

**R/V Maurice Ewing Cruise EW00-01
High-Resolution Multichannel Seismic Survey,
Offshore Canterbury Basin, New Zealand**

9-29 January 2000

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Introduction

High-resolution, multichannel seismic (MCS) reflection data were collected from the middle to outer shelf and slope, in the offshore Canterbury Basin, New Zealand (Figure 1) by the University of Texas Institute for Geophysics (UTIG). Lamont-Doherty Earth Observatory (L-DEO), under subcontract to UTIG, provided support personnel and GI air guns from its high-resolution MCS system. The survey was designed to image Neogene depositional sequences indicative of sea-level change and stratal geometries inferred to represent sediment drifts. This work is in support of an existing Ocean Drilling Program (ODP) proposal (JOIDES No. 511), which will be revised following processing and interpretation of the new seismic data.

Benefiting from good weather and the excellent performance of the seismic system, we exceeded our pre-cruise goal for data recovery. We lost only about 12 hours total to bad weather and occasional minor equipment failures. The professionalism of the Captain, officers, and crew of R/V *Maurice Ewing* contributed greatly to the success of the cruise.

MCS Acquisition and Recording

Source

Two 45/45 cu. in. GI (generator-injector) guns @ 2000 psi

Towing depth: 2.5 m

Gun firing was timed to yield a distance between shots equal to the streamer group interval at a nominal ship speed of 4.86 kt. With 12.5 m group intervals, the interval between shots was 5 s. Actual ship speed varied, but was almost always within 10% of the target speed. The guns were suspended from floats to maintain a 2.5 m towing depth.

Three GI guns were carried, but only two included spacers used to reduce chamber volumes to 45/45 cu. in. from 105/105 cu. in. Firing signatures were monitored in the main lab as well as in the gun shop. Occasional misfires of the starboard airgun were indicated on the monitors. These were thought to be false indications, because an oscilloscope used to check the starboard gun signal did not reveal misfires. Double peaks that occasionally appeared on the port gun display were likewise judged to be false, because the peaks were identical and no known gun problem could cause such a pattern.

Streamer

R/V Ewing carries a Syntron Reduced Diameter Array (RDA; diameter 64mm, [2.52 in.]), oil-filled, digital streamer containing Benthos RDA hydrophones. The streamer was deployed with a 50 m stretch section and a fiber optic tow leader. Active sections are 74.5 m long. We used 12.5 m groups, each of which contain 16 hydrophones. Two 50 m stretch sections and a 25 m tail rope attached to a Norwegian float terminated the streamer (Figure 2).

We began recording with 96-channels (1200 m active length). After 2.5 days of recording, we increased the streamer length to 120 channels (1500 m active length). We produced preliminary stacks of the seismic data after completing acquisition of each profile and, based on these records, felt that increasing the streamer length would enhance our ability to remove the multiples that are pervasive beneath the shelf. Increasing streamer length had the beneficial side effect of improving its towing characteristics by enabling it maintain a more uniform depth (normally 2.5 m, but 3.5 m was also used during intervals of bad weather) along its entire length.

Initial Streamer Configuration (Lines 2, 4, 6, 8, 23, 82, 80 78, 74)

96 x 12.5 m group length (1200 m total).

11 birds, most at 150 m intervals and programmed to maintain a depth of 2.5 m.

1 msec sampling writing to 3490 tape cartridges (~600 shots/tape).

3 second records.

29.25 m near-trace offset, 1216.75 m far-trace offset.

Final Streamer Configuration (Remainder of lines)

96 x 12.5 m group length (1500 m total).

12 birds, most at 150 m intervals (inboard bird omitted) programmed to maintain a depth of 2.5 m or 3.5 m (depending on sea state and streamer towing characteristics).

1 msec sampling writing to 3490 tape cartridges (~480 shots/tape).

3 second records.

29.25 m near-trace offset, 1516.75 m far-trace offset.

Noise appears on shot gathers at regular 6-trace intervals, with increased noise on traces 1 and 7 and every 12th trace thereafter (1, 7, 19, 31, 43, 55, 67, 79, 91, 103, 115). Many of these traces were logged as noisy traces before this pattern was noticed. The noise is probably caused by vibration at bird locations (channels 1, 7, then every 12th trace). Together with lesser noise from connections between streamer sections, affecting channels 13, 25, 37, 49, 61, 73, 85, 97, 109, the result is noise every 6 traces, starting at trace 1.

Recording

The Syntrak 480-24 Multiple Streamer Telemetry System (MSTS) involves Delta-Sigma analog to digital conversion in 24-bit digital acquisition modules (DAMs) within the streamer. There were 12 DAMs (also known as “cans”), spaced ~150 m apart. Digital data is then fed through the Multiple Streamer Telemetry Processor (MSTP) to the Multiple Streamer Recording System (MSRS), both of which are located in the main lab, and recorded on 3490 tape cartridges in SEG D.

