Feasibility of High Resolution Seismic Reflection Surveying near the Present and Former Dry Cleaning Facilities on the Fort Riley Army Post near Junction City, Kansas

by

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The high resolution seismic survey of approximately 5-6 lines totaling approximately 2400 ft was proposed near the laundry facilities on the Ft. Riley Army Post. The proposed primary targets were the bedrock surface beneath fill and/or weathered material at depths on existing boring logs of between 20 and 50 feet, and the thickness of a shale layer directly beneath the limestone bedrock surface suspected to be approximately 15 ft (Figure 1). The goal was to identify locations on the bedrock surface and within layers immediately beneath the bedrock surface that could possess sufficient permeablity to act as conduits for surface introduced contaminates. Faults and/or joints were of particular interest since they would compromise the integrity of any non-permeable materials.

To image the bedrock surface at this very shallow depth and to resolve the top and bottom of the shale present directly beneath the limestone surface, high frequency and broadband were essential. The dominant frequency of data recorded without analog filters was very nearly 100 Hz. Assuming an average velocity in this area of around 2000 to 3000 ft/sec down to the bedrock surface, the maximum resolution potential of a seismic survey using the available equipment would have been about 8 ft.

Proven high resolution techniques (Steeples and Miller, 1990) were to be used to insure the highest quality (both resolving power and signal-to-noise ratio) recorded data. The walkaway noise testing completed at this site was designed to determine the feasibility of acquiring data in a standard CDP format (Mayne, 1962) using roll-along type acquisition techniques similar to conventional petroleum exploration data acquisition. The geophone spacing, analog filtering, seismic source, geophone type, spread geometry, sampling interval, total samples, shots/pt, and acquisition philosophy are all normally determined during pre-production tests.

The project was designed to consist of two major phases: testing and production. The testing phase consisted of one day of walkaway noise surveys at four locations near planned survey lines. The walkaway noise tests were gathered according to common shot station and receiver offset and separated into distinct groups according to recording parameters (plus AGC scale and digitally filtered). The quality and potential of the test data were used to determine whether the production portion of the project was feasible and should be undertaken. It was determined after careful consideration of both the data quality requirements, the necessary effort, and potential of successfully producing a meaningful stacked section that the survey should not proceed to the production phase.

EXPERIMENTAL (TESTING) PHASE

The testing phase began on October 20, 1993, and consisted of a series of walkaway noise tests at four different locations (Figure 2). The first test line was oriented approximately east/west and located in the grassy area immediately north and on a bench overlooking the current dry cleaning/laundry facility. The second test line was situated in a grassy area across the creek and to the east of the former dry cleaning facility. The third test line was directly southeast of the former dry cleaning facility and approximately parallel to the back wall of the building. The fourth and final test line was directly in front of the former dry cleaning facility, parallel to Custer Road, directly beneath a group of overhead power lines, and above a utility corridor. The test data set should be representative of overall data quality that could be expected from a CDP survey in this area.

Testing at this site included evaluation of both reflected and refracted energy arrivals. The data were acquired on a 48-channel, 15-bit EG&G Geometrics 2401x seismograph sampling at 1/5 ms, various analog low-cut filters (18 dB/octave rolloff from their indicated -3 dB point), and 500 Hz analog high-cut filters. The dynamic range of the seismograph was more than adequate to record high-quality reflection information in the presence of source-generated and cultural noise at this site.

The high levels of cultural noise and large velocity contrast very near the ground surface had a detrimental effect on the overall data quality. The heavily traveled road, power lines, noise from machinery around and in the dry cleaning facilities, lack of surface and subsurface obstructions, and minimal low velocity native fill material over the first consolidated layer drastically reduced the potential of the reflection survey to image the proposed targets. The downhole 30.06 possessed sufficient energy and bandwidth to image the target reflectors. The receiver array consisted of single Mark Products L40A 100-Hz geophones with approximately 6 inch spikes centered at each station. All applicable acquisition parameters and available equipment that could be safely tested at this site were tested to determine feasibility of the technique under existing conditions.

With the drill-defined geologic setting and proposed target, a downhole explosive source was the source of choice. A strong cyclic ring with an apparent linear velocity consistent with either the direct wave, refracted wave, or ground roll inhibited the recording of near-vertically incident reflected energy. With the target being extremely shallow (with respect to seismic reflection surveys, in general), reflections of significance would have arrived at offsets very near the source and at times of less than 50 msec. Within that optimum window (Hunter et al., 1984) only ground roll, refractions, air wave, and direct wave can be interpreted either with digital filtering or without.

The spreads used for testing were generally end-on with source-to-receiver-offsets that ranged from 4 ft to as much as 200 ft. The large range of source-to-receiver offsets allowed for definitive determination of the optimum recording window (Hunter et al., 1984). The tight receiver spacing (2 ft) was used to improve the coherency of recorded data within the optimum window. The cable/roll switch/seismograph combination allowed a maximum of 48 channels to be recorded from one source location and, therefore, due to multiple shot locations on some gathers, slight time mis-ties (shot static) can be observed on shot gathers with more than 48 traces. Equivalent shots recorded from both ends of the spread allowed evaluation of the consistency in energy arrivals independent of localized near-surface conditions. The spread used during testing was designed to facilitate the recording of reflected energy from depths between 10 and 300 ft provided the velocity structure is consistent with the drill reported lithology and geologic setting.

Critical data collected during the testing phase of this survey were reduced to the appropriate display format on-site. The on-site data reduction and associated analysis allowed confident decisions concerning the feasibility of the technique to image the proposed target. All single shot gathers were displayed in raw, AGC, and digital filtered format at the time of recording. Walkaway noise tests for this report were displayed according to source-to-receiver offset with separate displays for each source, receiver type, and low cut filter tested. Data displayed in this report have been trace balanced and/or digitally filtered and displayed in a variable-area wiggle trace format.

SITE #1

The grassy area above the current dry cleaning/laundry facility seemed to possess the highest possibility for acquiring good reflection data. This suggestion was based on the apparent 15 ft or so between the ground surface and the first competent limestone unit (as exposed in outcrop). The initial shots recorded at this site contain arrivals in the middle portion of the spread that are suggestive of a non-uniform near-surface. The non-uniform nature of the wavetrain near the 24th geophone is strong evidence for a disturbed near-surface (Figure 8a). Some coherent events at depths in excess of 120 msec could be interpreted as deep reflections (Figure 3b). The isolated nature of these events along with the 200 Hz dominant frequency and horizontally varying wavelet characteristics are consistent with reflection characteristics. These probable reflections are significantly outside the geologic window of interest. The horizontal arrivals with a dominant frequency in excess of 200 Hz prior to the first arrivals leads to some skepticism with respect to the deeper arrivals, but are not sufficient evidence alone to rule out the possibility these deeper events might be reflections. The event at 110 msec (Figure 6b) has unique wavelet properties with respect to other coherent high frequency events and could be indicative of a deep reflection event.

Analysis of refraction arrivals suggests a near-surface velocity of around 2000 ft/sec down to a depth of in excess of 10 ft. A layer with a velocity in excess of 10,000 ft/sec represents the next interpretable first arrival beyond the first cross over at about 160 ft.

SITE #2

The grassy strip southeast of the old dry cleaning and laundry facility where trees had been cleared away was the location of Site 2. The planting conditions and source conditions seemed very good. No data recorded at Site 2 seems to possess shallow arrivals that could be interpreted as reflections (Figures 9 and 10). The near-surface at this site was very attenuative as evidenced by the very consist lower frequency refracted arrival interpretable on the unfiltered data but not present due to the lower dominant frequency on digitally filtered data. The CDP data collected at this site possess reflections from depths in excess of 250 ft but no indication of events from depths less than 100 ft.

Refraction analysis at Site 2 suggests a near-surface velocity of less than 1200 ft/sec to a depth of less than 5 ft with a 2000 ft/sec layer lying directly beneath. No data were recorded at a long enough offset to observe the cross-over between the 2000 ft/sec layer and any underlying unit.

A data set was acquired at Site 2 in a roll-along format to allow CDP style processing. To minimize the field effort necessary to effectively evaluate the feasibility of CDP processing to enhance reflection events beneath the dynamic range of the in-field displays, the 48-station spread deployed for the walkaway noise tests were "shot through" with an in-line offset of about 8 ft. The individual field files possess indications of cyclic reflection events at times greater than 80 msec. These reflections visible on the field files are from reflectors at depths greater than 200 ft (Figures 22 and 23). Any reflection event of significance to this survey would have to be at times between 40 and 60 msec; within that time window no reflections are easily interpretable.

The CDP stacked section is nominal 24-fold but due, to the "shoot through the spread" acquisition format, it was not possible to maintain the optimum window. It is possible without much difficulty to interpret reflections deeper than 80 msec. The CDP stacked section has not had any statics and only limited velocity analysis. This is mainly due to the lack of reflections within the window of interest. It is unlikely that even with the optimum recording parameters and conditions that reflections from depths less than 30 ft could be confidently mapped using shallow seismic reflection at this site.

SITE #3

The line recorded behind the old dry cleaners did not possess sufficient length to record source receiver offsets greater than 150 ft (Figures 11 through 16). The near-surface material was the same velocity fill material observed (acoustically) at Site 2. The cross over to 2000 ft/sec material occurred at offsets greater than 100 ft. This suggests a layer approximately 15 to 20 ft thick of extremely low velocity material overlying a 8,000 to 10,000 ft/sec layer. No reflection arrivals can be interpreted on either the raw or digitally filtered data at this site. The noise from the equipment in the building as well as air wave echo off the building can be observed on most files.

SITE #4

The site located in front of the old laundry facility was very near the road and possessed an excessive amount of 60 Hz noise. Any reflection energy in the 150 to 200 Hz band is totally obscured on digitally filtered data by 60 Hz power line noise. The unfiltered, scaled files possess arrivals that are very suggestive of reflections but at frequencies much below those required to image and resolve the target interfaces (Figure 18a). The event at about 70 msec possesses many of the key characteristics of reflections from this high velocity near-surface environment. The approximate depth of the reflector responsible for this reflection is about 250 to 300 ft deep.

From refraction analysis, the low velocity (<1200 ft/sec) material present behind the old dry cleaning facility and southeast across the creek, is present in front of the dry cleaner at a thickness consistent with across the creek (Figure 18a). The material that lies directly beneath this low velocity fill has a approximate refraction/ interval velocity of around 12,000 to 15,000 ft/sec. This is most likely a limestone unit. The limestone unit has a depth of burial at this location of less than 10 ft.

CONCLUSION

The final decision concerning the feasibility of seismic reflection surveying at this site were made at the completion of testing. The data used to make the final determination had been sorted, bandpass filtered, AGC scaled, and displayed in wiggle trace format. These plots possessed sufficient information and detail for a qualitative judgment concerning the feasibility of shallow high resolution CDP seismic reflection methods to delineate the structural and stratigraphic features of interest in this area. The CDP seismic reflection method does not have the potential to produce meaningful information at depths less than 50 ft at this site.

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Miller, R.D., S.E. Pullan, D.A. Keiswetter, D.W. Steeples, and J.A. Hunter, 1992, Field comparison of shallow P-wave seismic sources near Houston, Texas [Exp. Abs.]: Soc. Explor. Geophys., v. 1, p. 694-697.

Steeples, D.W., and Miller, R.D., 1990, Seismic-reflection methods applied to engineering, environmental, and ground-water problems: Soc. Explor. Geophys. Investigations in Geophysics no. 5, volume on Environmental Geophysics, S. Ward, ed., 1-30.

FIGURE CAPTIONS

Figure 1) Generalized geology of the entire site.

Figure 2) Site map locating the four test areas.

Figure 3-7) Test site #1, analog low cut filter out to 400 Hz, receiver spacing 2 ft, (A) AGC scale 50 msec, (B) digital bandpass filter 50-100--300-450.

Figure 8) Test site #1, analog low cut filter out to 400 Hz, receiver spacing 2 ft, (A) AGC scale 50 msec, (B) digital bandpass filter 50-100--300-450, reverse shot.

Figure 9) Test site #2, analog low cut filters out to 400 Hz, receiver spacing 2 ft, (A) AGC scale 50 msec, (B) digital bandpass filter 50-100--300-450.

Figure 10) Test site #2, analog low cut filters out to 400 Hz, receiver spacing 2 ft, (A) AGC scale 50 msec, (B) digital bandpass filter 50-100--300-450, reverse shot.

Figure 11-15) Test site #3, analog low cut filters out to 400 Hz, receiver spacing 2 ft, (A) AGC scale 50 msec, (B) digital bandpass filter 50-100--300-450.

Figure 16) Test site #3, analog low cut filters out to 400 Hz, receiver spacing 2 ft, (A) AGC scale 50 msec, (B) digital bandpass filter 50-100--300-450, reverse shot.

Figure 17- 21) Test site #4, analog low cut filters out to 400 Hz, receiver spacing 2 ft, (A) AGC scale 50 msec, (B) digital bandpass filter 50-100--300-450.

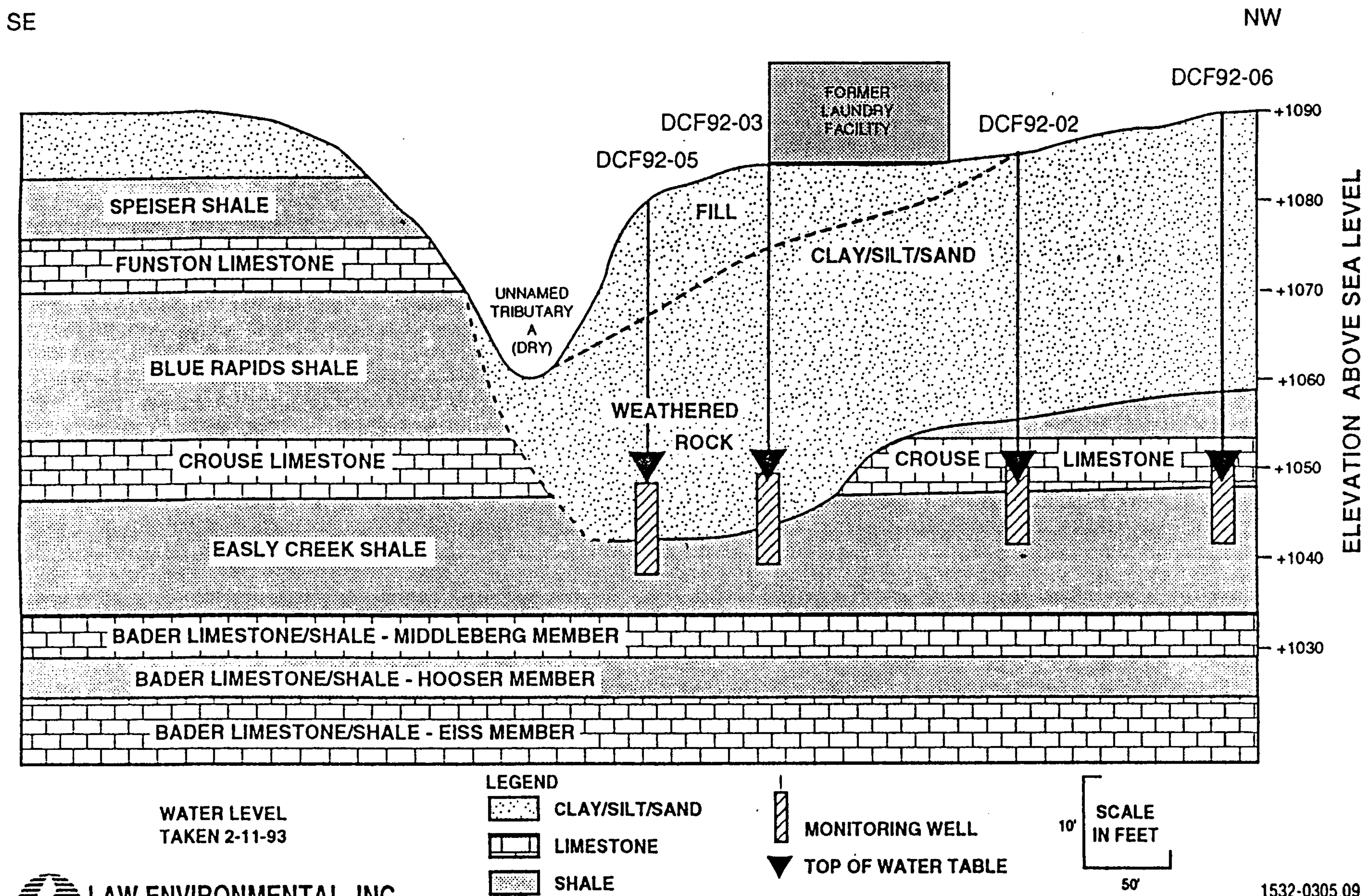
Figure 22) Field file from CDP line at Site #2. Reflections at time greater than 80 msec are interpretable on shot gathers.

Figure 23) Multi-fold CDP stack from Site #2. No reflections are interpretable at times less than 50 msec, representative of depths less than 150 ft.

Figure 1

NORTHWEST TO SOUTHEAST CROSS SECTION

DRY CLEANING FACILITY
FORT RILEY, KANSAS



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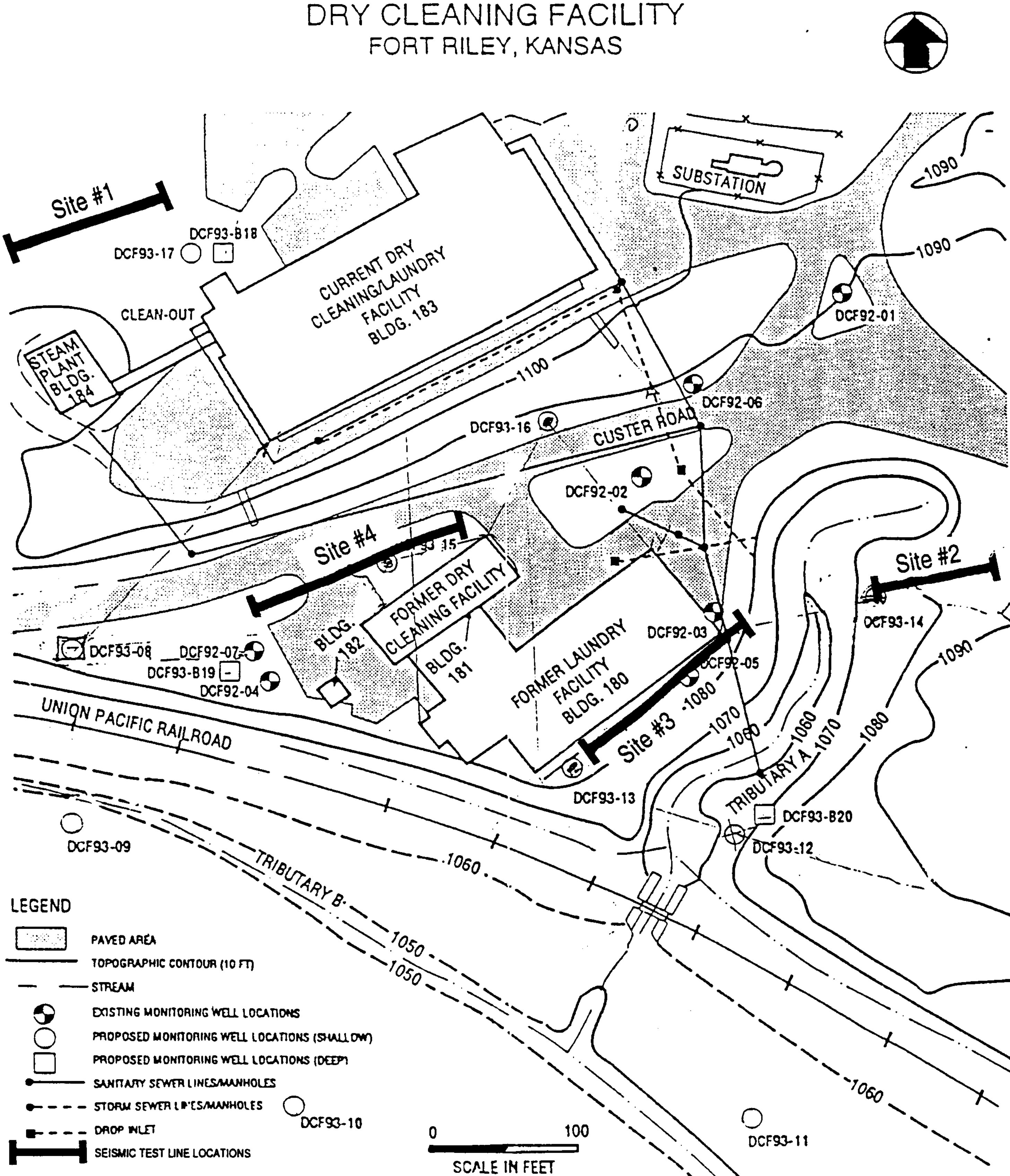
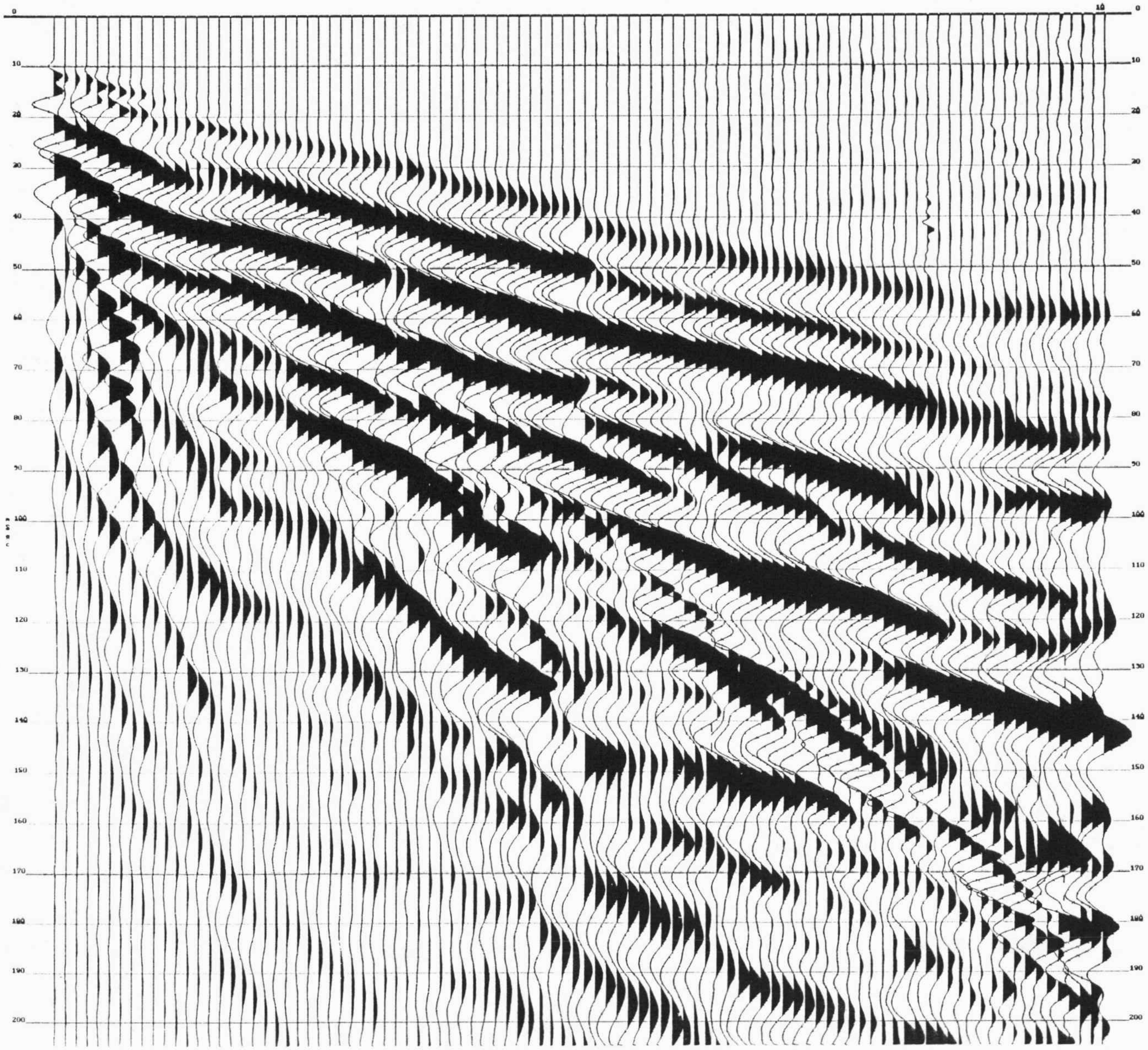
1532-0305.09

