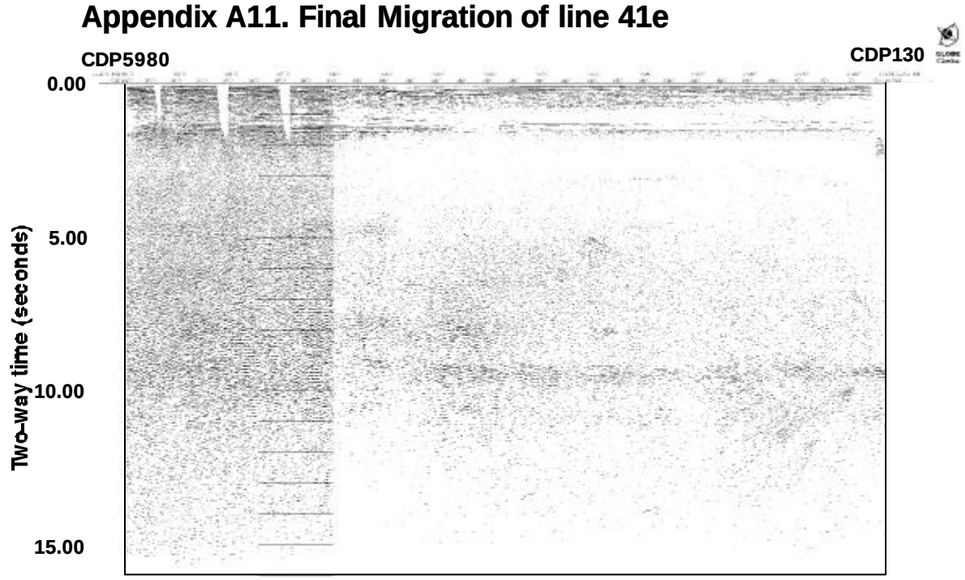
Appendix A9. Final Migration of line3w



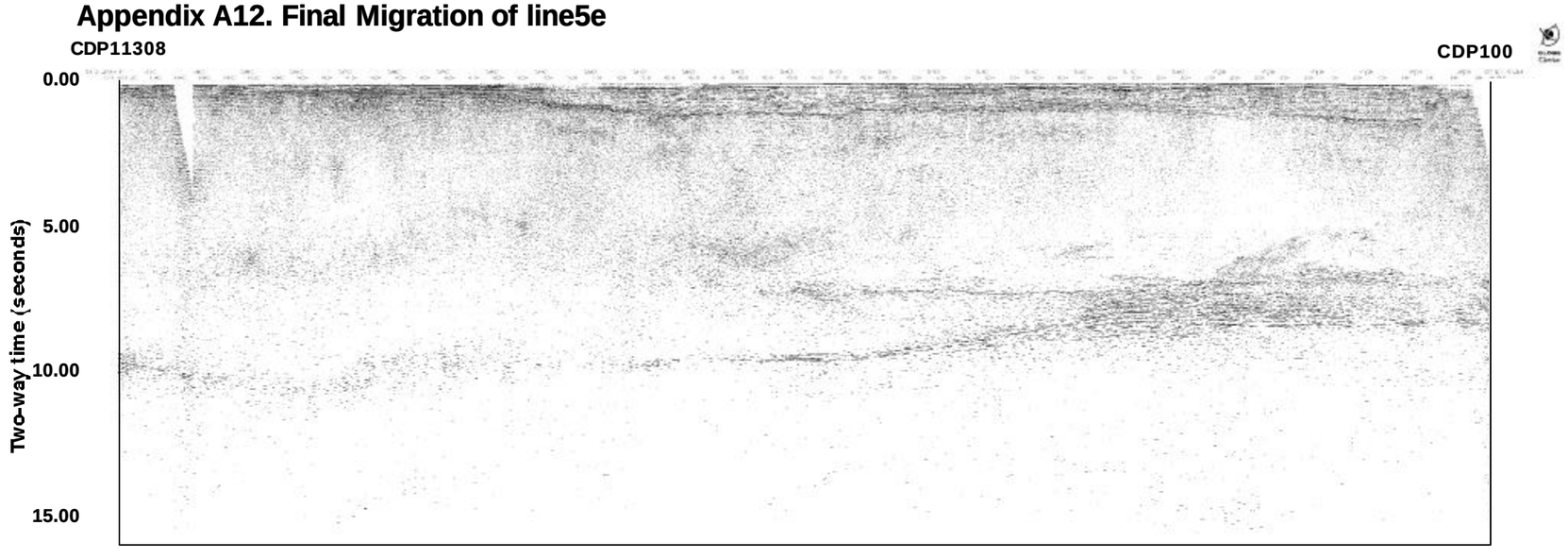
Appendix A10. Final Migration of line 4e



Appendix A11. Final Migration of line 41e



Appendix A12. Final Migration of line5e



Appendix A13. Final Migration of line 6e