Shipboard Processing

The SEG D field tapes were converted to SEG Y and copied to DAT DDS-3 tapes. It had been planned to make two sets of copies for additional security, but one of our DAT drives failed and only a single copy was made.

Brute stacks were made for each profile, using *Sioseis* software early in the cruise, and switching to *Focus* software on J.D. 16. This was the best indication of data quality, though various other quality control plots were created. The stacks revealed that we were achieving the desired penetration of >1.6 s. Furthermore, it was based on the stacked profiles that we made the decision to lengthen the streamer from 96 to 120 channels. Discontinuities in the stacked data occurred on lines shot from shallow to deep water. These are thought to be a consequence of the way *Sioseis* interpolated between water-depth-related velocity functions. Much experimentation was carried out by Saustrup and Dolan, shipboard processors, to find ways to overcome this limitation and improve the stacked sections. Switching from *Sioseis* to *Focus* for processing removed the problem.

Internal mutes were applied to reduce multiples beneath the shelf. Additional processing of line 72, the closest 120-channel line to the proposed ODP drilling transect, was carried out in order to evaluate better the true potential of the data. Saustrup picked stacking velocities and restacked and migrated this profile. This greatly improved the display, even without deconvolution. These improved velocities were used for stacking subsequent profiles. Frequency response spectra were produced to evaluate the effects of towing the streamer at 2.5 m versus 3.5 m.

Navigation

The ship followed lines defined by waypoints, most of which were selected prior to the cruise. Navigation for this was by DGPS, using the ship’s Trimble receiver, since the

ship's PCODE GPS was not working. DGPS positions were fed to the ship's autopilot, which generally kept the ship within 60 ft (18.3 m) of the true track (the ship itself has a beam of 45ft [13.7 m]).

A CRT (Instar system) on the bridge allowed the ship track to be monitored. The navigation fed to the Instar system was civilian GPS, not DGPS. However, this was used for display only. A CRT in the main lab duplicated the bridge Instar display and enabled the scientific party to monitor progress.

3.5 kHz Profiles

Good quality analog 3.5 kHz profiles at 1-sec sweep were collected almost continuously on the shipboard EPC recorder (including all turns and other seismic down time). These data were not recorded on tape; only paper copies exist. The only places where 3.5 kHz data were not collected were during two attempts to use the ship's Chirp system (Ocean Data Equipment Corporation, Bathy 2000-P). However, the Chirp system did not record reliably, hanging up frequently, and attempts to use it were discontinued.

Seismic Survey

Cruise EW00-01 departed Lyttelton, New Zealand, at 22:53Z, Julian Day (J.D.) 8, corresponding to 11:53 AM, 9 January, local time (Greenwich Mean Time [GMT], or "Zulu" time, was used during the cruise). The cruise ended in Lyttelton at ~19:30Z on J.D. 28 (08:30 AM, 29 January, local time). The survey area lies in the Canterbury Bight, south of Banks Peninsula.

The survey consists of 58 profiles (~3250 km) and covers an area extending ~46 n.mi. (85 km) from northeast to southwest (along strike) and ~30 n.mi. (56 km) from northwest to southeast (dip direction) on the mid to outer shelf and slope (Figure 1).

Experience interpreting similar data from New Jersey, as well as lower frequency commercial seismic data from the Canterbury Bight itself, highlighted the need for close line spacings. The seismic grid was therefore designed to provide dense coverage (2 km or less) in regions of primary scientific interest, i.e., near the proposed ODP drilling transect in the south and in the vicinity of large sediment drifts to the north. Seismic coverage in the central part of the grid, between these two focus areas, was less dense (see below for details).

The principal characteristics of the survey layout were as follows (Figure 1):

- Most shore-normal, "dip" profiles (even-numbered profiles) are spaced 2 km apart. There are two main zones of more closely spaced dip profiles: 1) in the immediate vicinity of the proposed ODP transect along line 74, where line spacings are 0.8 to 1 km and 2) lines adjacent to that passing through ODP Site 1119, where spacing is 1.2 km. In addition, dip profiles in the central part of the grid are more widely spaced (~3 km)
- Spacing of shore-parallel "strike" profiles (odd-numbered profiles) are variable (2-5.5km). Some strike lines were placed to intersect the ODP drilling transect (line 74) at locations of proposed drill sites.
- Profiles 74 and 17 intersect at Clipper exploration well. Profile 74 duplicates BP Shell Todd profile CB-82-54, along which the ODP drilling transect, as currently proposed, lies.
- Profiles 23 crosses ODP Site 1119.