Figure 2

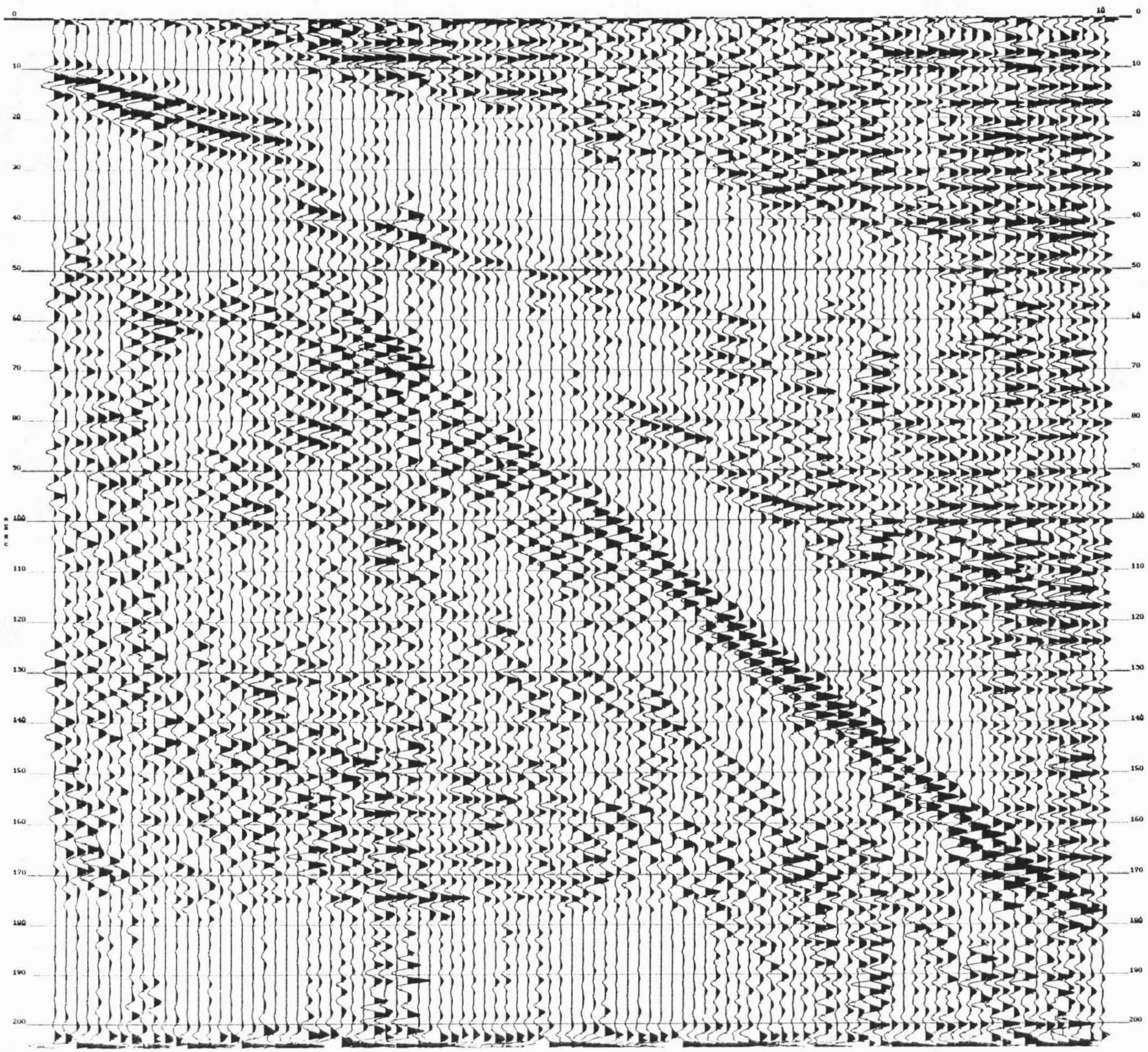
PROPOSED MONITORING WELL LOCATIONS
DRY CLEANING FACILITY
FORT RILEY, KANSAS



Site 1a
Figure 3a



Site 1a
Figure 3b



Site 1b
Figure 4a

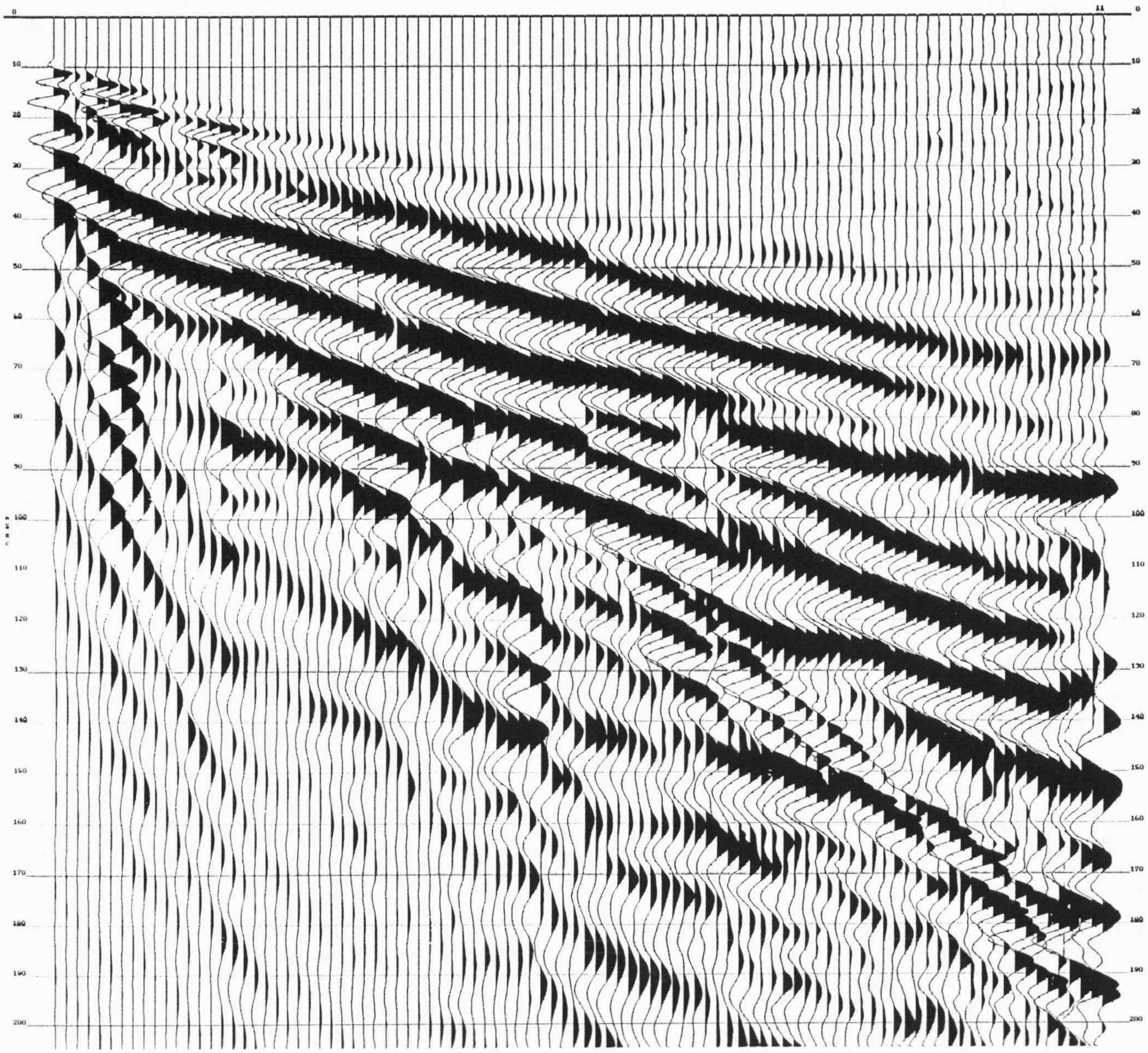


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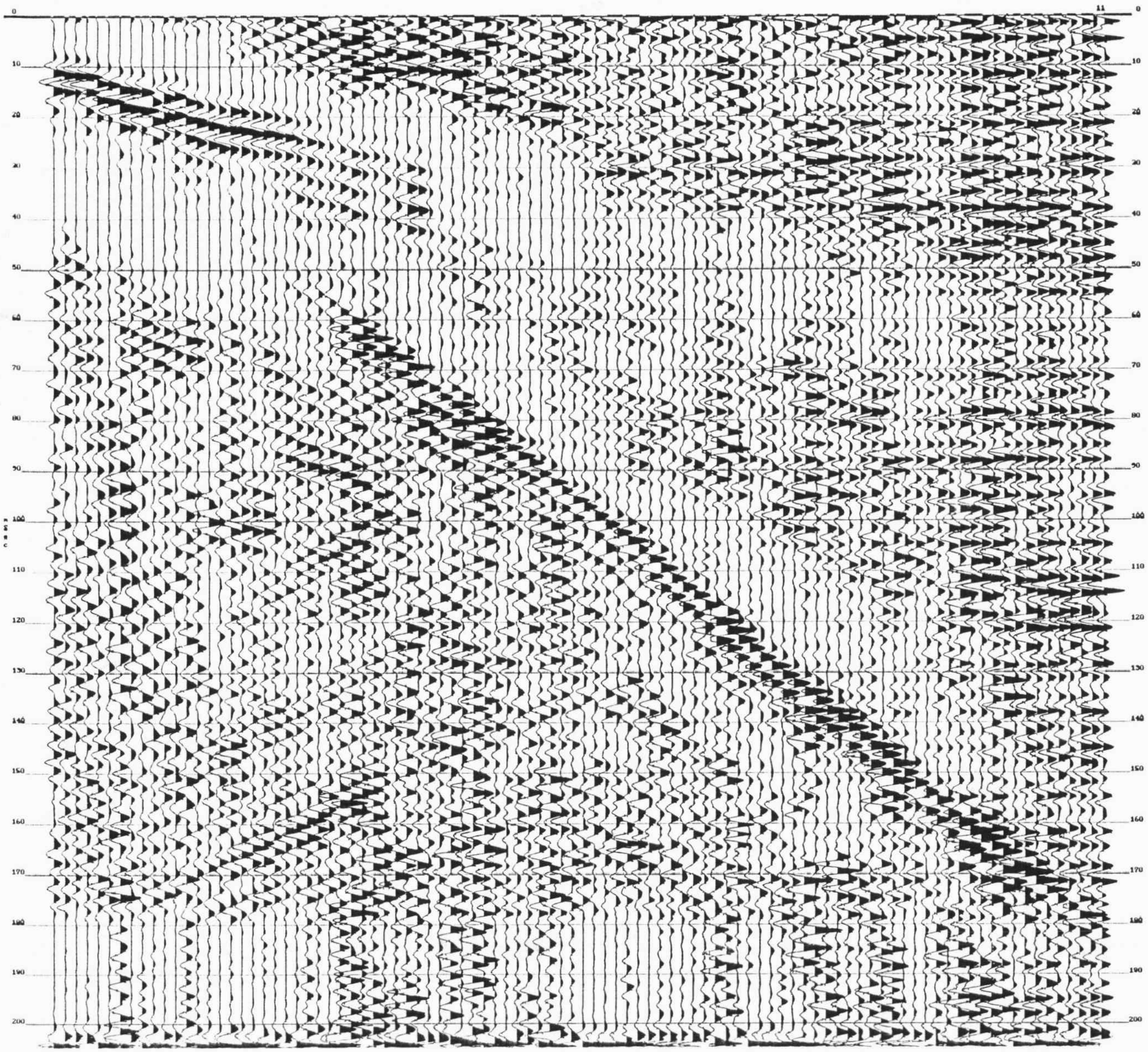
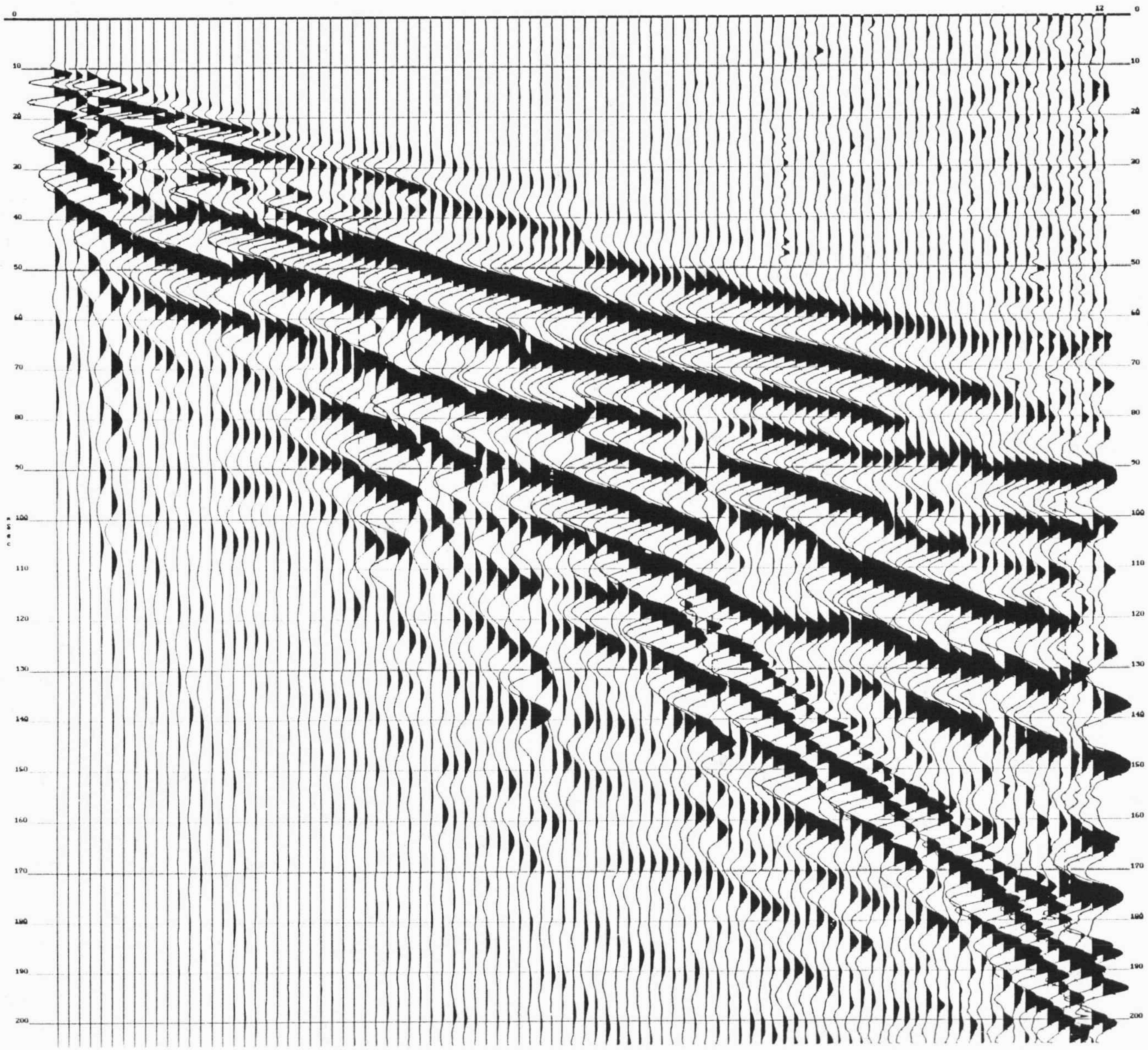
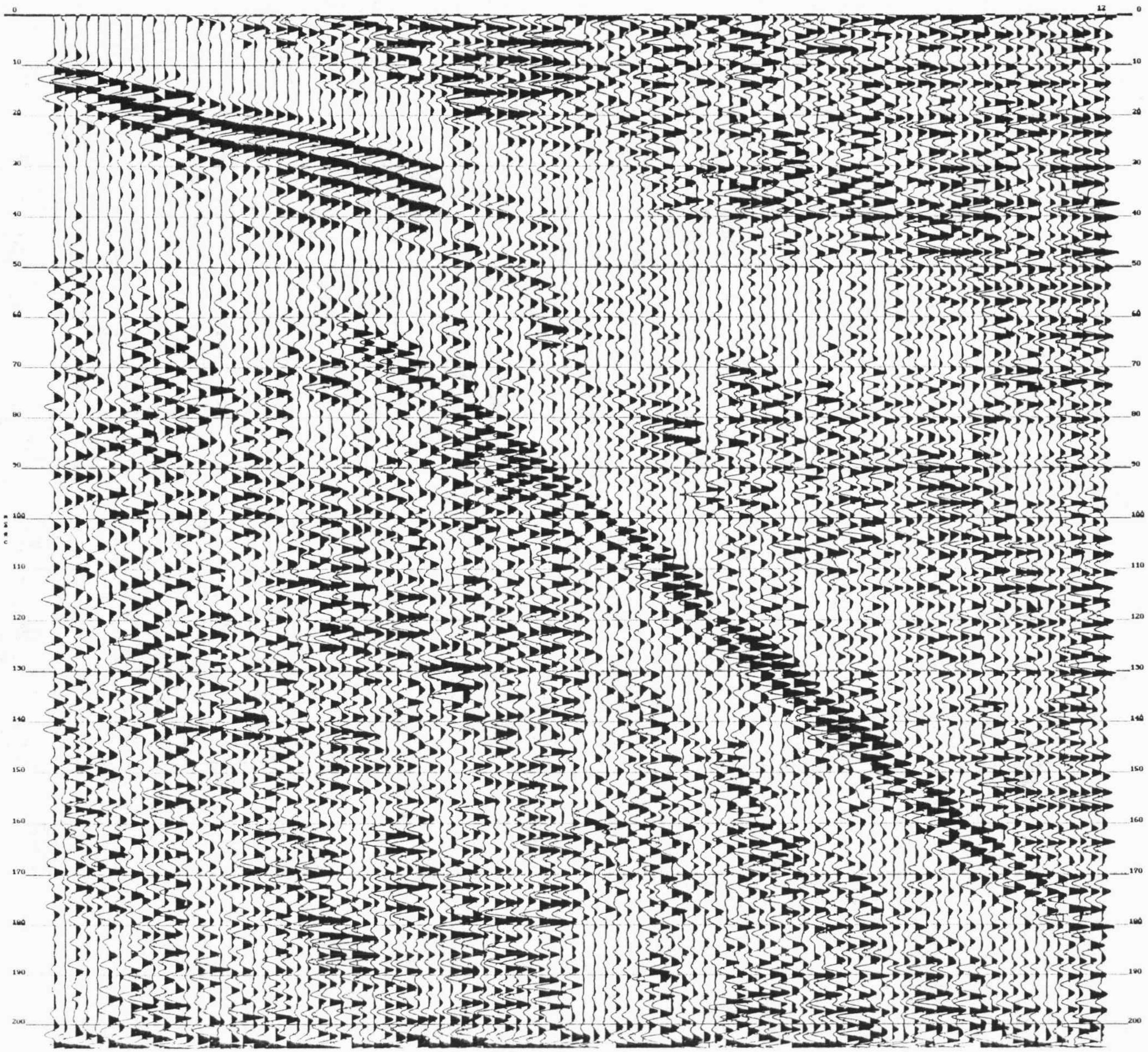
Figure 4b



