# DATA REPORT
# PHASE 1
# REPROCESSED SEISMIC REFLECTION LINES
# 1979 CHEVRON SURVEY

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Prepared for

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San Onofre Nuclear Generating Station
Seismic Research Projects

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## 1.0 Introduction

This data report, including its accompanying Appendices A and B, presents the results of the first phase of reprocessing 2D offshore seismic reflection profiles from a legacy 1979 Chevron multichannel seismic (MCS) survey as part of the San Onofre Nuclear Generating Station (SONGS) *Seismic Research Projects' Existing Geophysical Data Reanalysis Project*. The objective of this effort was to reprocess legacy offshore seismic reflection records using modern processing software and techniques. By employing modern processing approaches and the considerable effort to decode and reformat the data, the goal was to improve the existing image quality of well over 1000 line km of seismic data for use in the evaluation of tectonic models adjacent to SONGS. The resultant reprocessed seismic images can then be used to:

(1) Update and potentially modify proponent tectonic models,
(2) Assist in the planning of future seismic surveys, including their location and acquisition parameters; and
(3) Perform due-diligence requirements for offshore environmental permitting by exhausting the inventory of currently available offshore MCS reflection data.

This Phase 1 data report describes the reprocessing of 29 of the vintage 1979 Chevron MCS survey profiles by Geotrace. Approximately 16 lines of the remaining available 1979 Chevron seismic survey profiles are also presently being reprocessed at Geotrace as Phase 2 of the project, and will be reported on later in 2013.

## 2.0 Program Description

In order to perform the reprocessing, the existing vintage seismic data must be available in an appropriate unprocessed digital format (e.g., raw pre-stack field records collected on the vessel during data acquisition). The majority of the existing digital MCS reflection profiles identified offshore SONGS are available only in the original processed format (e.g. stacked data), which cannot subsequently be reprocessed. However, seismic reflection lines from a 1979 Chevron survey (H-17-79 and H-18-79) that were determined to be suitable for such reprocessing were identified within the United States Geological Survey (USGS), Menlo Park archives. A track map of the 1979 Chevron lines evaluated for the Phase 1 reprocessing effort is shown in Figure 1. Subsequently, after being identified in the USGS archives, the data from the 1979 Chevron survey were retrieved to:

(1) Test reprocessing feasibility and potential seismic image improvements, and
(2) Complete the optimum reprocessing scheme to improve seismic image quality on the 29 survey lines (Phase 1) closest to SONGS.

Appendix A of this data report includes reports by Dr. Graham Kent of University of Nevada, Reno (UNR) and Geotrace Technologies Limited (Geotrace), regarding their tests of potential seismic image improvements achievable by reprocessing the legacy Chevron data. Appendix B includes comparison plots of the original and reprocessed seismic data completed during Phase 1. Appendix B also provides the reprocessed data in SEGY format, the survey's navigation file, and files of available seismic reflection profiles and associated data in the IHS Kingdom format.

Feasibility of Reprocessing 1979 Chevron Seismic Data

Initially, Chevron Line 4520 that runs southwest-northeast (dip line) adjacent to SONGS (see Figure 1) was tested by Dr. Kent to evaluate if the original digital data could be decoded and the original survey parameters could be reconstructed to facilitate modern reprocessing. He also performed a cursory reprocessing effort on a portion of data from Line 4520 to verify the reconstructed survey geometry and evaluate the potential of modern reprocessing to improve the quality of the vintage seismic images. The results of his Line 4520 tests are discussed in his report included in Appendix A-1. Based on Dr. Kent's evaluation, he concluded:

(1) The digital data could be decoded and reformatted to facilitate modern reprocessing,
(2) The original survey geometry could be reconstructed and
(3) It is feasible that these data could be reprocessed to improve image quality.