- Strike profile 3 was extended to tie to Resolution exploration well. A diagonal profile (25) links Resolution and ODP Site 1119.

Operations

After a transit to the northeastern corner of the proposed grid, streamer deployment (96 channels) began at 06:00Z, J.D. 9, and was completed by 09:30Z. We began shooting the first seismic profile (line 2) at 14:28Z, J.D. 9.

The port gun failed at 14:22Z, J.D. 10, during shooting of line 23. We continued shooting with the starboard gun until the port gun was operational again at 15:16Z.

Shipboard processing revealed pervasive multiples beneath the shelf. It was decided that we would be better able to suppress such multiples during final processing onshore if we used a longer streamer. Therefore, at the end of line 74 (22:30Z, J.D. 11) we began operations to add 24 channels to the streamer, extending the active section by 300 m to 1500 m. This work was complete by 01:14Z, J.D. 12 and we shot subsequent lines with the new 120-channel configuration.

The float for the starboard gun was punctured and the gun sank at some point during the turn following line 68 (~07:40Z, J.D. 12). The float was replaced before beginning the next line.

The recording system crashed at ~15:48Z, J.D. 15, on line 21. We circled back to rejoin the line and to ensure that there was no gap in the data. Recording started again at 18:28Z. However, the seismic controller failed at shortly after we rejoined the line (19:11Z). The controller was restarted at 19:21Z. We decided not to circle, since we had already lost much time on this line and the down time was only ten minutes. As a result, there is a data gap in line 21.

At 21:40, J.D. 15, the Syntron gun controller went down when the line number was being changed during a turn. The problem could not be corrected before reaching the start of the next line (17), so we circled once.

While shooting strike line 17, sea conditions deteriorated and, with the swell from astern, wave noise was apparent in many channels on the cable data display. In addition, the inboard bird (No. 12) was being lifted by the ship's surges. During the turn between lines 17 and 15 (~09:30Z, J.D. 16), we therefore added two chains to the outboard end of the tow leader, providing extra weight to depress the inboard end of the streamer. This proved effective and, in addition, the sea state moderated during shooting of line 15.

At 06:00Z, J.D. 17, while approaching the end of line 13, it was noted that the bubbles from the starboard gun were consistently reaching the sea surface before those of the port gun. Both guns were retrieved during the turn to line 11. The shackles attaching both suspension chains to the port gun were found to have broken and the gun was hanging from its cables. It had therefore been towing somewhat (~1 m?) deeper than the starboard gun, accounting for the late appearance of the bubbles at the surface. All shackles on the towing assemblies of both guns were replaced with stronger types. On returning the port gun to the water, one of its chambers, probably the injector, failed to fire. The gun was retrieved and replaced with the spare (placing the spacers from the defective gun into the spare). Line 11 was begun at 09:40Z, J.D. 17. The defective port gun was refurbished and, at the end of line 11, was used to replace the starboard gun, which was retrieved for preventative maintenance.

A loss of pressure to the guns occurred at ~00:58, J.D. 18, while shooting profile 9. Pressure was quickly restored and only 15-20 shots were missed.

The bird closest to the ship was observed to be at a depth of 5 m at 09:38, J.D. 18, after the end of line 11. Line 7 was begun, but it was decided to terminate the line, after 30 minutes of acquisition, and pull in the streamer as far as the inboard bird to investigate the problem. No leaks were noted in the streamer, but the inboard bird was replaced. Its collars were a little close together, perhaps preventing it from rotating freely around the streamer. Meanwhile, the ship returned to the start of line 7, which was entirely reshot as line 7A. Prior to this, at 02:10Z, J.D. 18, the starboard gun had been observed to be towing near the streamer as a result of trailing a large piece of floating weed, which it then threw off. This does not seem to have affected the streamer and occurred far forward of the birds.

A short data gap occurred from 00:01Z to 00:10Z, J.D. 18, during shooting of line 5. The reasons for this are not clear. It coincided with interrogation of the bird removed from the streamer at the start of line 7 (see above), using the cable display window, though it J. Stennett did not believe that this should impact acquisition.

The port gun float was observed to be towing awkwardly while on line 34 (17:44Z, J.D. 19). Concerned that the suspension chains may have failed again, the gun was retrieved. It was found that a large mass of entangled seaweed was responsible. This was removed and the starboard gun also retrieved and a small amount of weed removed. Meanwhile, the ship turned to rejoin line 34, overlapping the previously shot section to avoid a data gap. The remainder of line 34 was shot as line 34A, commencing at 19:00Z.