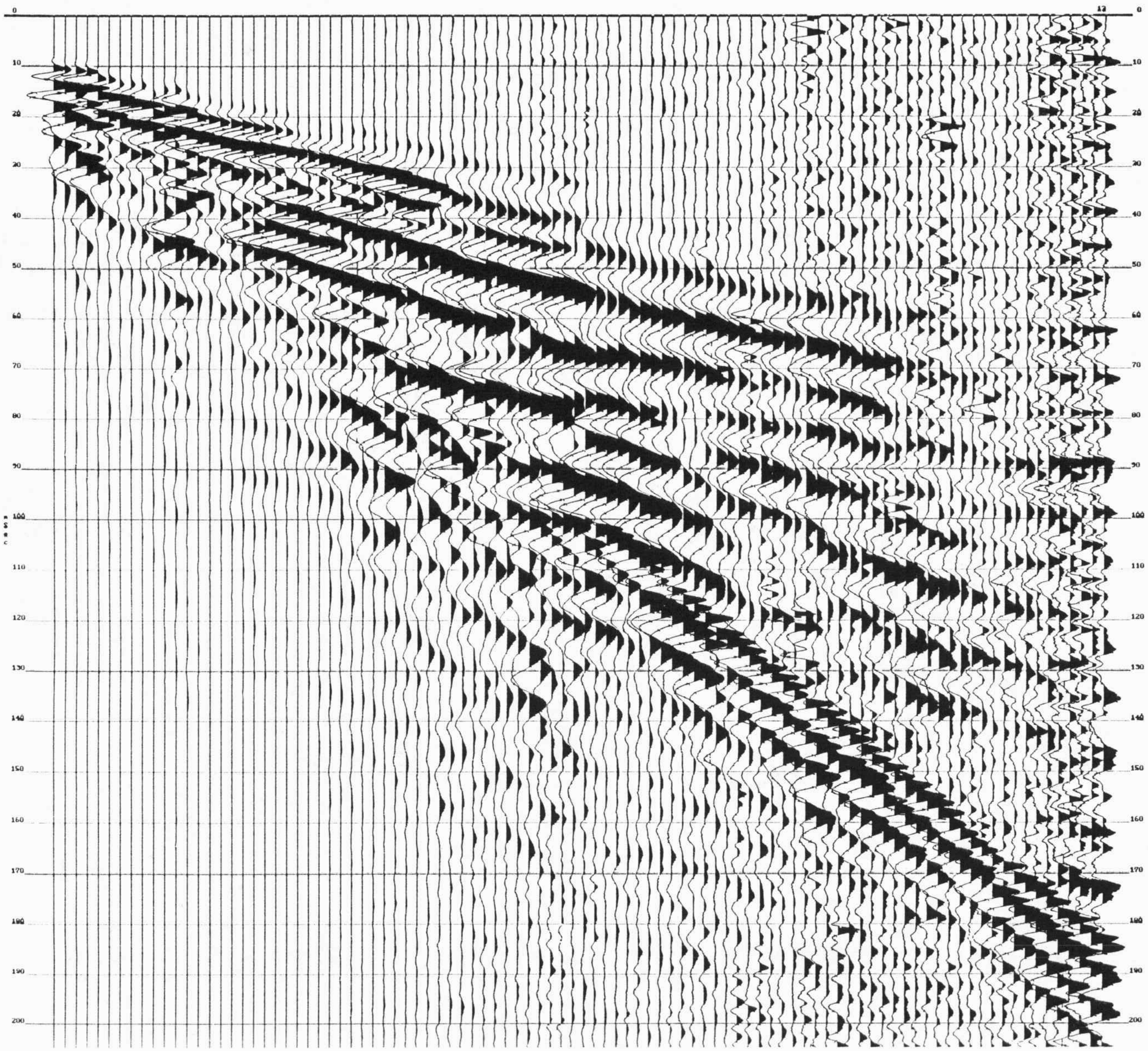
Site 1c
Figure 5a



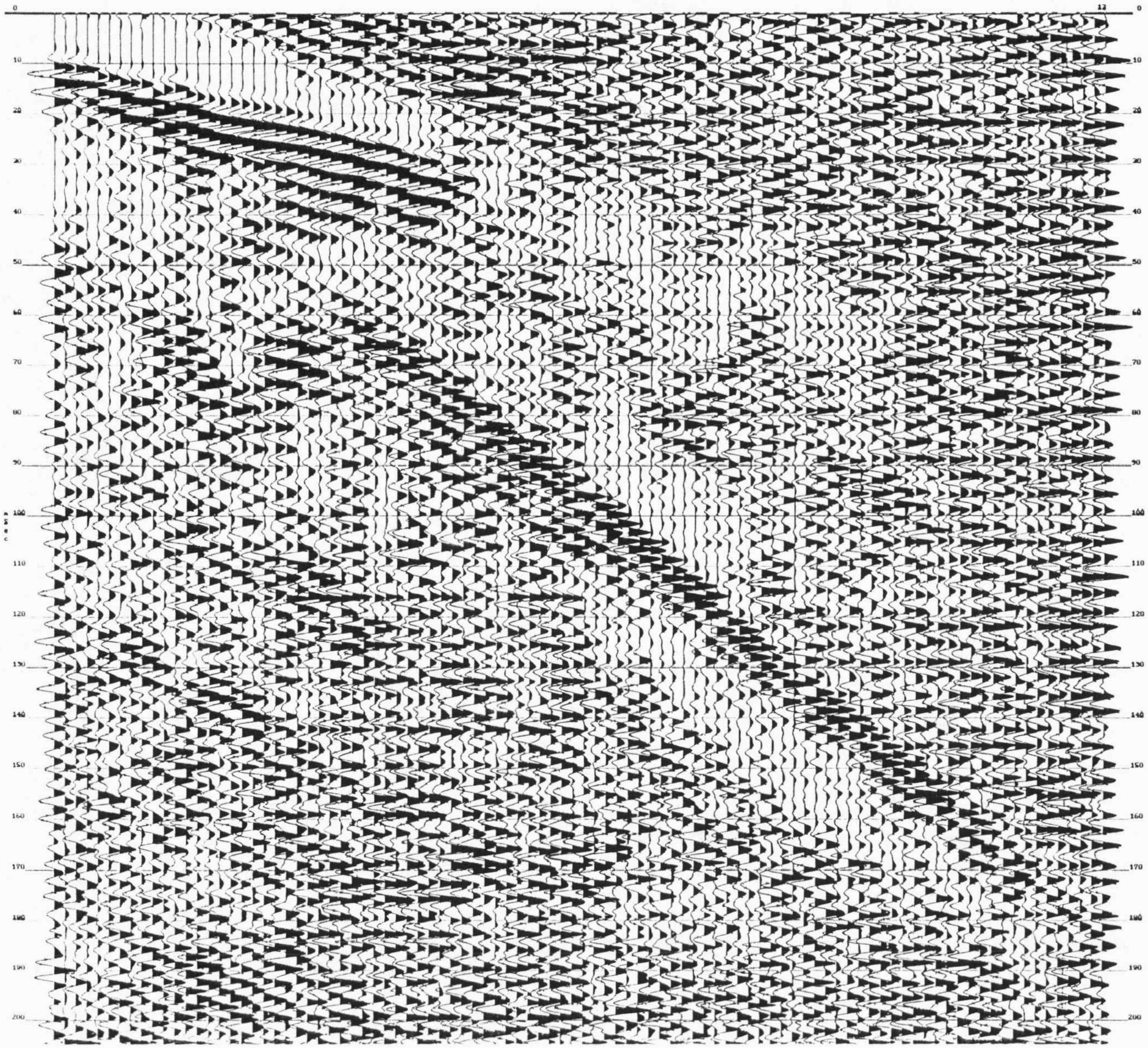
Site 1c
Figure 5b



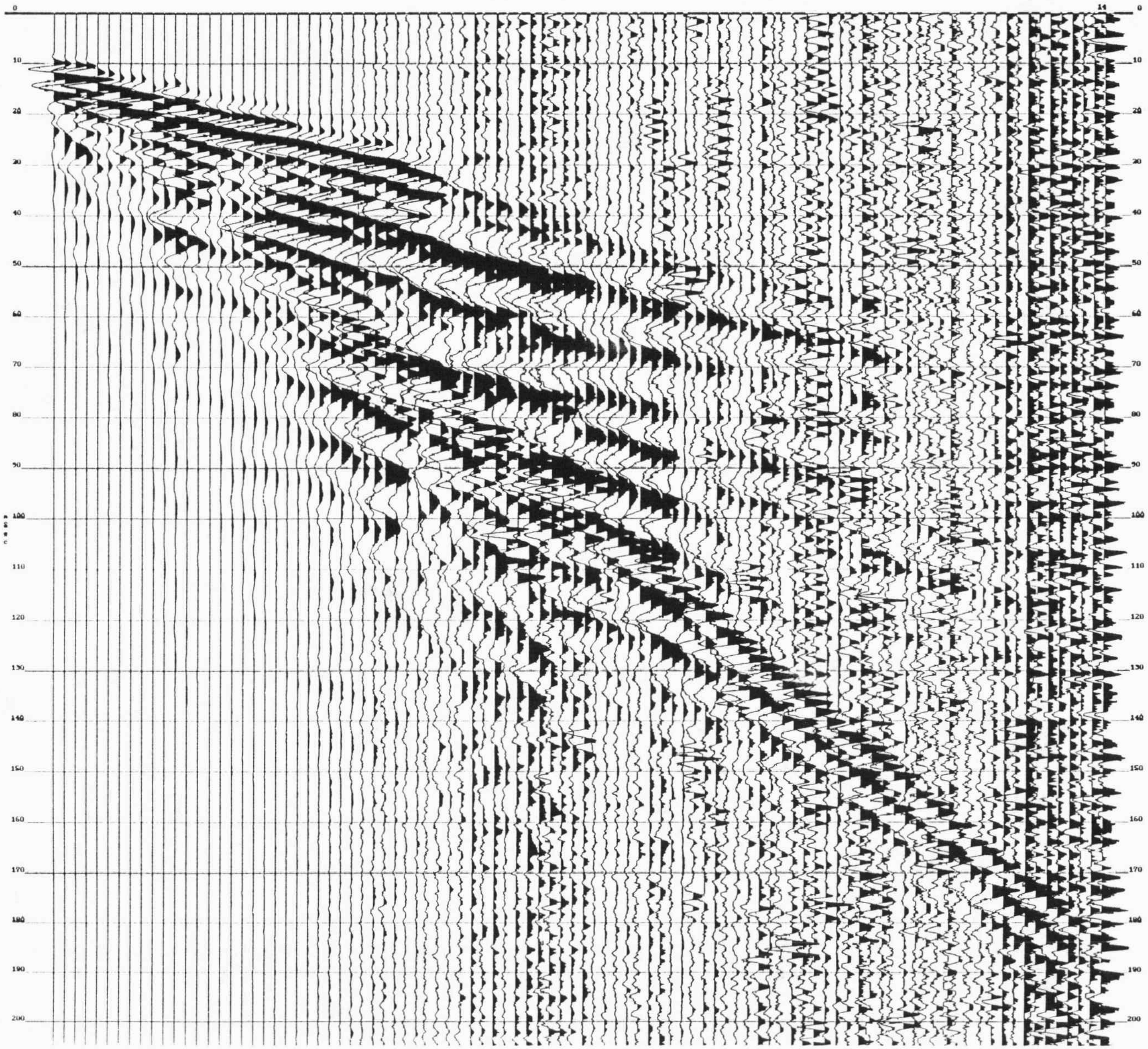
Site 1d
Figure 6a



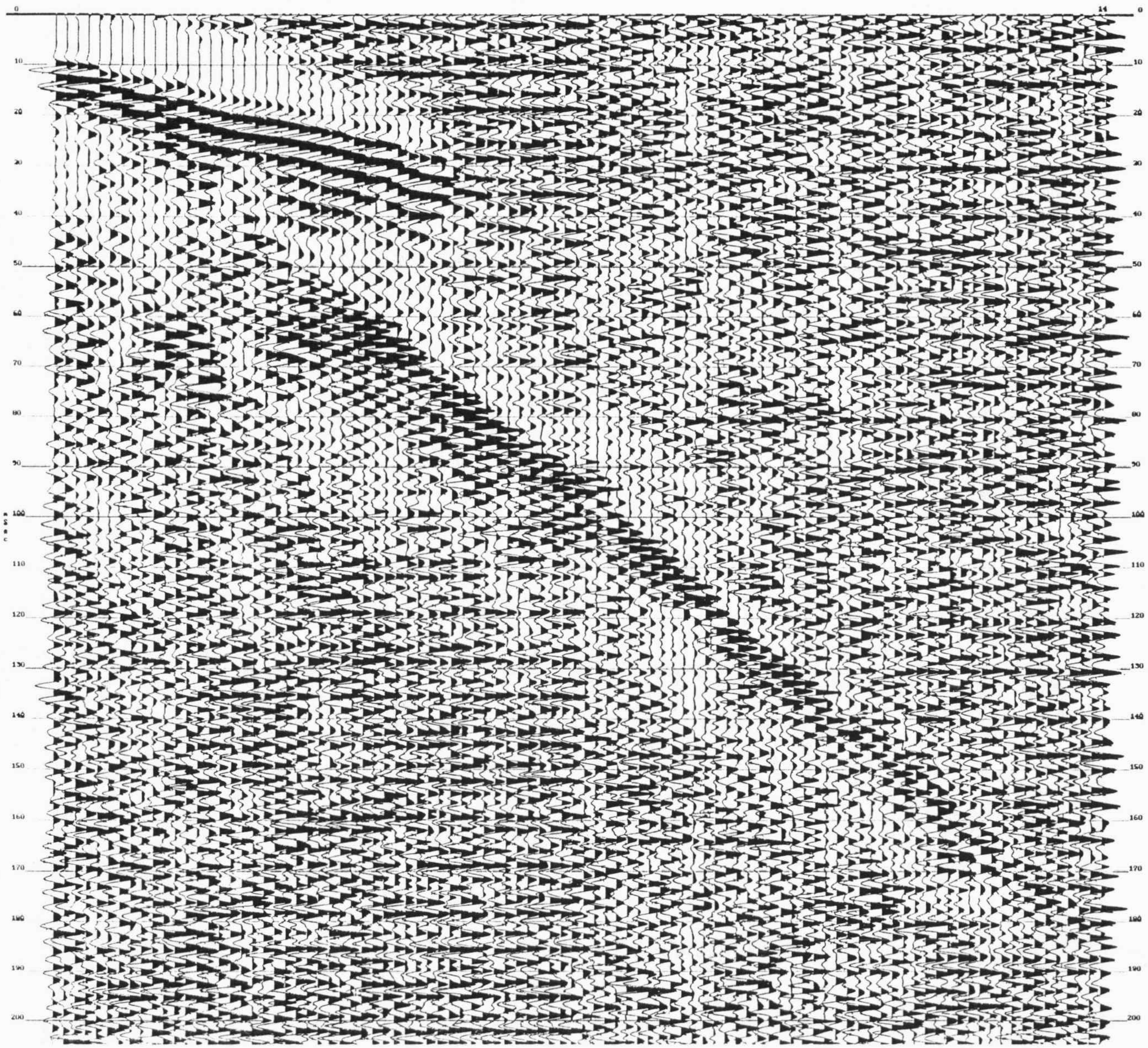
Site 1d
Figure 6b



Site 1e
Figure 7a