Bird 2, second from the outboard end of the streamer, was observed to be at the surface at 22:20Z, J.D. 19, line 32. The bird was still in communication. J. Stennett set bird 2's wing angle to zero and the adjacent birds brought the streamer back into the required depth range (the birds are relatively closely spaced at the outboard end of the streamer: birds 1 and 2 are 39 m apart and birds 2 and 3 are 90 m apart). Data quality was not affected by this incident and it was decided not to pull in the streamer to replace bird 2. It may have snagged some debris and/or been upside down, therefore forcing itself to the surface when applying a negative wing angle in an effort to go deeper. At the end of line 32, J. Stennett reactivated bird 2 and it functioned normally.

It was noted (~21:30Z, J.D., 20) that noise appears on shot gathers at regular 6-trace intervals, with increased noise on traces 1 and 7 and every 12th trace thereafter (1, 7, 19, 31, 43, 55, 67, 79, 91, 103, 115). Many of these traces had been previously logged as noisy traces, without the pattern being noticed. The noise is probably caused by vibration at bird locations (channels 1, 7, then every 12th trace). This combines with lesser noise from connections between streamer sections, affecting channels 13, 25, 37, 49, 61, 73, 85, 97, 109, to produce noise every 6 traces, starting at trace 1.

The starboard airgun became hung up on the streamer during the turn from line 28 to line 22 (~06:30Z, J.D. 21). Line 22 was abandoned after only 10 minutes of acquisition and a turn to port, to restart line 22, was begun. In conjunction with partial reeling in of the gun, this freed the gun from the streamer. The gun was retrieved and the chafing protection was repaired. This was loose and could have contributed to the hang up.

Tape 356 spontaneously ejected from the recorder (11:24Z, J.D. 21) during shooting of line 22. The tape was reinserted, but the recorder instead overwrote tape 355. There is therefore a data gap of ~40 minutes on line 22 (this gap was reshot at the end of cruise as line 22A). During the turn from line 22 to line 20, the gun monitor software failed and had to be reinstalled (~16:30Z, J.D. 21).

The starboard gun veered into the streamer during line 18. The gun was retrieved and found to be encumbered with a large amount of seaweed. This was removed and the

gun subsequently towed normally. As a result of this operation, line 18 was shot with only one gun from ~03:05Z to 03:10Z, J.D. 22. This also happened at the beginning of line 10 (06:11Z, J.D. 23). The starboard gun was retrieved to remove weed and the first 9 minutes of the line were shot using only the port gun.

From 15:42, J.D. 22, to 06:25, J.D. 23, part of the navigation display monitor initially worked intermittently and was finally lost. Course made good and speed made good were obtained from the bridge at half hourly intervals from 21:00Z, J.D. 22, until the end of this period.

Weather conditions had heretofore been good, and sea state had only occasionally affected data quality; there had been no interruption of acquisition. However, the weather deteriorated at ~21:00Z, J.D. 23. Wind speeds reached 35 kt, gusting to 40 kt, during the next 3-5 hours, while shooting line 36. We reset the birds to take the streamer from a depth of 2.5 m to 3.5 m to reduce wave noise at 22:50Z. Speed through the water fell, though speed over the ground was maintained, and the two inboard birds sank to depths exceeding 5 m. This was probably beneficial, since the guns were towing close to the streamer and might otherwise have collided with the streamer. At ~03:00Z, J.D. 24, during the turn from line 36 to line 40, it was noticed that the starboard gun's towing wire was wrapped around its hose/cable. The gun was retrieved and the wire unwound after unreeling it from its winch. Wind speed remained ~30 kt with swells of 2-3 m. Because of high streamer tension on the new, southeasterly heading for line 40, which were into the seas, the nominal speed of 4.86 kt over the ground could not be maintained. Speed over the ground was closer to 4 kt. The starboard gun was crossing and recrossing the streamer in heavy seas and we therefore retrieved both guns to avoid damage to the streamer and gun hoses/cables. Line 40 was terminated at 05:15Z, J.D. The guns were refurbished (seals replaced) as the ship continued along line 40 without acquiring data, waiting for the seas to moderate.

The guns were deployed during the turn to line 44 when the wind speed had fallen to ~20 kt and shooting of line 44 began at 12:20Z, J.D. 24. The tow cable of the starboard gun became tangled again. This was corrected during the turn from line 44 to line 48, which began at 18:40Z, J.D. 24.

The weather continued to moderate and the birds were reset from a 3.5 m to 2.5 m towing depth at 06:15Z, J.D. 25, during the turn from line 52 to line 56. However, low-frequency wave noise during line 56 led to a decision to reset the birds to 3.5 m during the turn to line 19A, at 12:35Z, J.D. 25. Comparison of several frequency spectra of stacked data from lines shot with birds at 3.5 m and at 2.5 m showed a slight increase in high-frequency content with birds at 2.5 m. Furthermore, notch frequencies are 214 Hz at 3.5 m towing depth, 250 Hz at 2.0 m, and 300 Hz at 2.5 m. Saustrup calculated that while most of the source energy is below 250 Hz, there is some useful energy up to 250 Hz. The sea state had continued to improve and we therefore reset the birds to 2.5 m during the turn to line 33 (at 19:56Z, J.D. 25) to maximize high-frequency content. Low-frequency noise, when present, was concentrated in the vicinity of birds 7-9, which also showed a tendency to be shallow. One theory put forward was that the streamer may have picked up some debris in that interval. However, data quality remained good and the noise was intermittent. We therefore continued shooting in order to maximize data acquisition. The low-frequency noise diminished in amplitude as the sea state improved, but continued to appear occasionally.

Differential GPS was lost during the turn from line 40A to line 19B during the period 16:42Z – 17:15Z, J.D. 27. The acquisition system failed at 21:31Z, J.D. 27, on line 19B. Acquisition was restarted at 21:35Z.

We stopped acquiring data at 06:15Z, J.D. 18. Guns and streamer were retrieved by 08:15Z and the ship departed the survey area for Lyttelton. Four streamer sections were found to have leaks, suspected to have been the result of shark bites. These were partly in the interval of low frequency noise (region of birds 7-9), but birds 7-9 were also encumbered by weed, which may also have affected towing characteristics and streamer noise.

Results

Interpretation will be deferred until final processing is complete. However, some observations are possible at this early stage.

Shelf

The shelf in this part of the Canterbury Bight is smooth at the scale of MCS vertical resolution (~5 m). Application of an inside mute was partially successful in reducing multiple energy beneath the shelf and revealing the gently dipping, clinoform surfaces that are of primary interest, particularly in the southern half of the grid. Some of these surfaces, which are of middle Miocene to Pliocene age, are sequence boundaries that have been inferred to be linked to cycles of global sea level (eustasy; Figure 3). They are targets of the proposed ODP drilling transect. Velocity analyses and predictive deconvolution during final processing onshore will further improve the imaging of these surfaces. Large, aggradational features, previously interpreted as sediment drifts, are also imaged. Beneath the shelf, these lie near the base of the prograding Cenozoic section.

The seismic profiles achieved sufficient penetration to image the offshore equivalent of the Weka Pass Limestone as a strong, nearly horizontal reflection at 1.6-1.7 s (Figure 3). The offshore extension of the Marshall Paraconformity, a regional omission surface, is interpreted to lie at the base of this limestone unit.

Slope

The morphology of the modern slope changes significantly along strike. In the southern part of the grid, the shelf edge is well defined and the distance from shelf edge to the toe of the slope is ~10 km. The slope descends to a shallowly dipping platform at a water depth of ~1100 m. Mounded reflections, suggestive of sediment drifts, underly the slope, but these are of low relief.

In contrast, the distance between shelf edge and slope toe increases to ~25 km at the northern end of the grid, though the water depth at the toe of the slope remains unchanged. Large, mounded, aggradational drifts (Figure 4) underly this gentle slope. These features have been previously recognized on low-resolution commercial seismic data, but those profiles are too widely spaced (3-8 km) to define the three-dimensional geometries of the drifts. This is a goal of future interpretation using our denser (2 km spacing) and higher resolution data.

Because of minimal down time, we were able to extend our seismic coverage of the slope. This will greatly enhance our ability to interpret the Pleistocene and Recent section and sediment drift histories.

Schedule for Meeting Obligations

New Zealand Participation

Greg Browne, of the New Zealand Institute for Geological and Nuclear Sciences, participated in the cruise.

Data

Paper and/or digital copies of the seismic data will be provided to the New Zealand government when data processing is complete. We expect to be able to provide the data by June 2002.

Scientific results will be made available through presentation at scientific meetings, beginning with the December 2000 meeting of the American Geophysical Union, and publication in the scientific literature, possibly beginning in 2001. We will also be interacting directly with New Zealand scientists.

Figure Captions

Figure 1. Survey track showing numbered MCS lines collected by the R/V *Maurice Ewing* during high-resolution MCS operations in the Canterbury Bight.

Figure 2. Streamer towing geometry. The survey began with a 96 channel streamer. Streamer length was subsequently increased to 120 channels.

Figure 3. Dip profile 72 (migrated, stacked with picked velocities), showing clinoform sequences between 0.7 s and 1.2 s in the southern part of the survey area. This interval is a target of proposed ODP drilling. The strong reflection at ~1.62 s is the top of a limestone interval (Weka Pass Limestone equivalent).