Site 1e
Figure 7b



Site 1r
Figure 8a

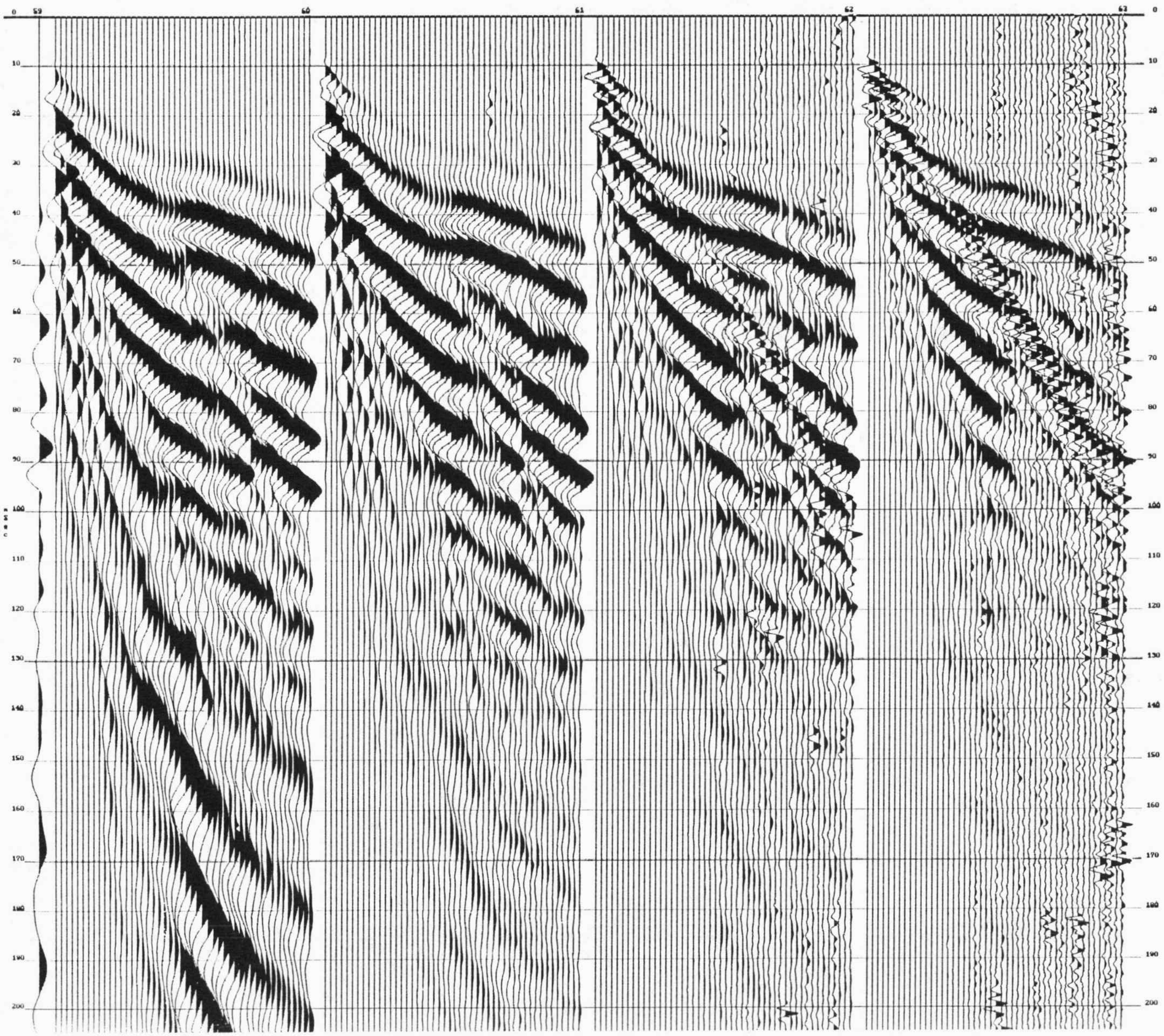


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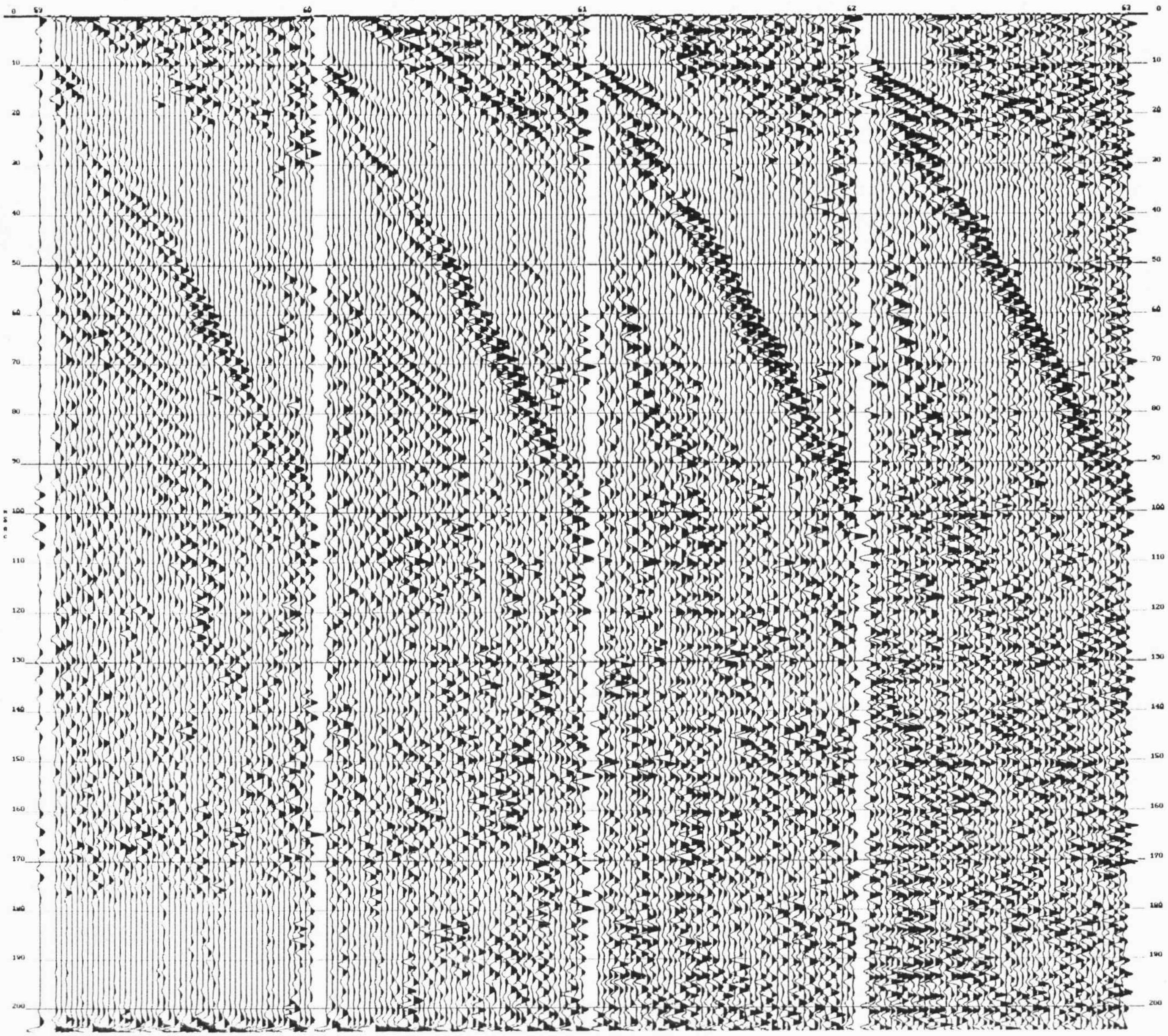
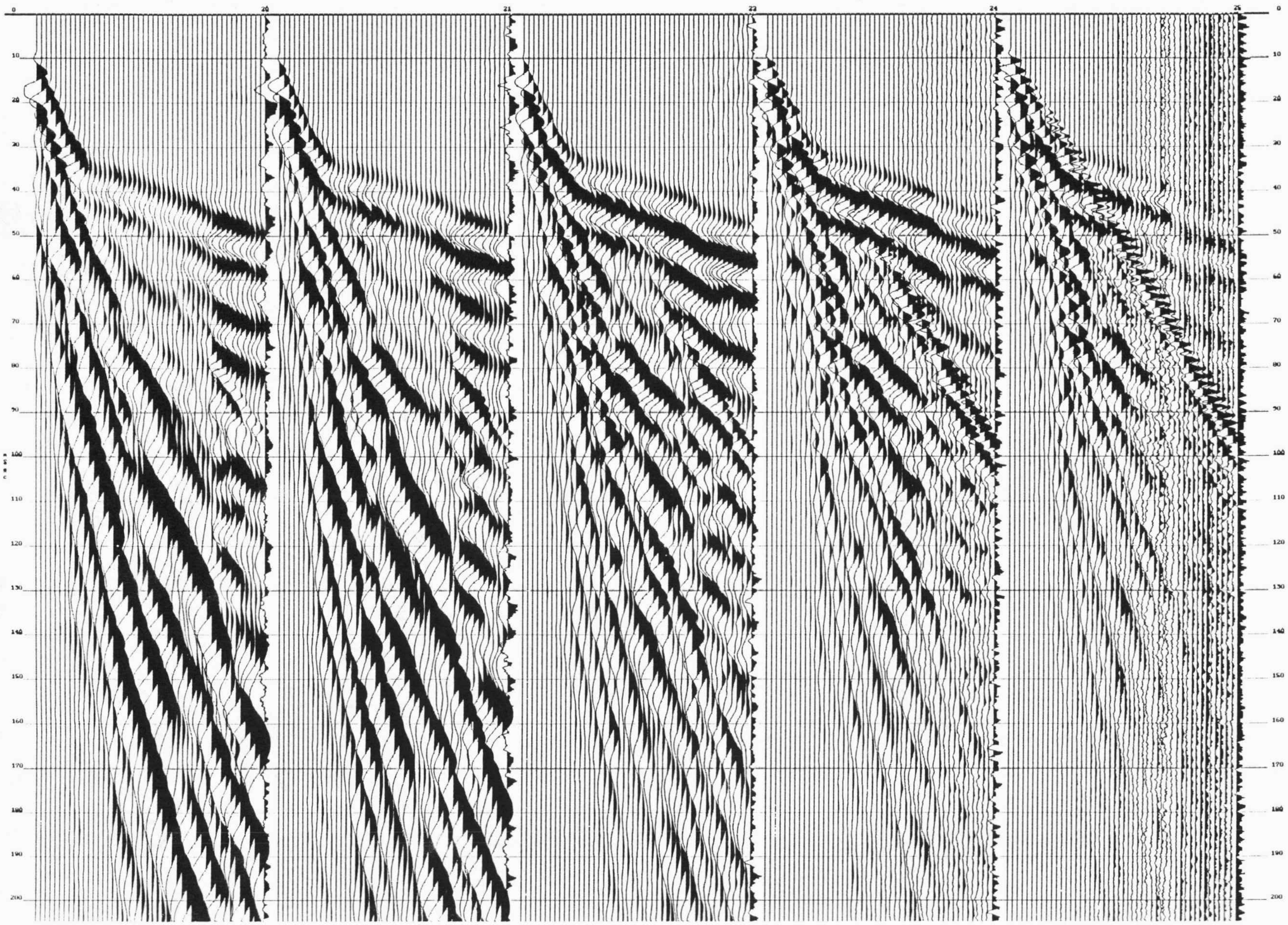
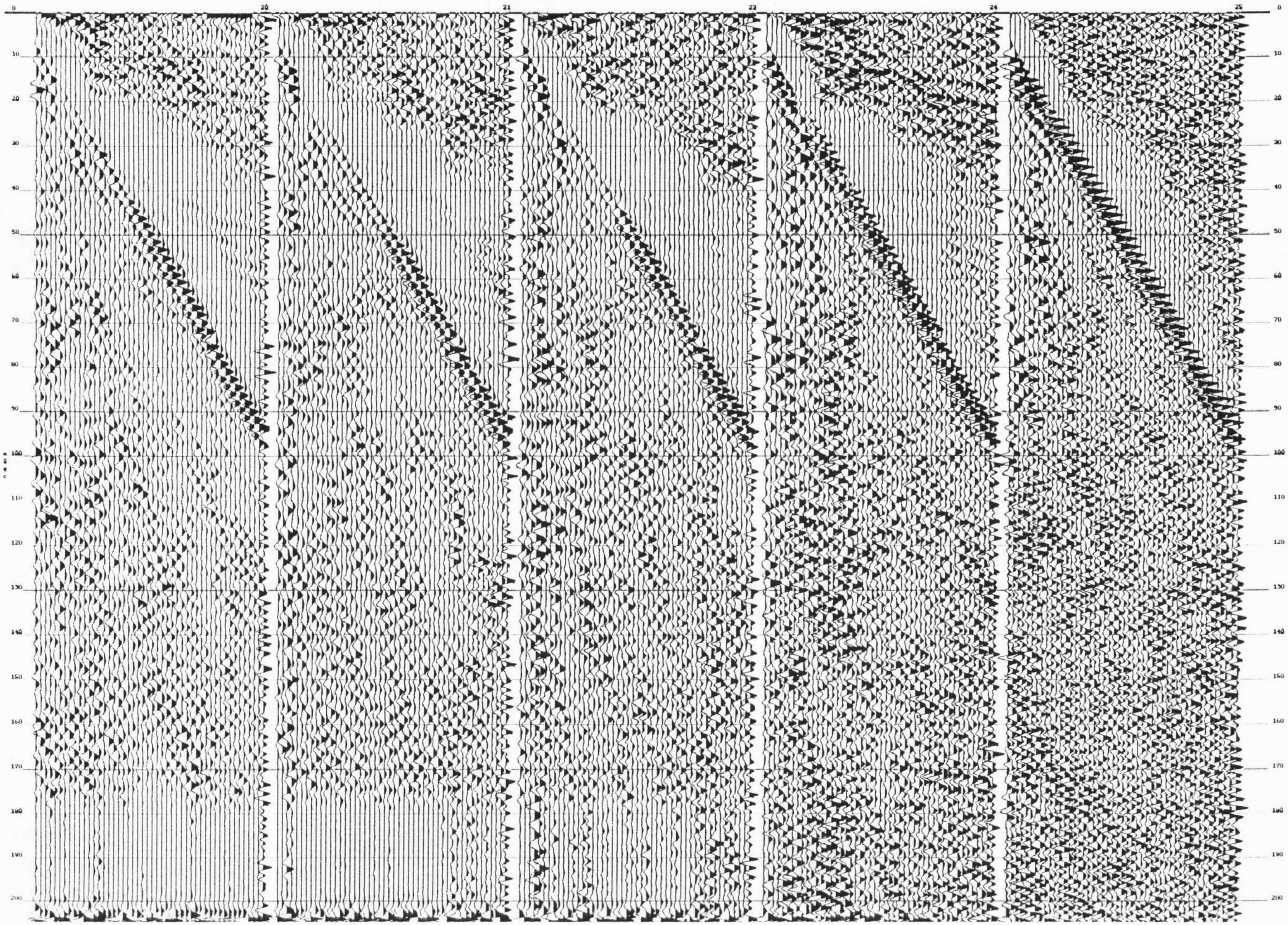
Figure 8b



Site 2w
Figure 9a



Site 2w
Figure 9b



Site 2e
Figure 10a

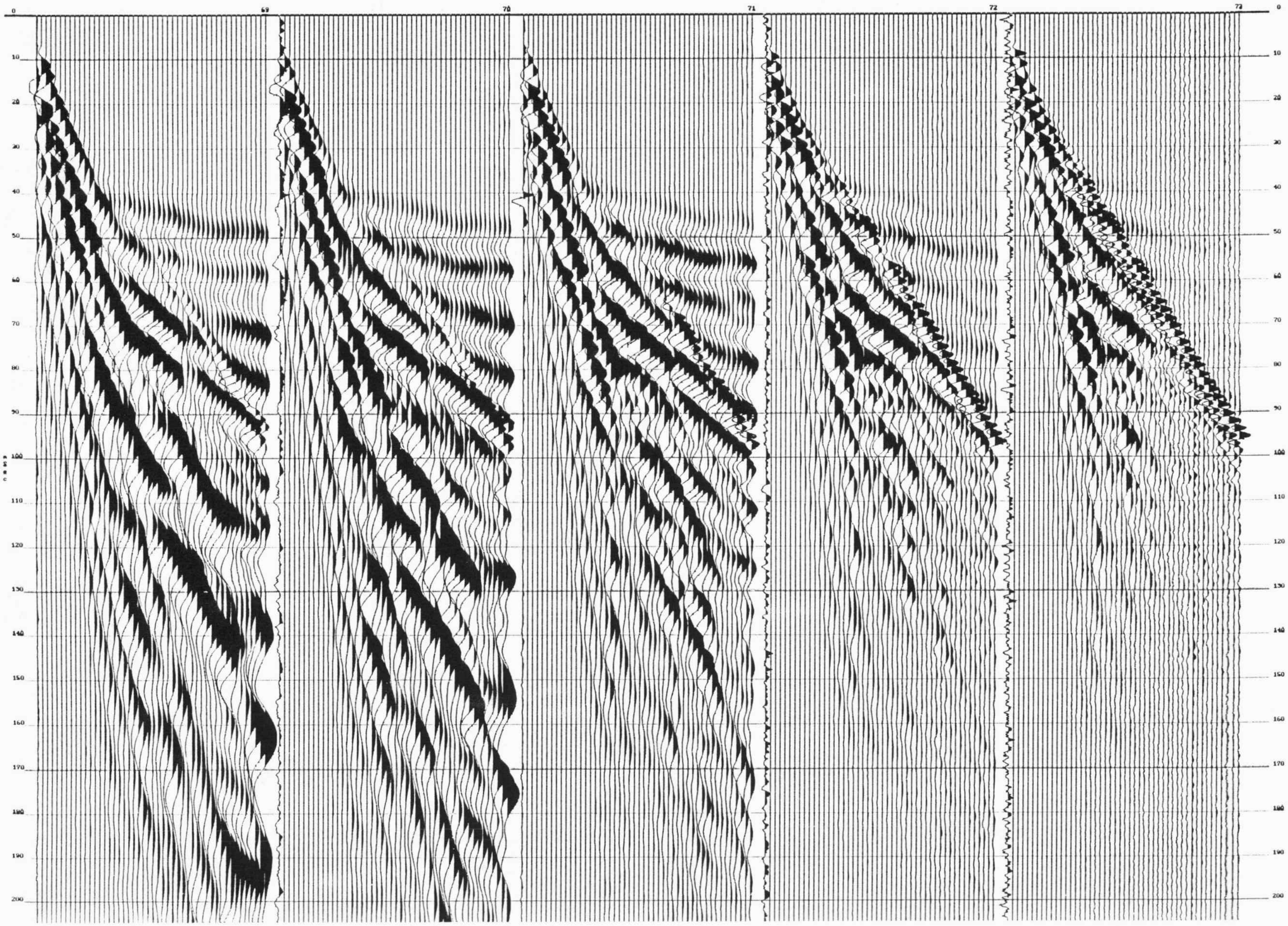


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Figure 10b

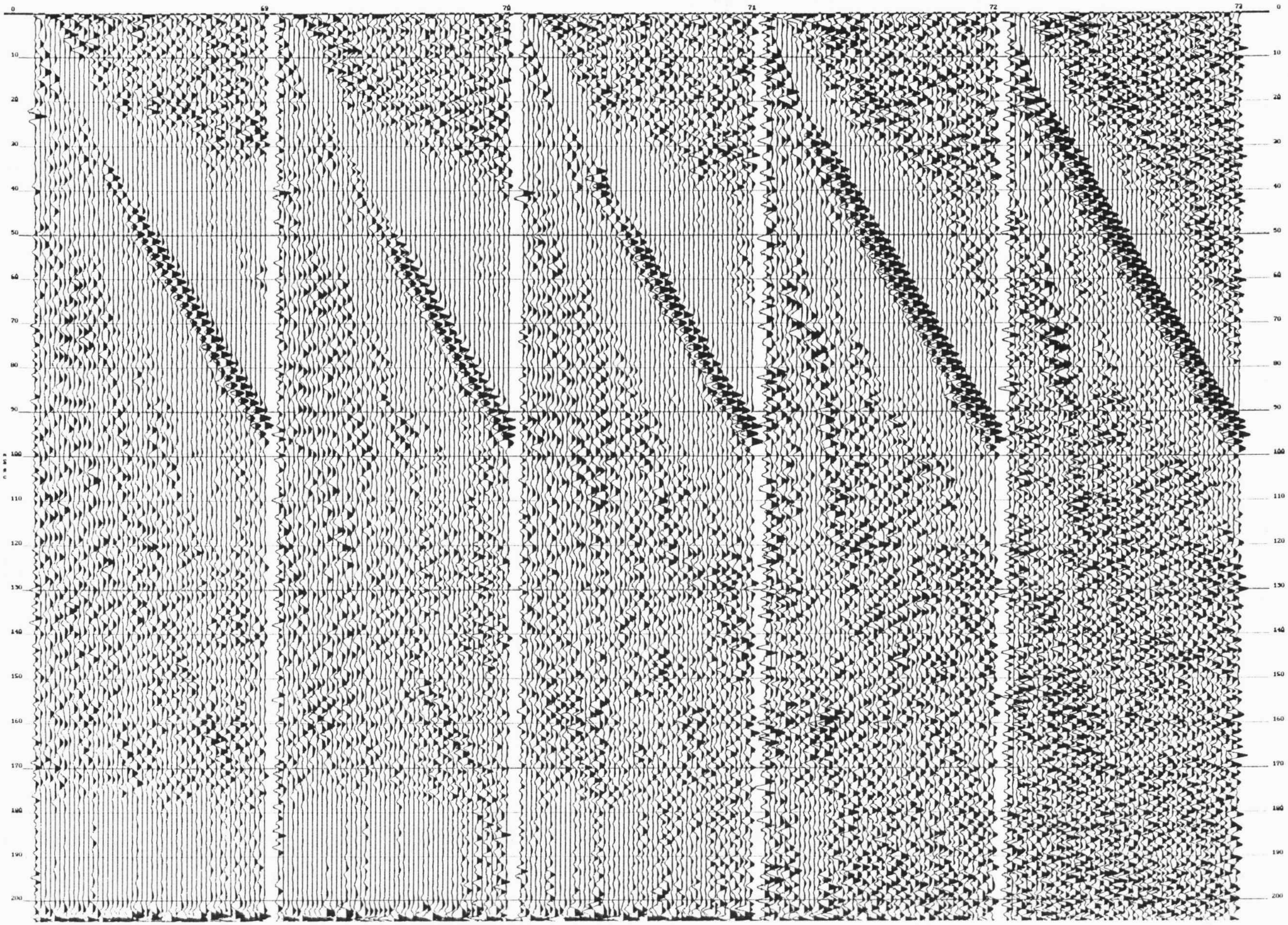

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Figure 11a

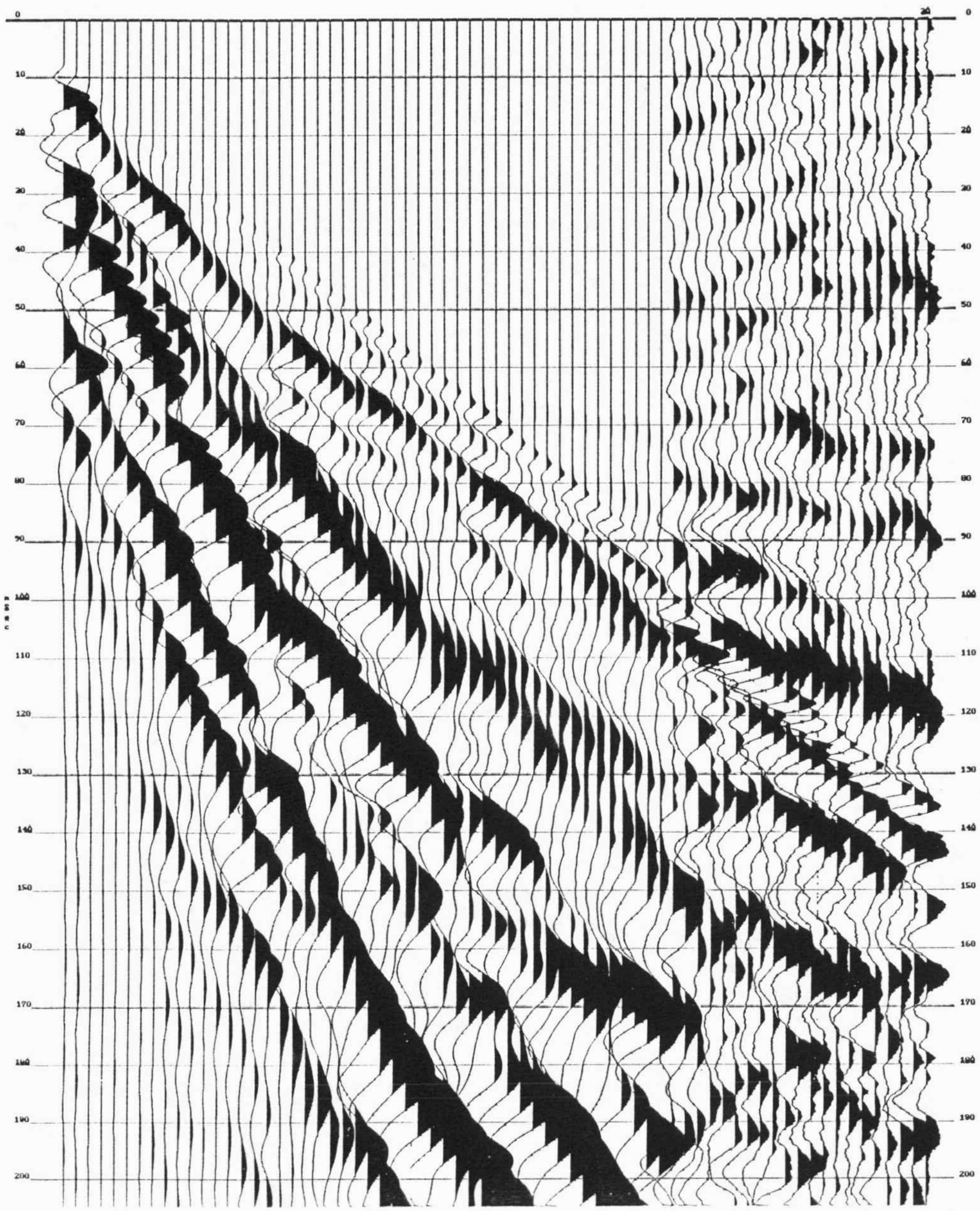

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Figure 11b

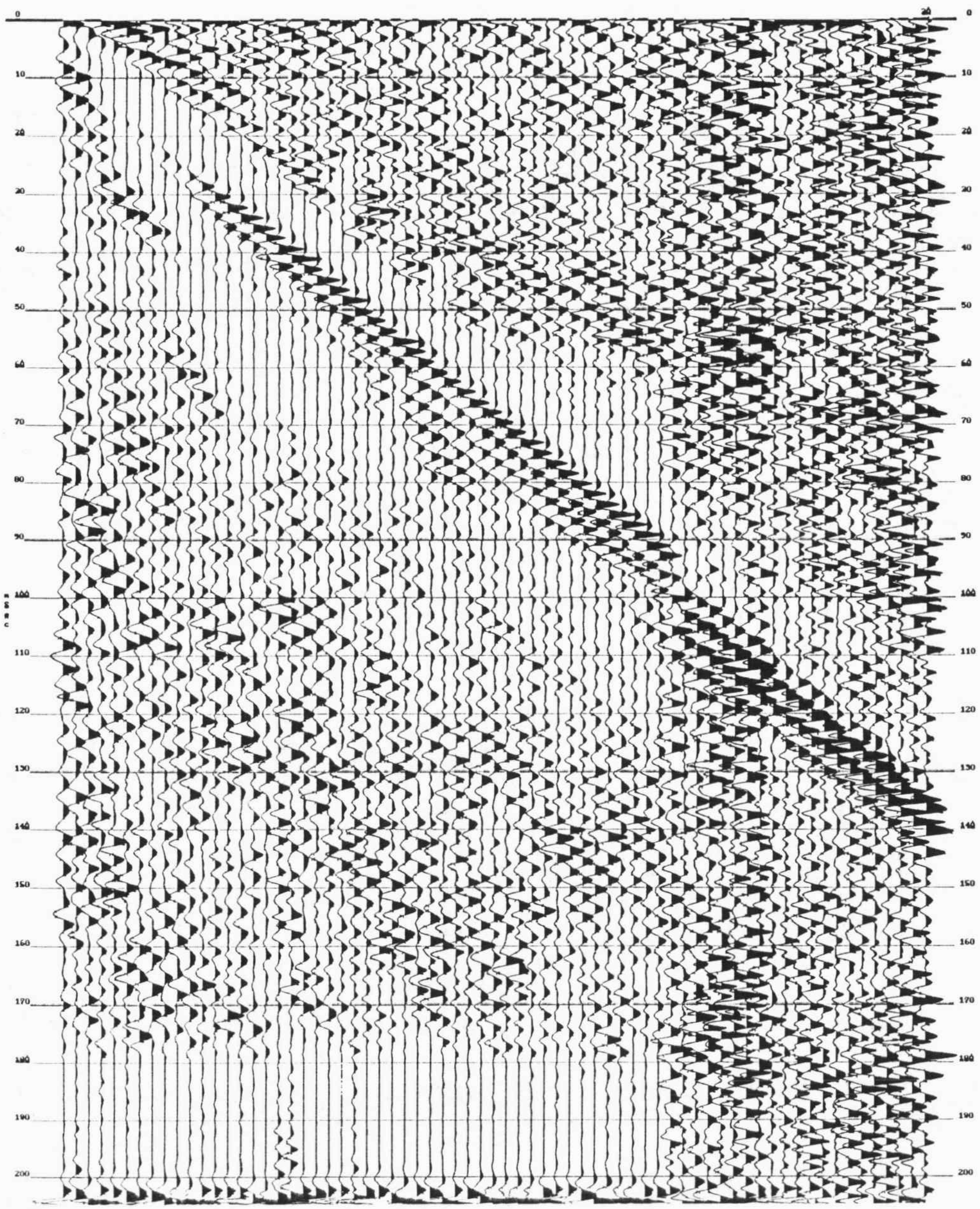

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Figure 12a

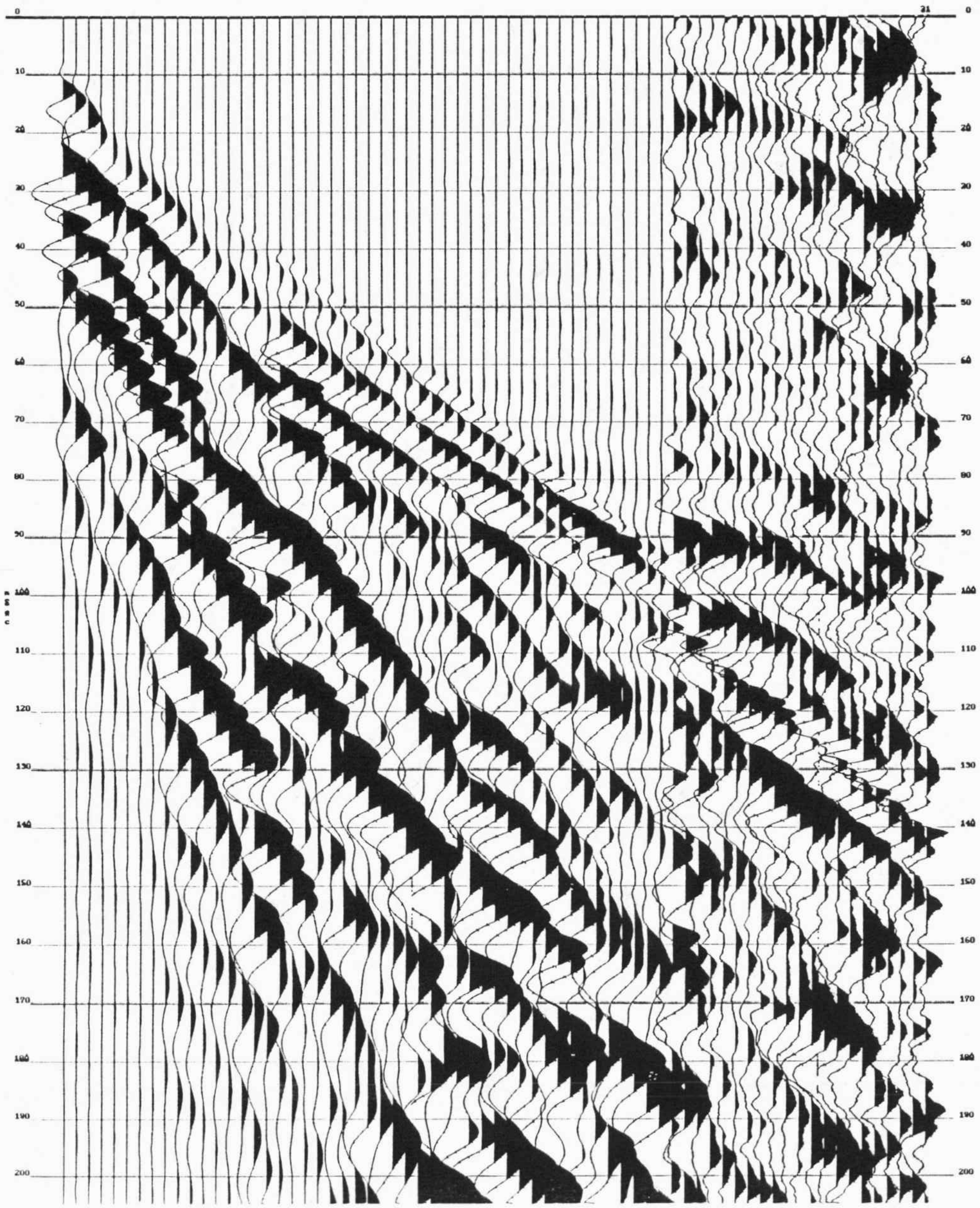

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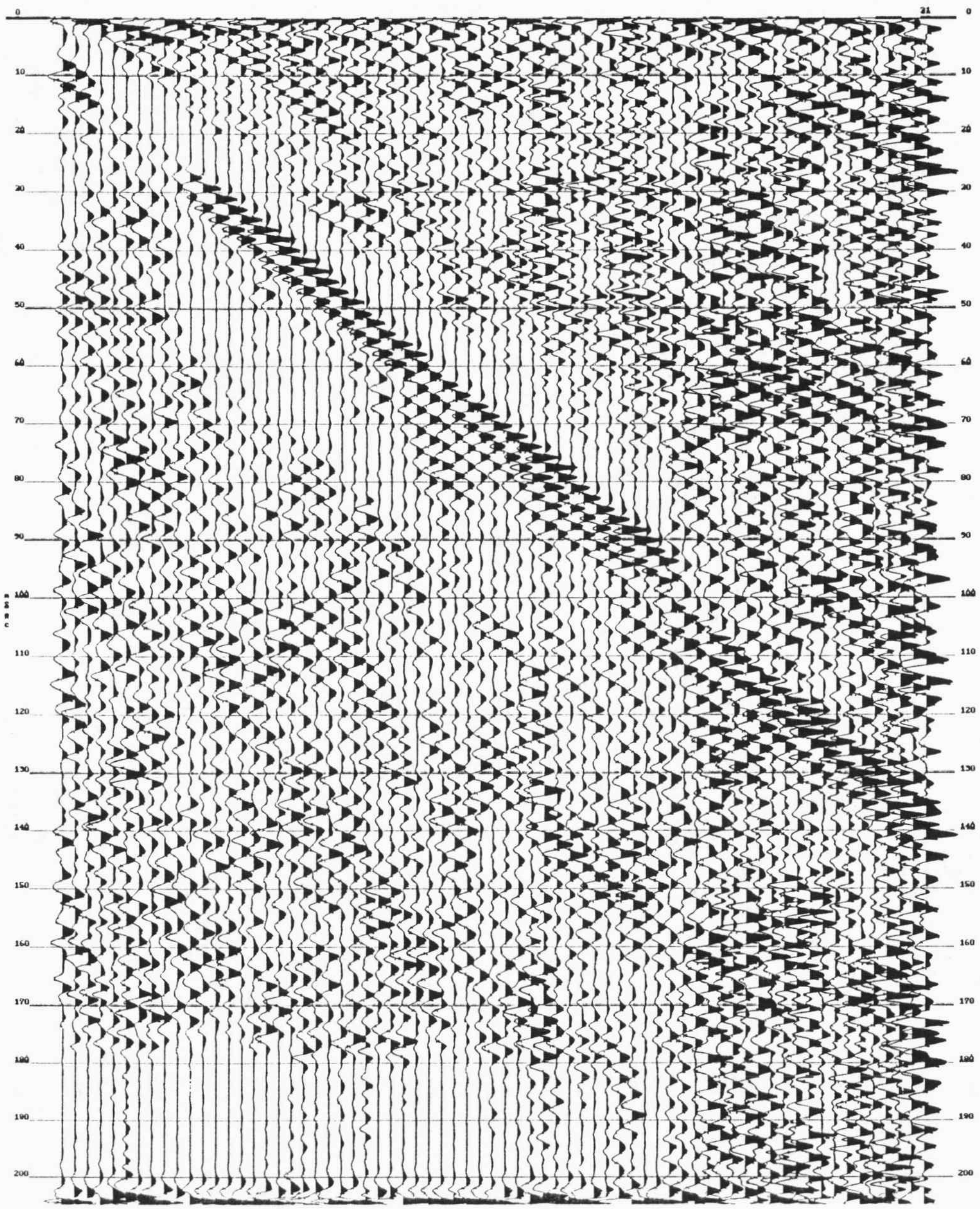
Figure 12b