Figure 4. Dip profile 8 (brute stack) showing large sediment drift beneath the modern slope in the northern part of the survey area.

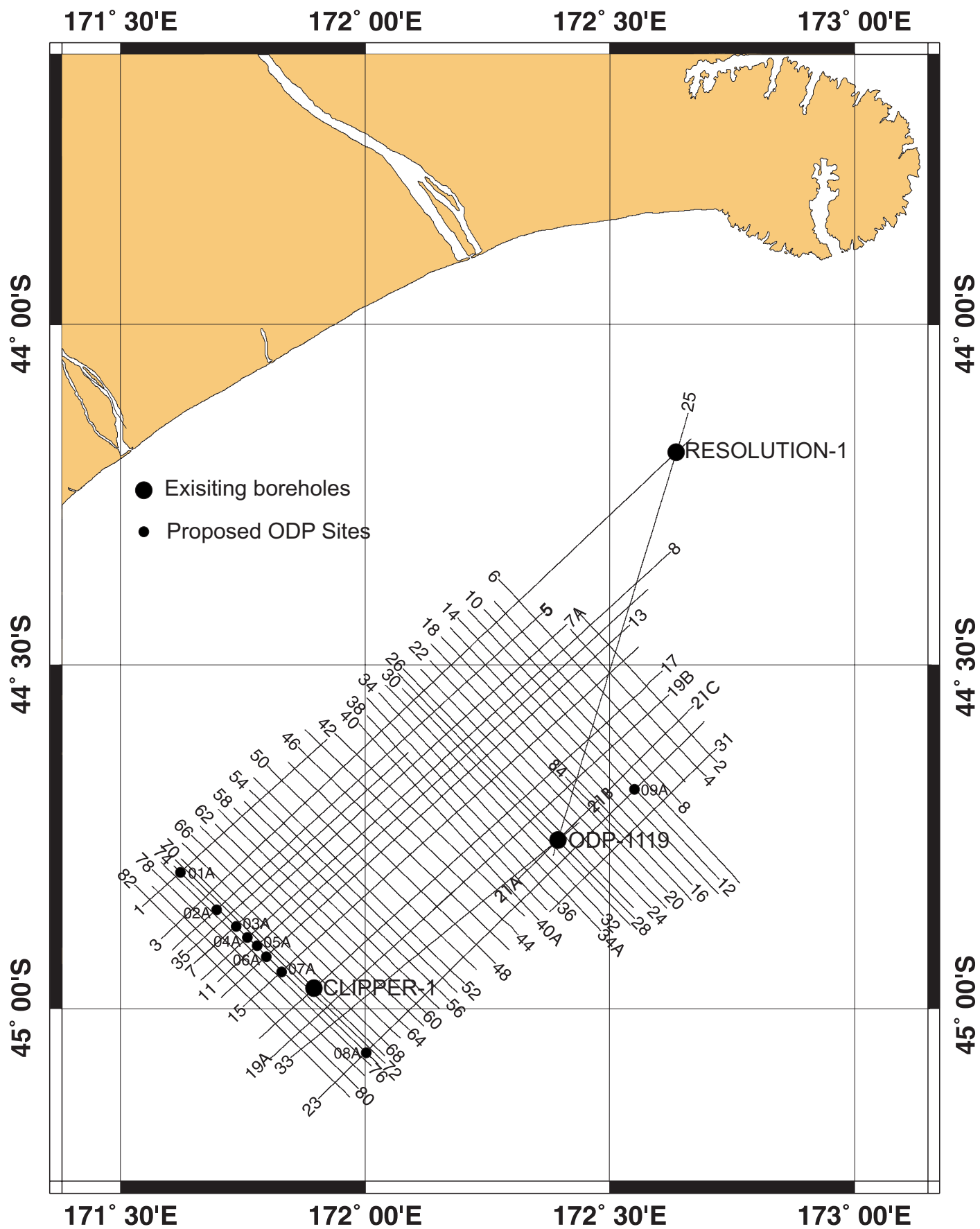


Figure 1

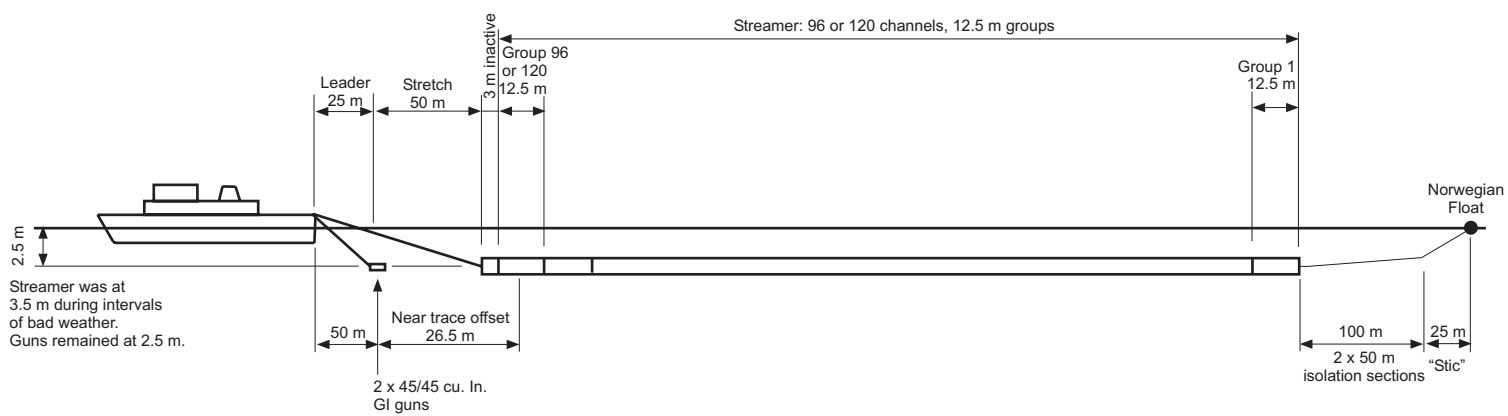