Site 3c
Figure 13a

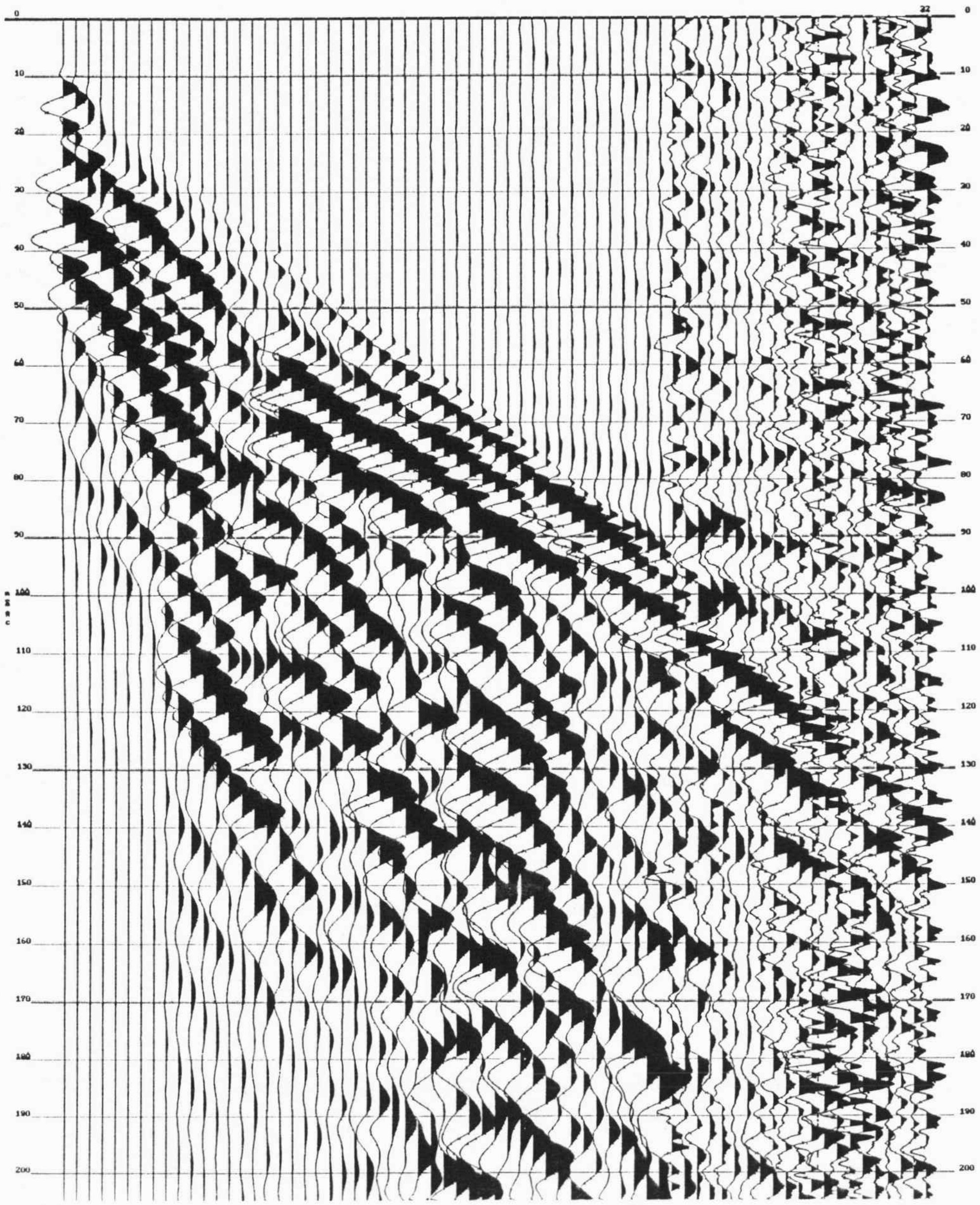


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Figure 13b

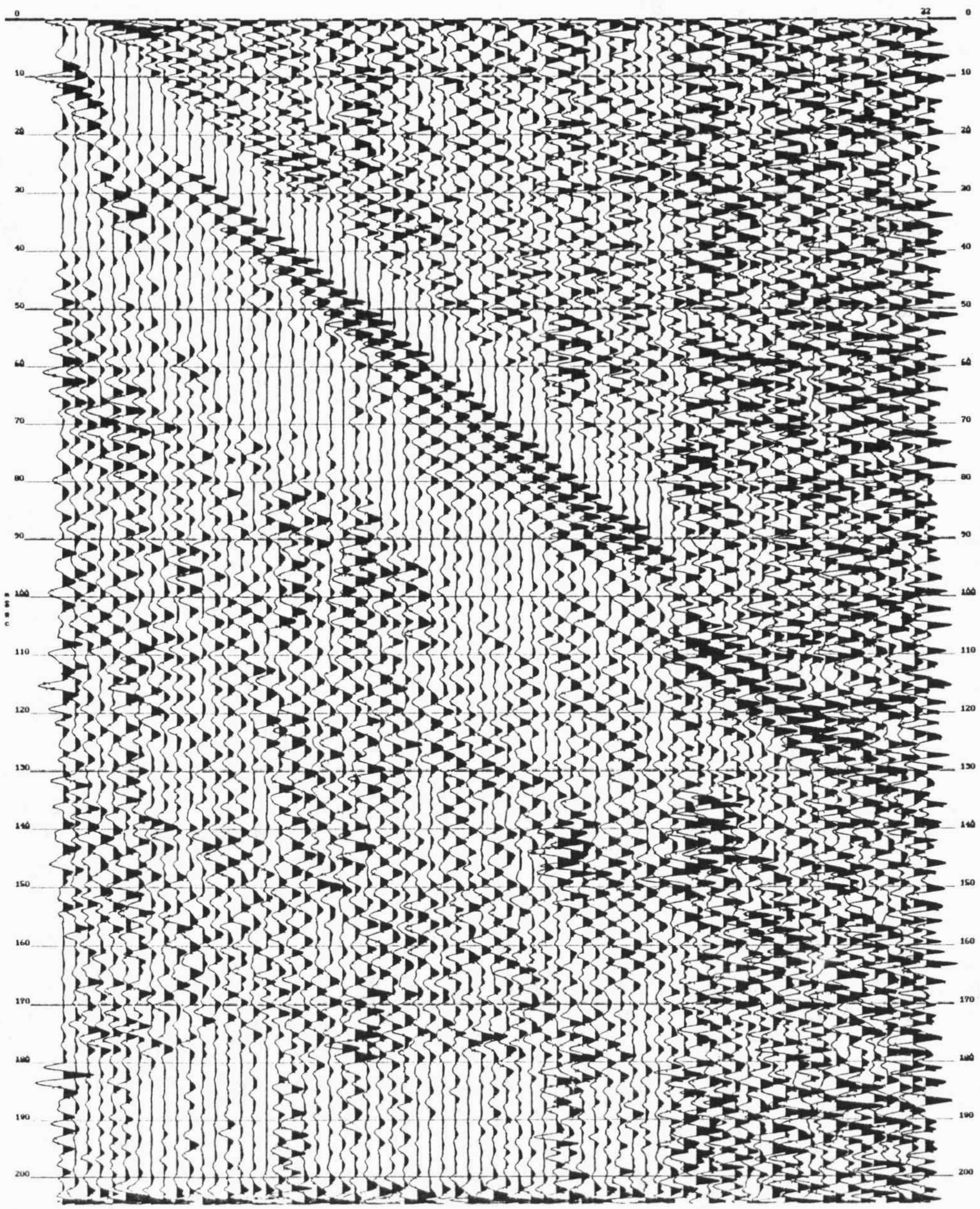

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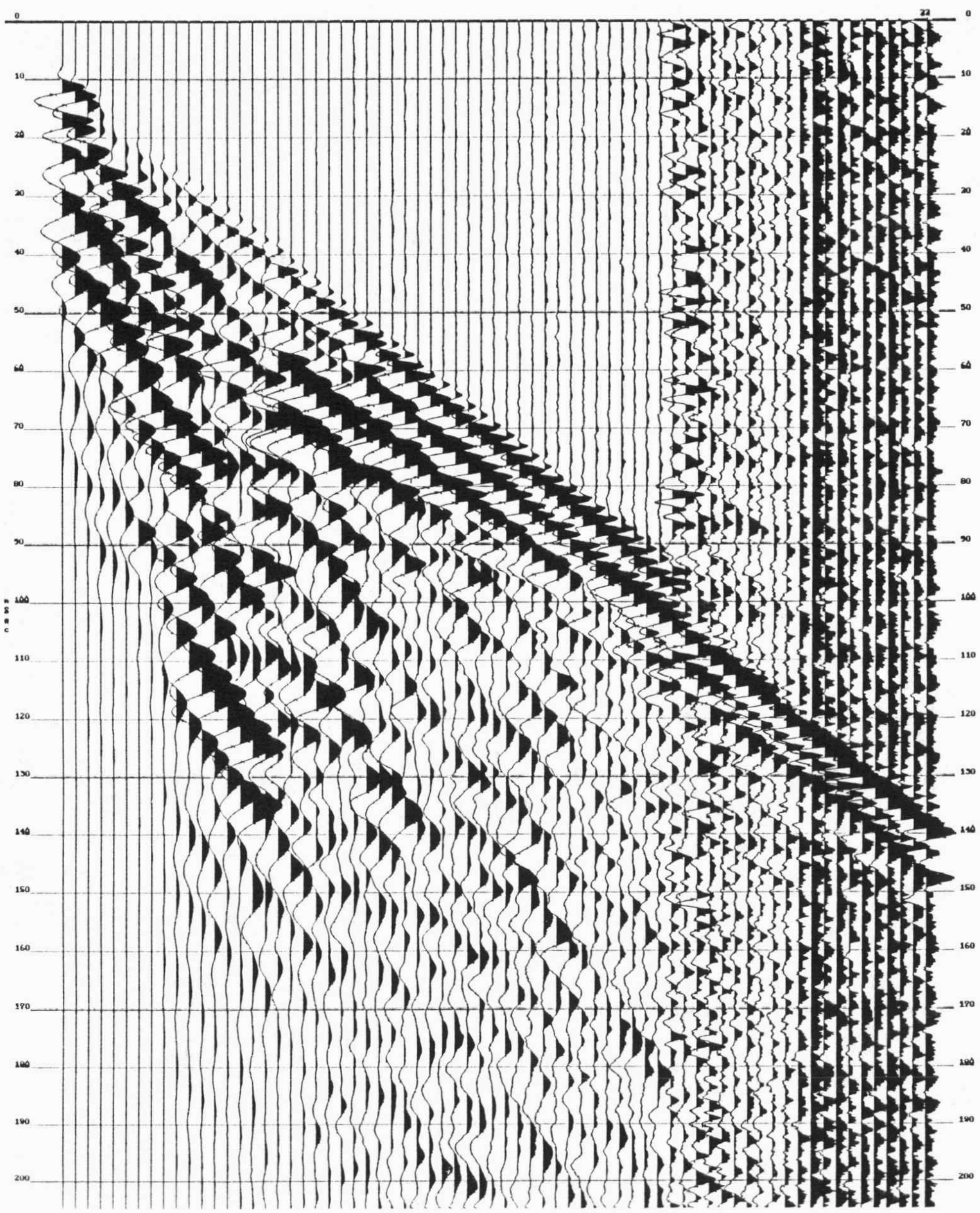
Figure 14a



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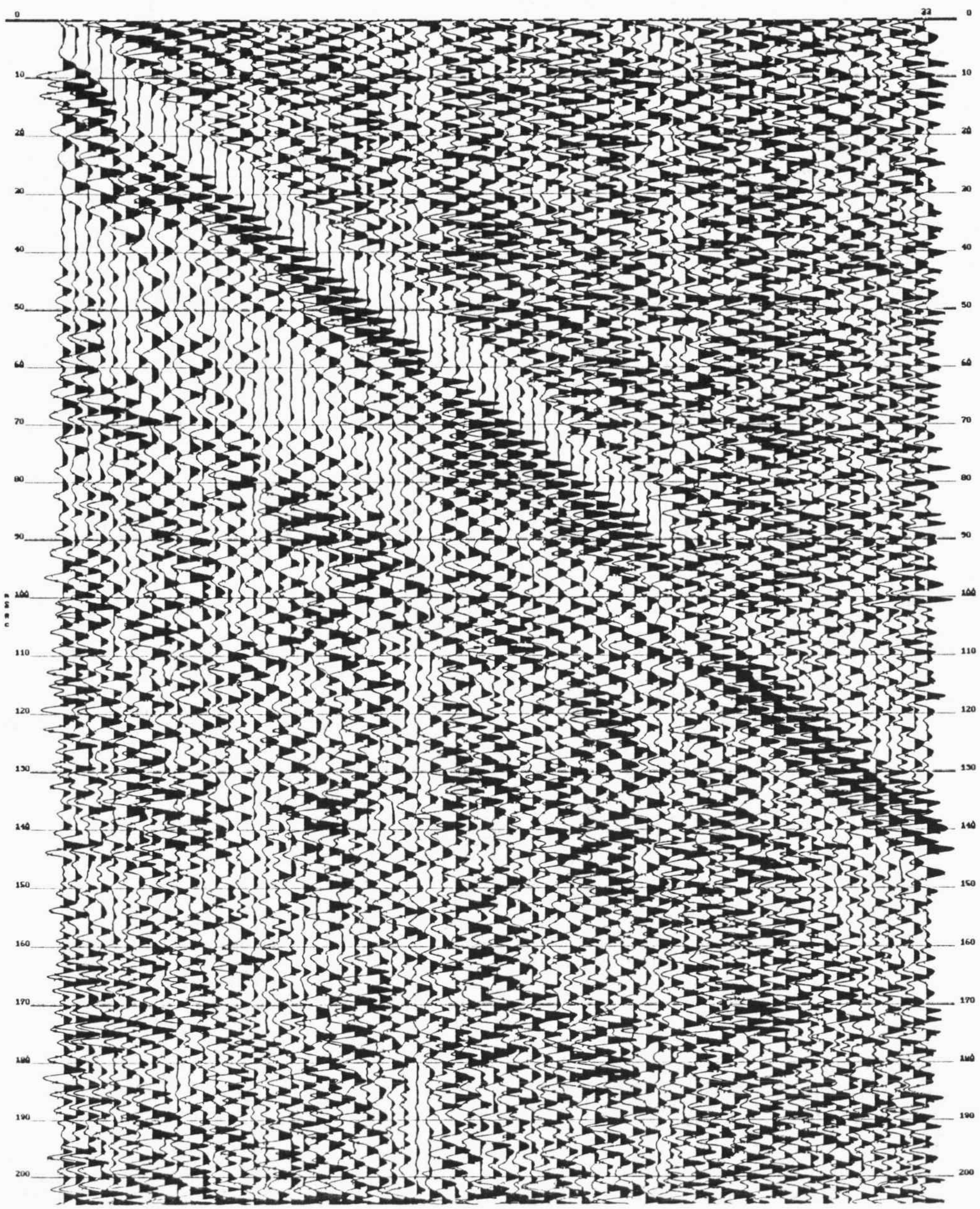

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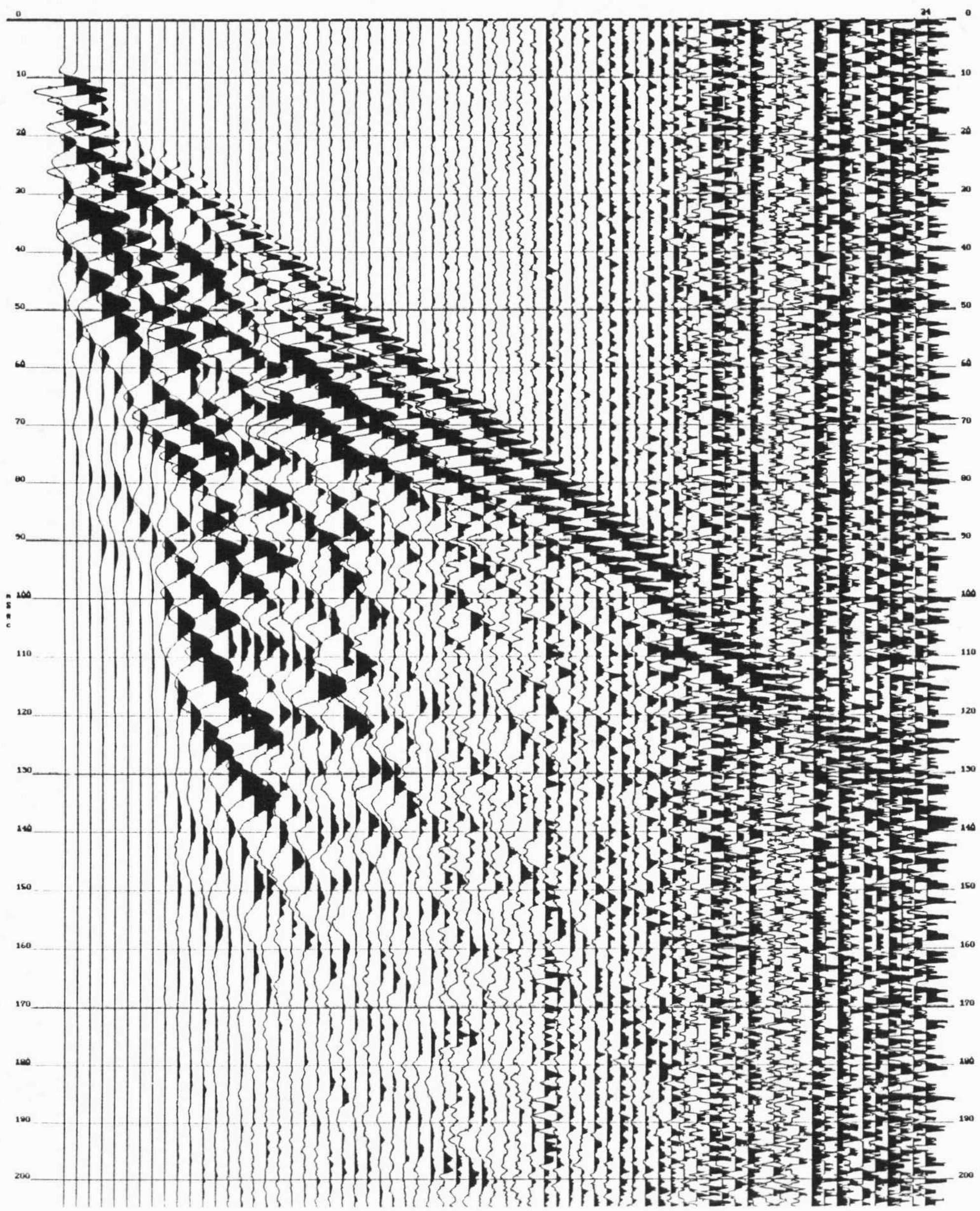
Figure 15a



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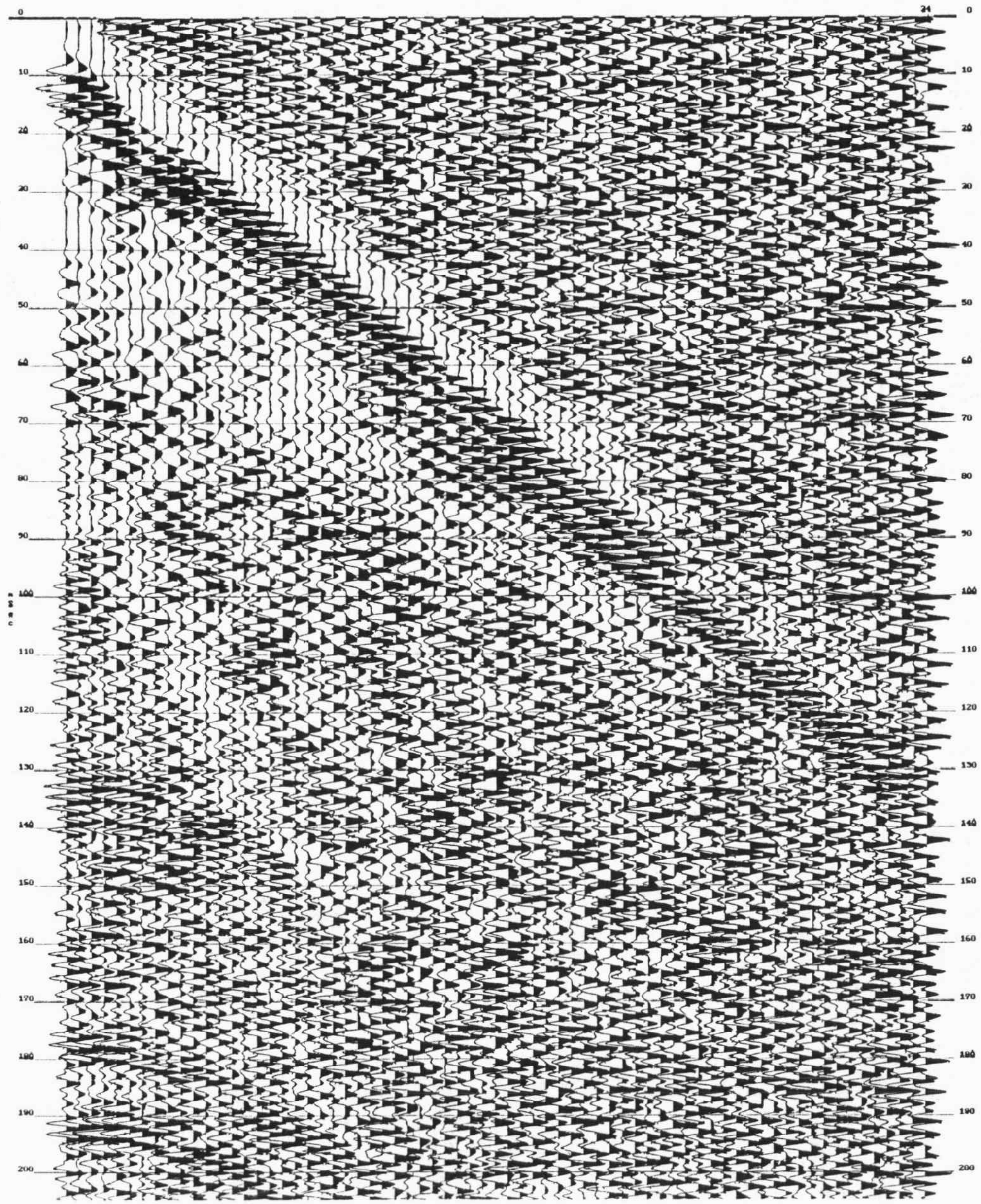

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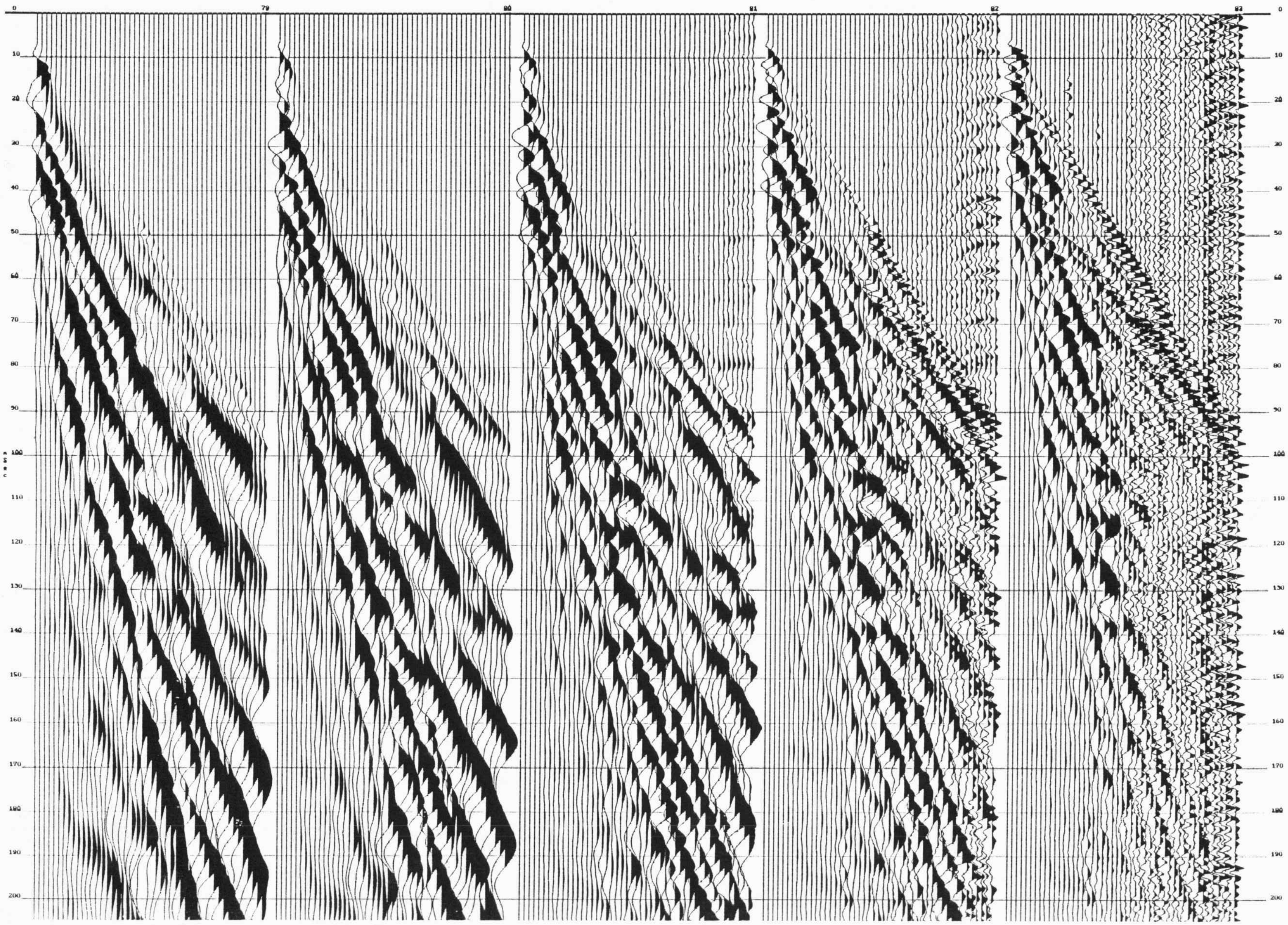
Figure 16a



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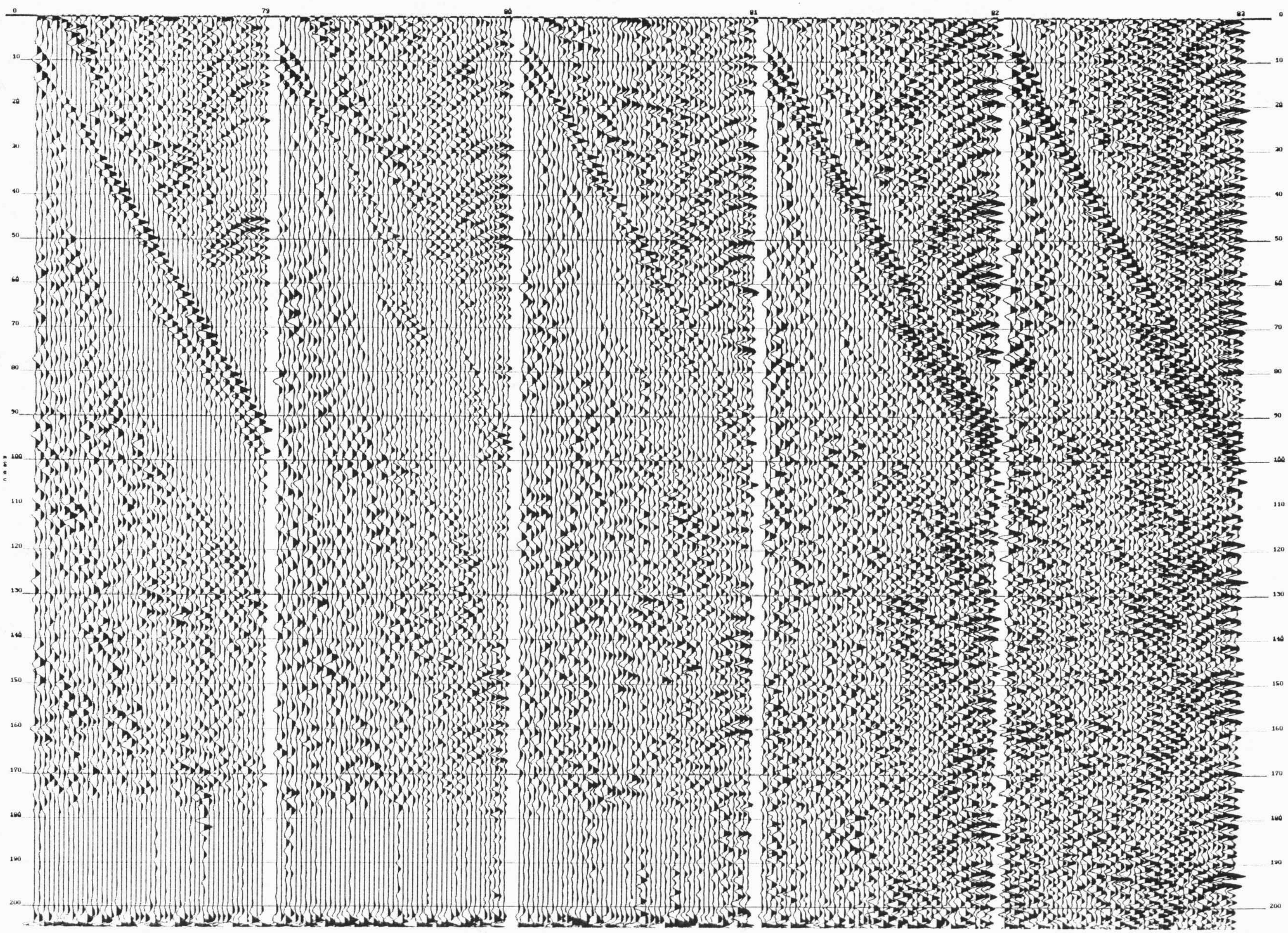

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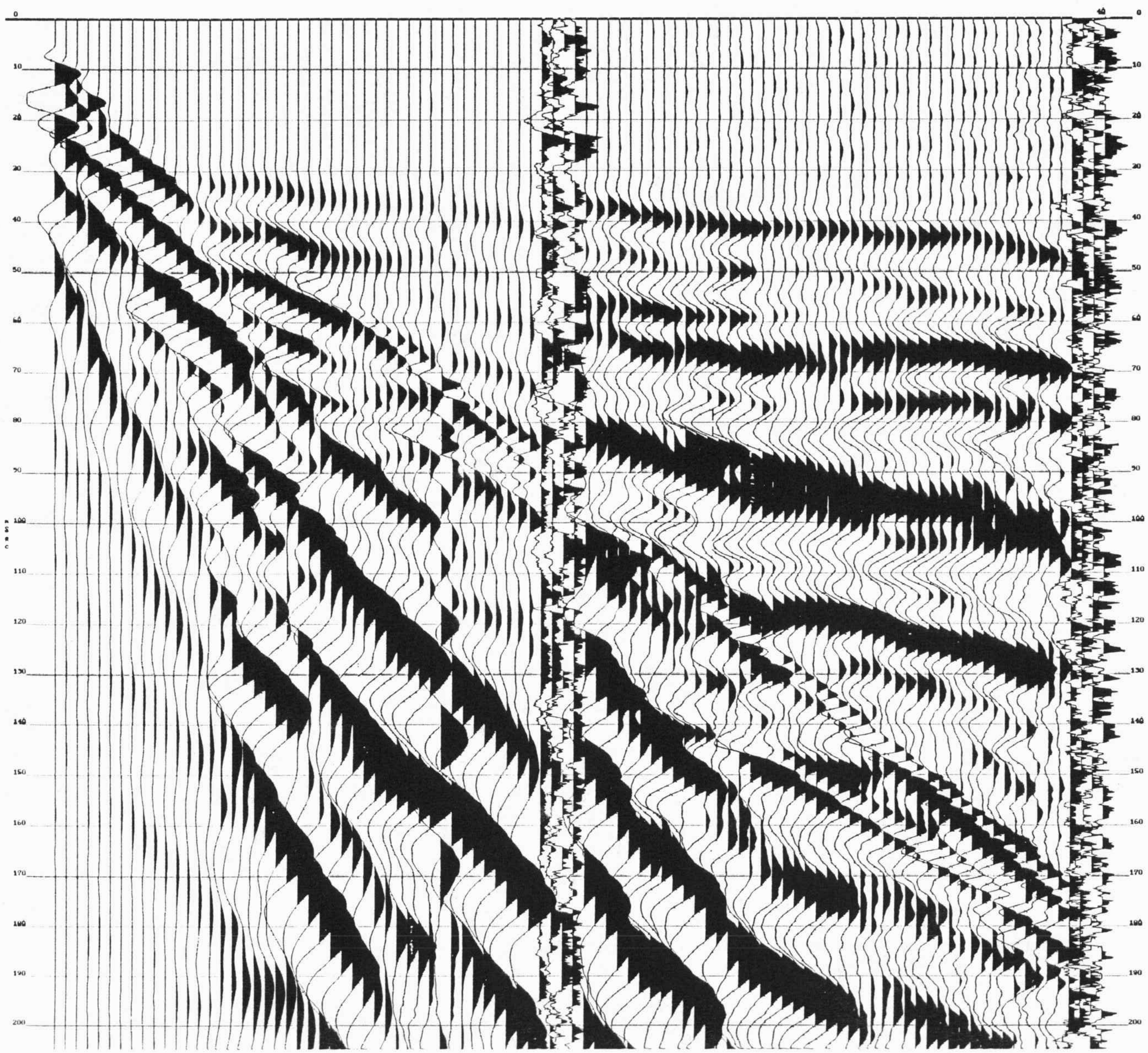
Figure 17a



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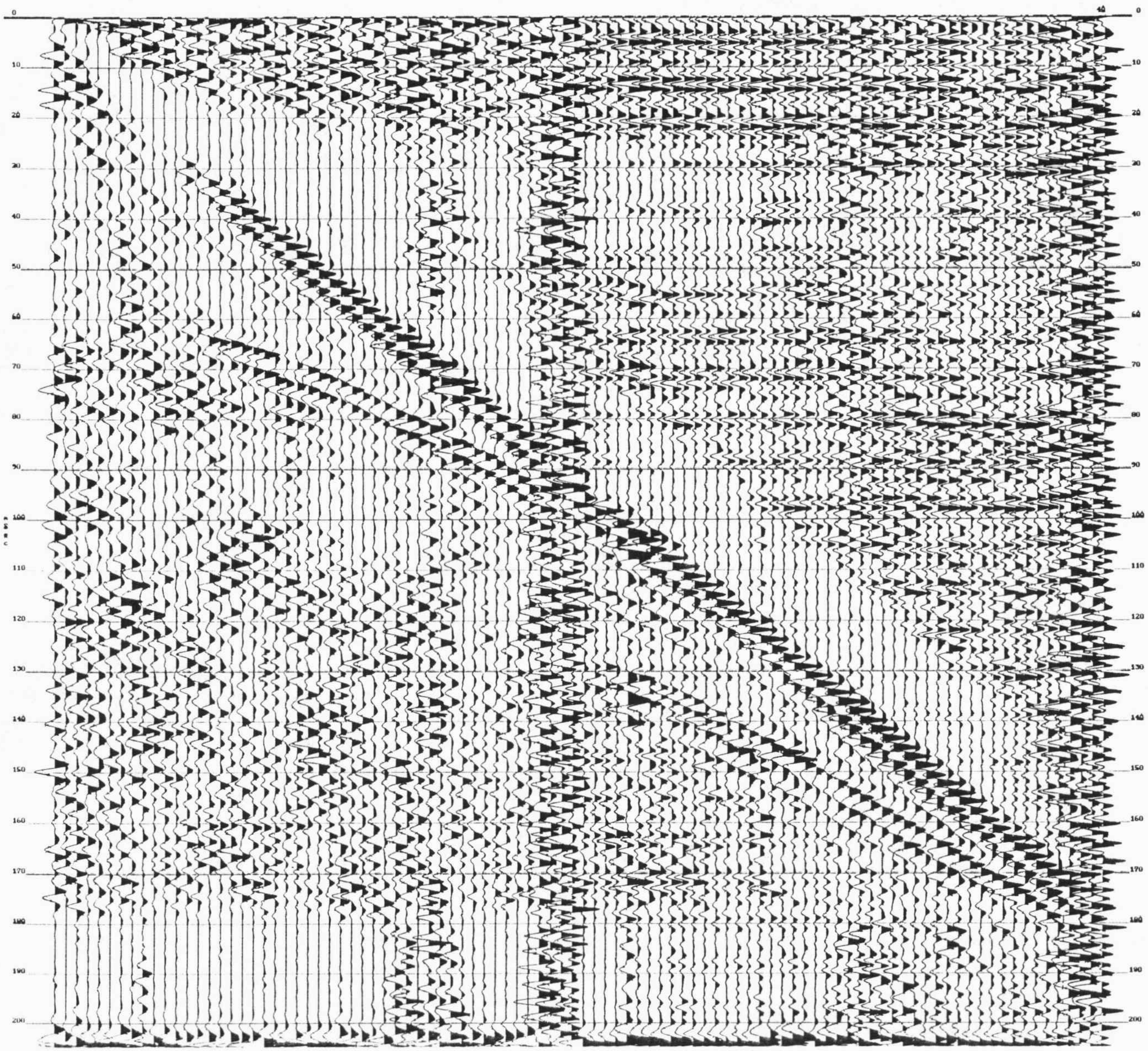

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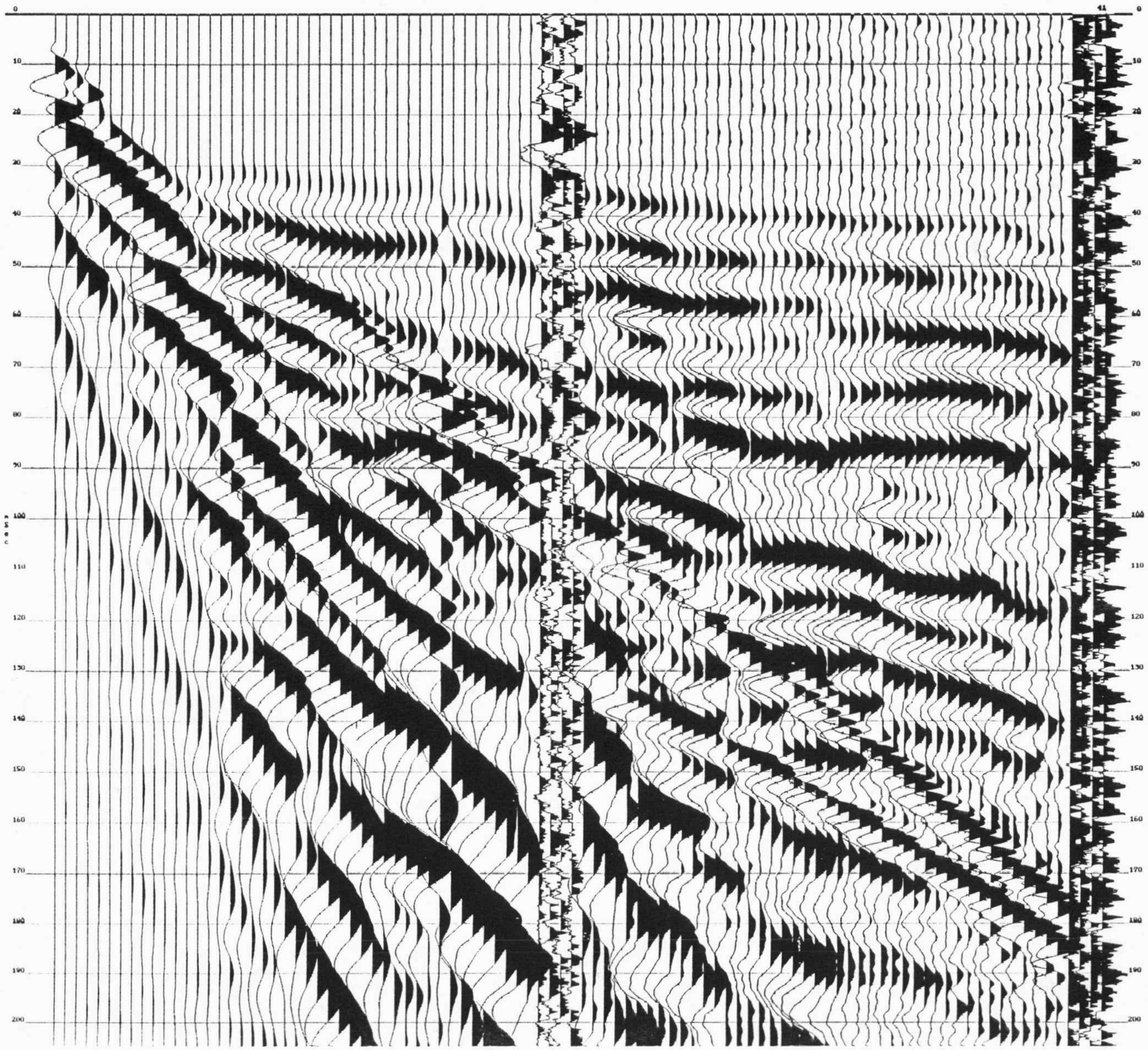

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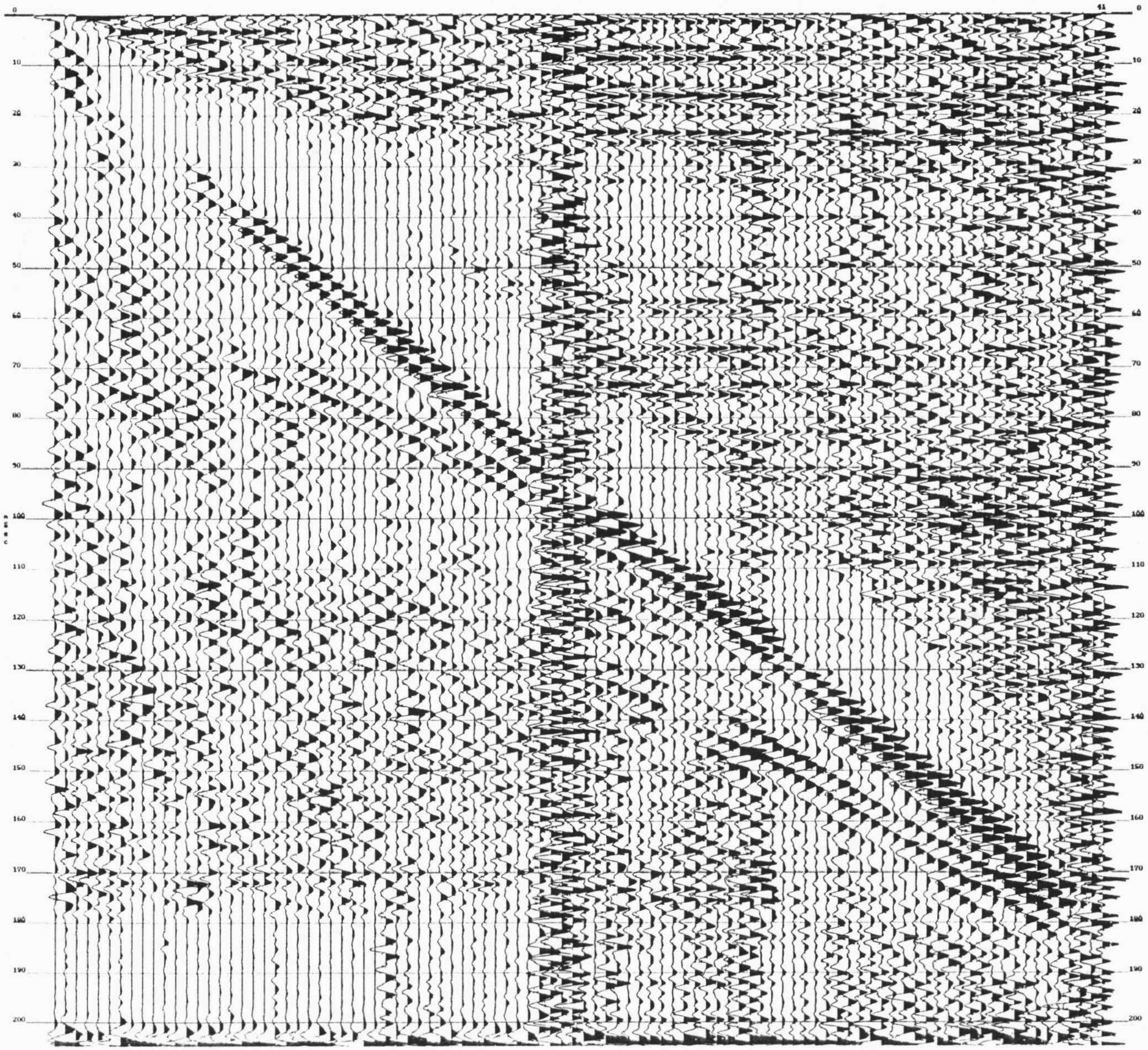

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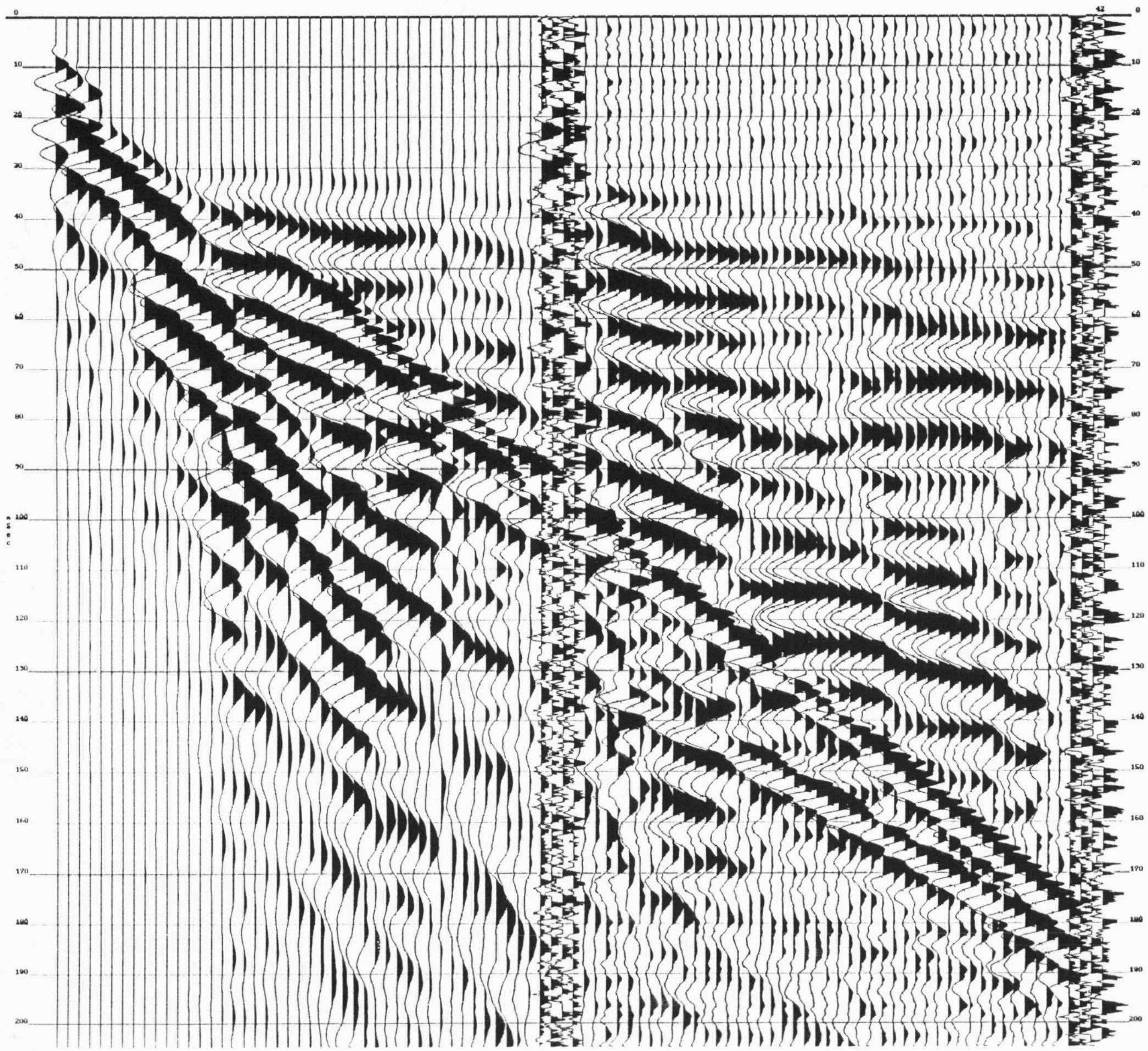
Figure 19a