Figure 2

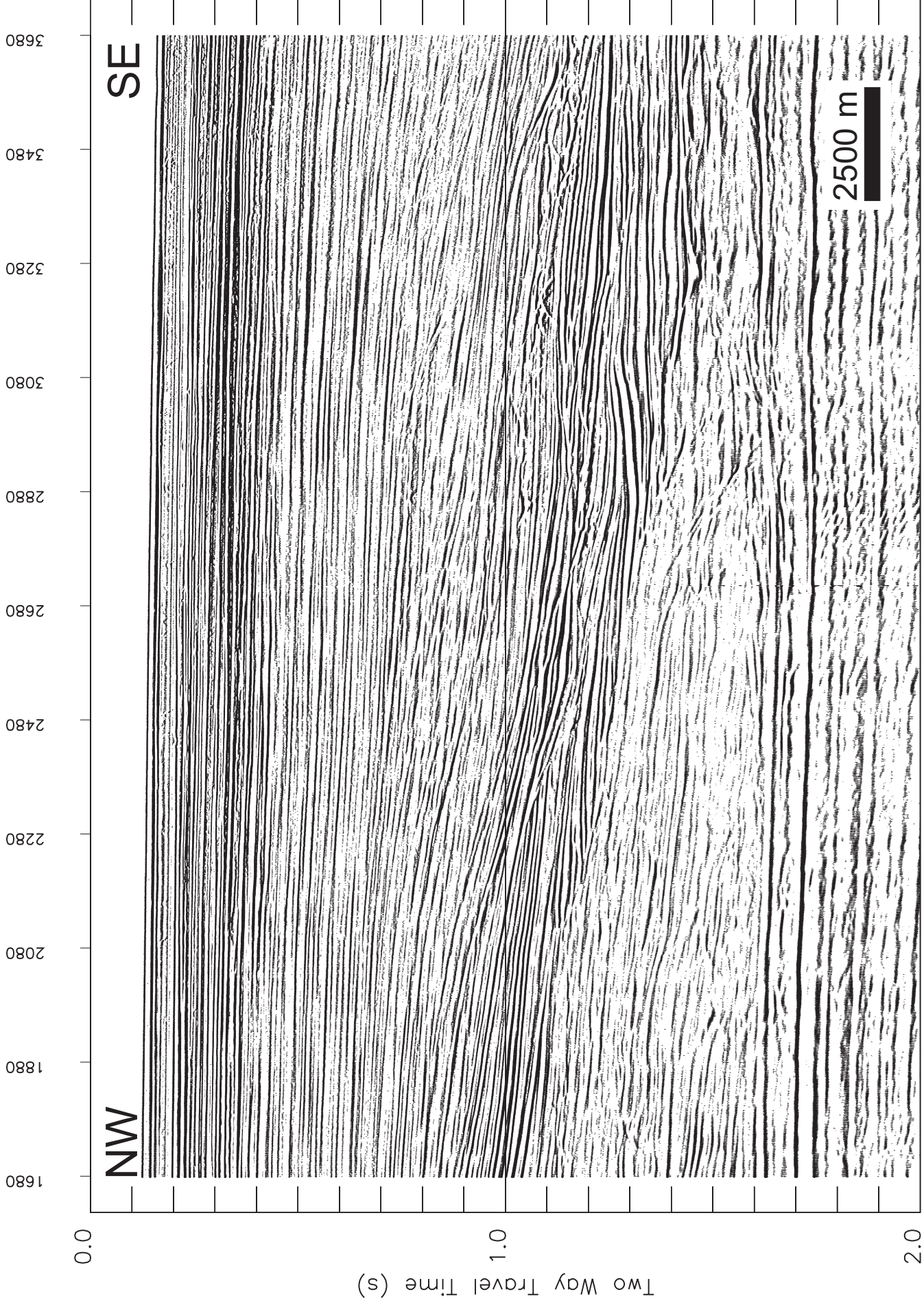


Figure 3.

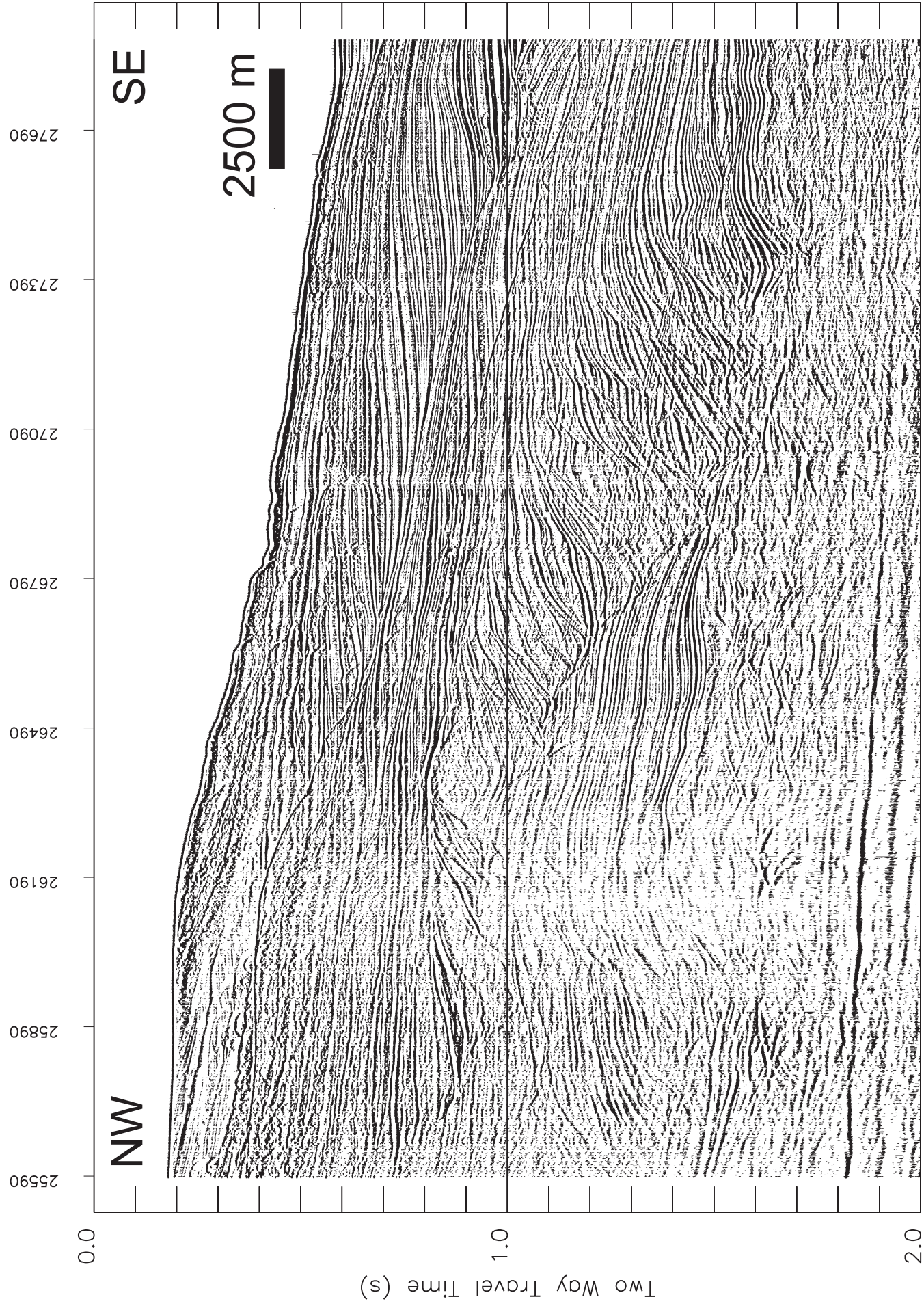


Figure 4