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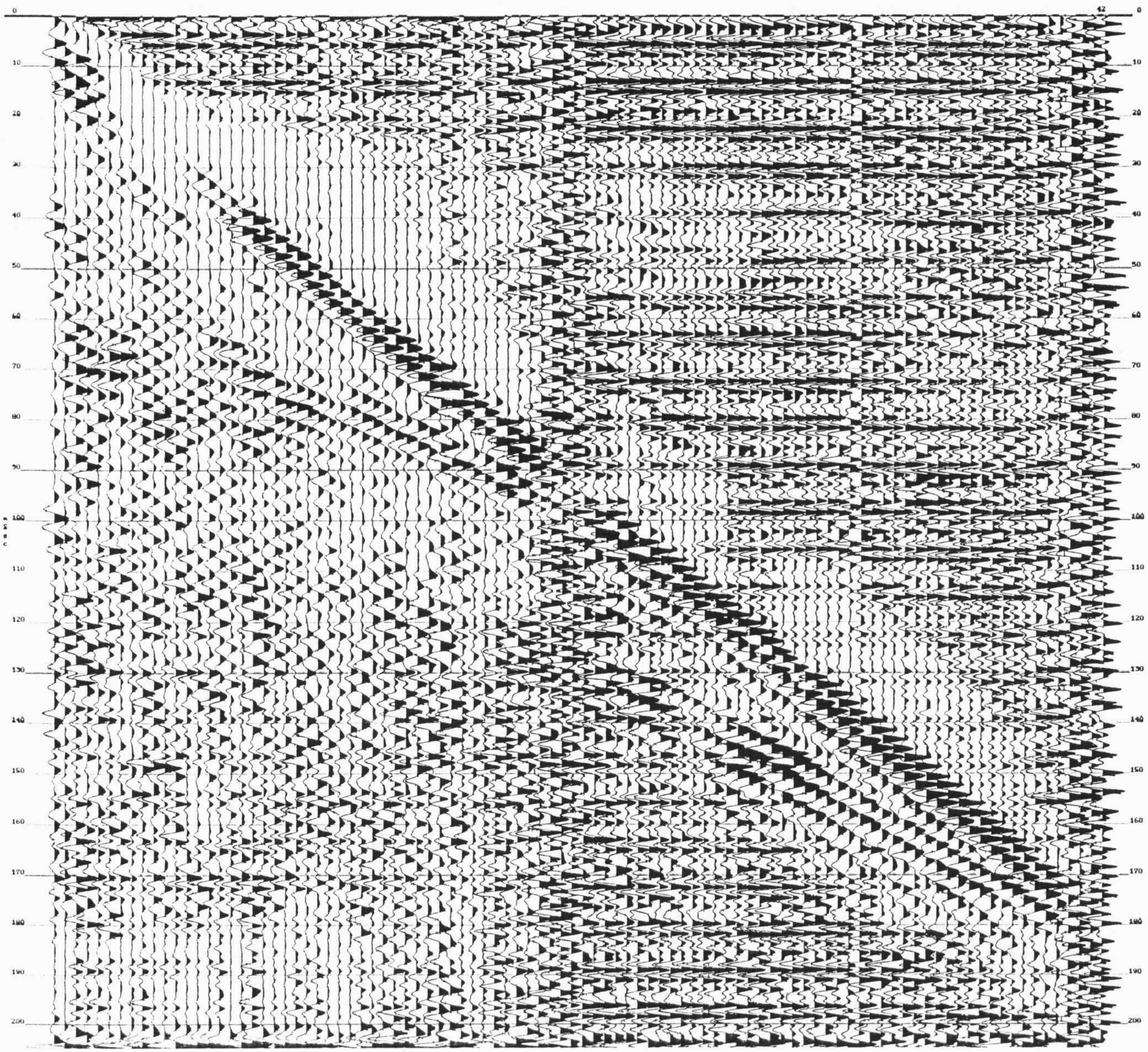

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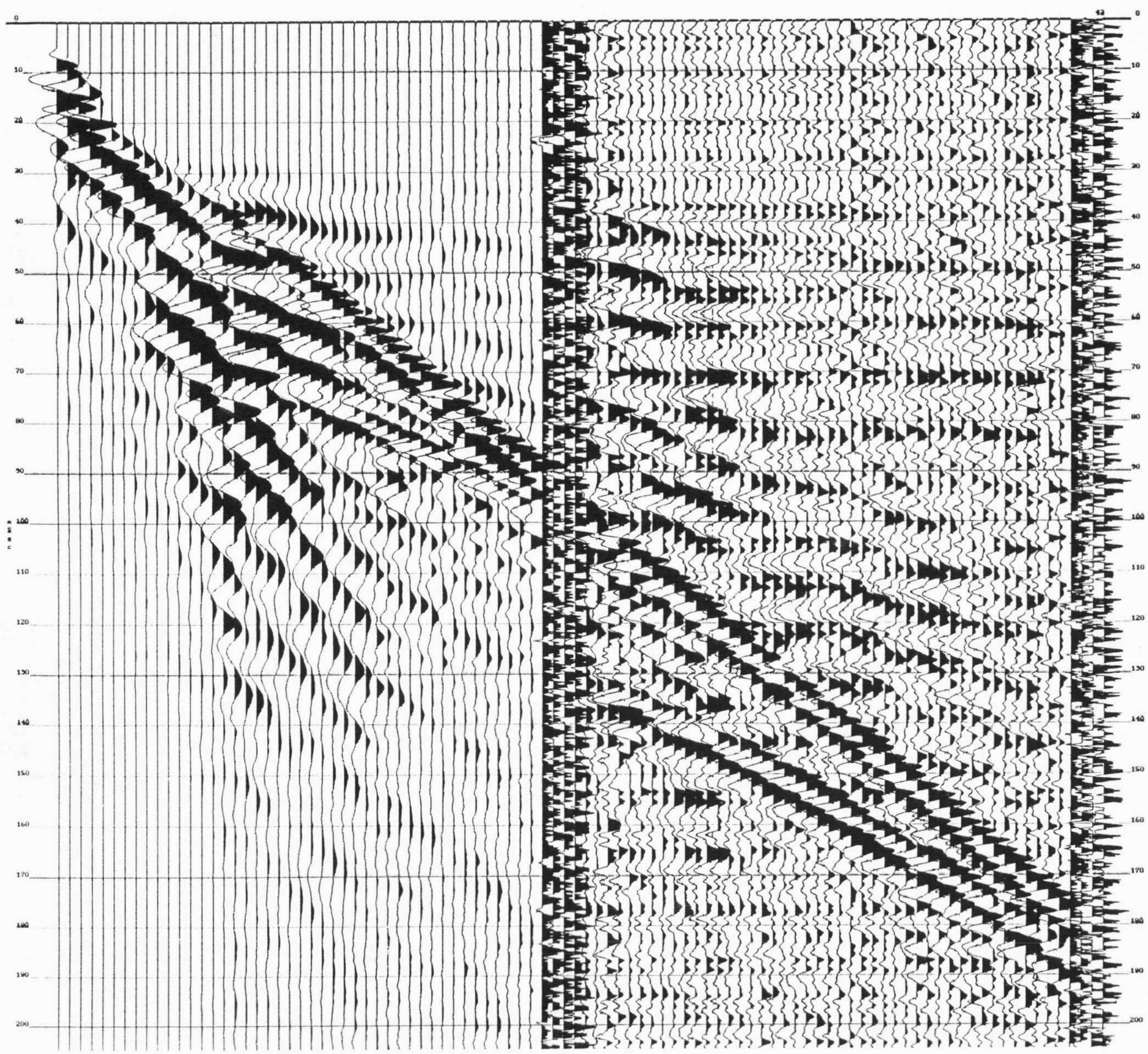

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Figure 20b

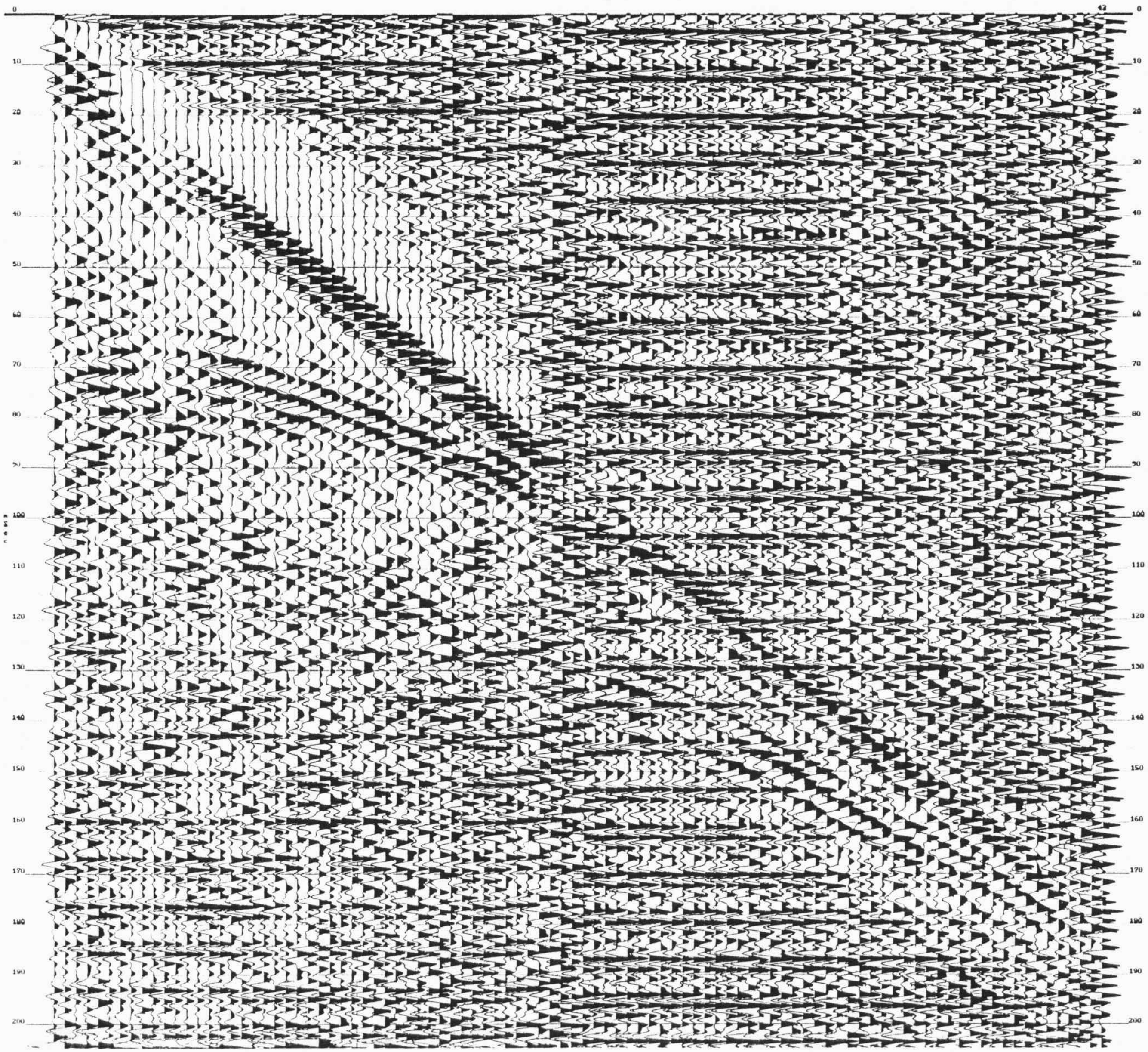

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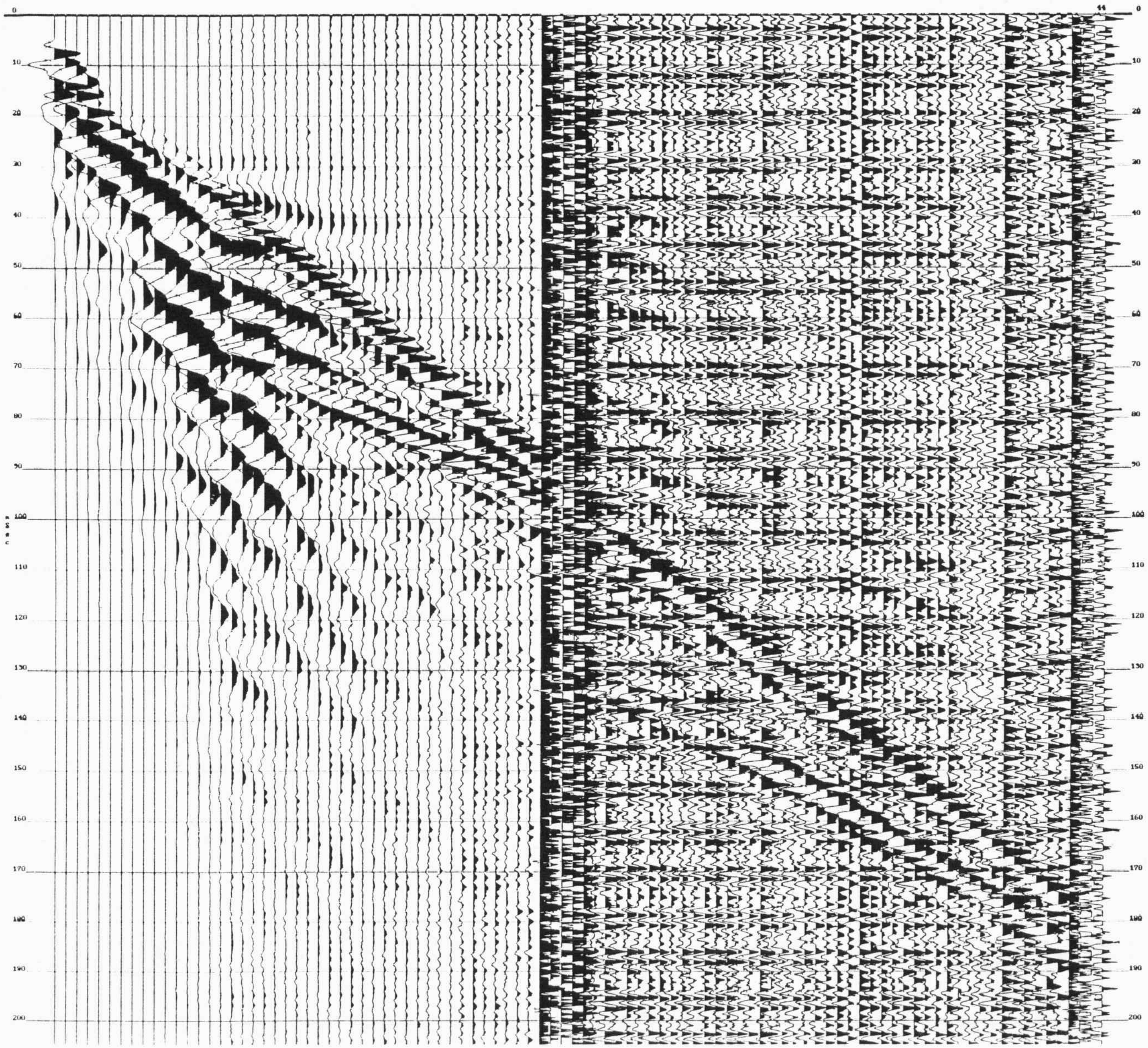
Figure 21a



Site 4e
Figure 21b

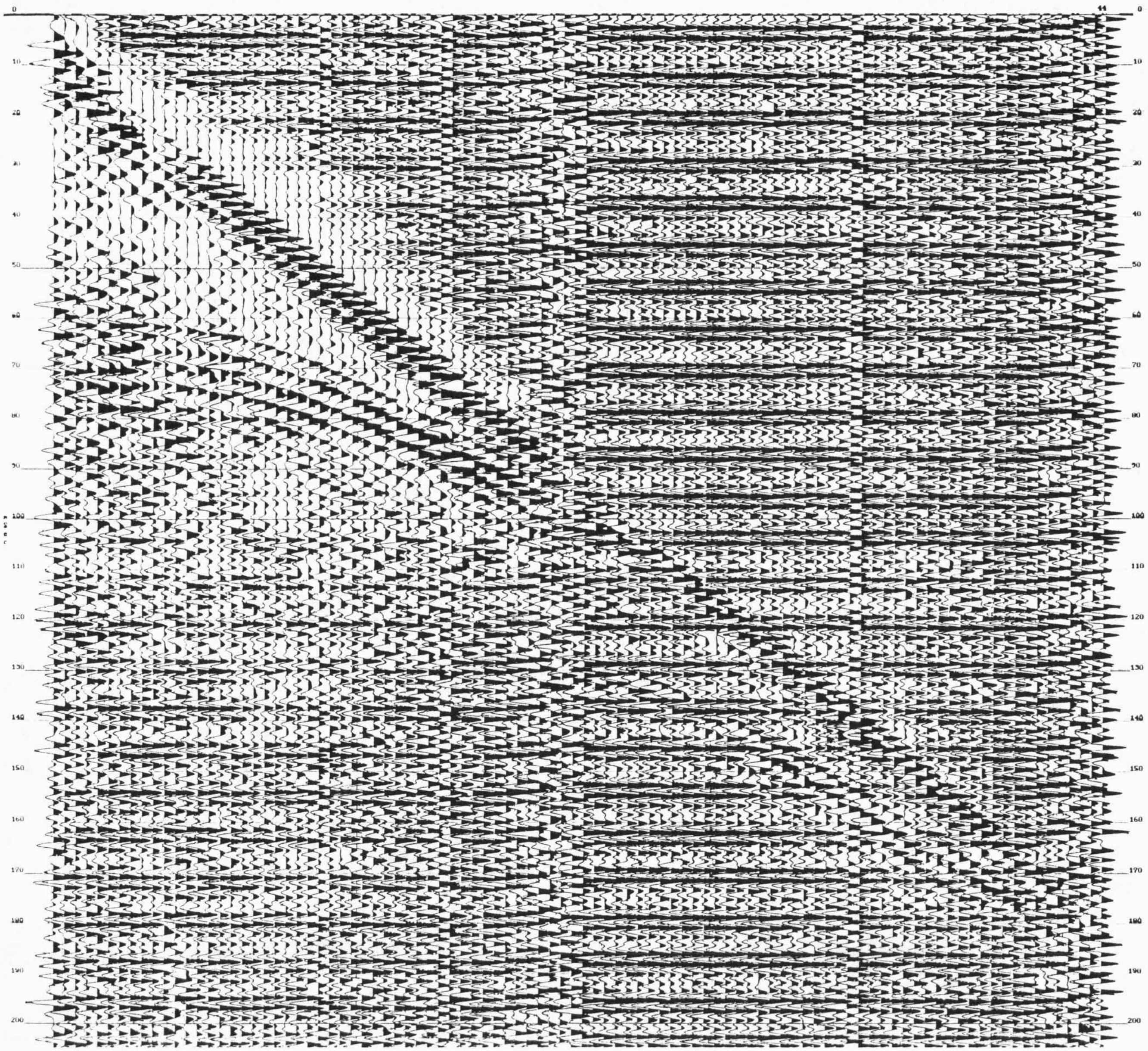


Figure 22

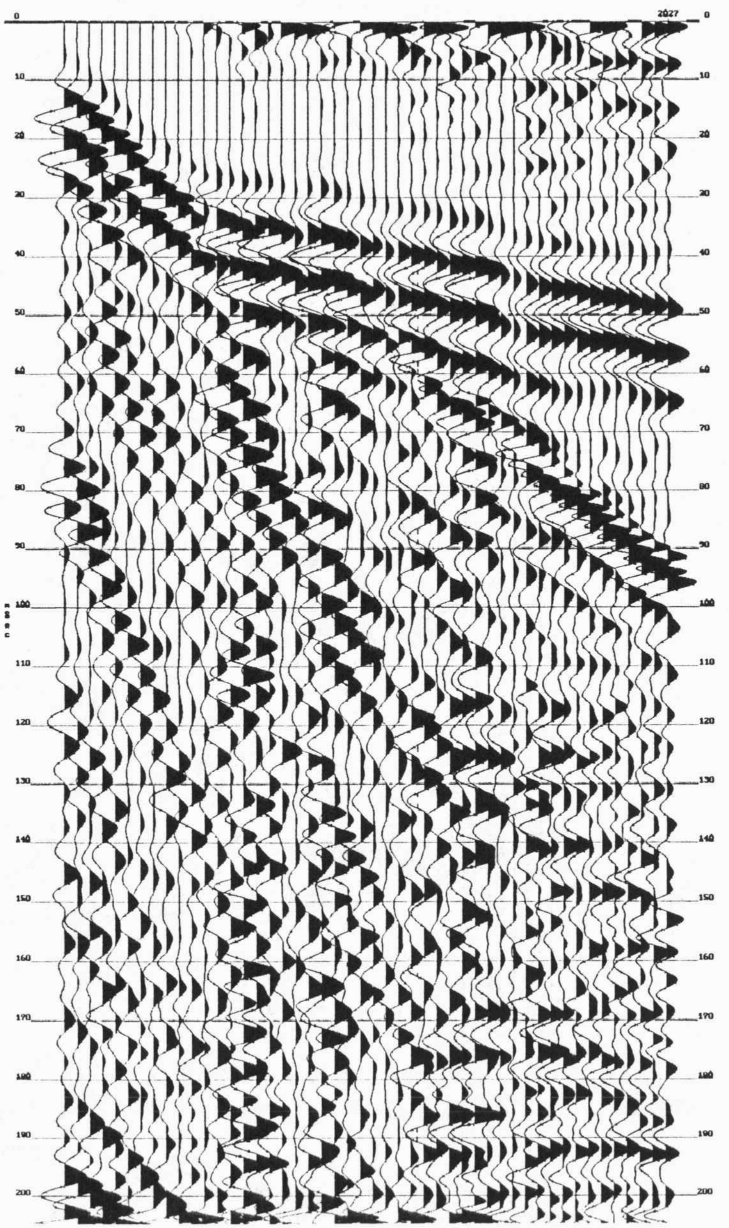


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Figure 23