Based on Dr. Kent's findings, Geotrace was contracted to analyze Line 4520 for the purpose of determining the optimal reprocessing scheme to improve seismic image quality of the 1979 Chevron dataset. This reprocessing scheme, together with Geotrace's conclusions, are documented in their report in Appendix A-2. As documented in Geotrace's report, they concluded:

(1) The data contains minimal noise content due to a 5 Hz low-cut acquisition filter,
(2) The 5-Hz low-cut acquisition filter may have attenuated the resolution of low frequency reflections at depth,
(3) Determination of seismic velocity gradients at depth to facilitate reprocessing were challenging due to the acquisition parameters used. This was particularly difficult below a depth of about 3 seconds, and
(4) Final reprocessing scheme improved overall data quality with nearly all remnants of multiples being attenuated in reprocessed profiles.

Using reprocessing scheme described in Appendix A-2, Geotrace was then given authorization to reprocess the remainder of the Phase 1 dataset.

Phase 1 Reprocessing of 1979 Chevron Seismic Data

Phase 1 of the reprocessing effort was focused on the seismic lines from the 1979 Chevron dataset that were closest to SONGS. Phase 1 Chevron lines are shown in Figure 1 and summarized on Table 1. Initially, 32 lines were assessed for potential reprocessing during the Phase 1 effort, including 24 dip lines (even numbered shore-perpendicular Lines 4500 through 4544, including 4542A) and 8 strike lines (odd numbered shore-parallel Lines 4501 through 4515). As summarized in Table 1, a total of 3 lines (Lines 4503, 4528, and 4542) could not be reprocessed due to digital corruption of the field records. The digital files for these lines contained extraneous/erroneous undocumented data that could not be decoded; therefore, the files for Lines 4503, 4528, and 4542 could not be pieced back together in a format to facilitate reprocessing. Additionally, Lines 4506 and 4536 were partially reprocessed because not all the seismic data for these lines could be recovered. Also, Line 4514 was found appended to Line 4512. Other profiles had extraneous pieces of other profiles embedded within; and these mislocated sections of data were removed. In all, a total of approximately 950 line-km of seismic reflection data along 29 lines were reprocessed during Phase 1.

## 3.0 Results

Examples of the typical degree of reflection image improvement as a result of the reprocessing are illustrated on Figures 2 through 4, which show enlarged portions of profiles 4520, 4522, and 4507, respectively. The top halves of these figures present the original seismic reflection profiles and the bottom halves present the reprocessed seismic reflection profiles. Typical resolution differences between the original processed and reprocessed profiles can be seen by comparing the top and bottom enlarged images on these figures. As illustrated on Figures 2 through 4, modern reprocessing was able to

(1) Attenuate multiples,
(2) Preserve high frequency content (increase vertical resolution) of reflection horizons, especially within the upper 2 to 3 seconds of the seismic profile, and
(3) Increase continuity and horizontal resolution of reflection horizons, especially within the upper 2 to 3 seconds of the seismic profile.

Comparison plots of all Phase 1 profiles are presented in Appendix B-1. For each line, the original processed reflection profile is presented on the same page with the reprocessed reflection profile. The reflection profiles on these figures are presented at the same vertical and horizontal scales. It is noted that original processed reflection profiles for Lines 4504, 4526, and 4536 were not available in the historical data archive; therefore, only the reprocessed profiles are presented for these lines.

The profiles presented in Appendix B-1 are shown in color format (brown [high positive amplitude] to white [zero amplitude] to blue [high negative amplitude]). Black and white (black [high positive amplitude to white [high negative amplitude]) is also a common profile viewing format available in most geophysical analysis software, such as IHS Kingdom. An example black and white profile from reprocessed Line 4522 is shown on Figure 5 together with the color profile for comparison.

Appendix B-2 includes a DVD with the digital reprocessed data in SEGY format that can be imported into geophysical analysis software, such as Halliburton SeisWorks. For each line, both amplitude and velocity SEGY data are provided as follows:

- Amplitude Data without Coherency Filter: The seismic reflection amplitudes as a function of time are provided without the application of a post-stack coherency filter. These files have the following name convention: "Final_pstm_stack_[Line#].segy".
- Amplitude Data with Coherency Filter: The seismic reflection amplitudes as a function of time are provided with the application of a post-stack coherency filter. These files have the following name convention: "Final_pstm_stack_enhance_[Line#].segy".
- Velocity Data - RMS Stacking: The RMS stacking velocity as a function of time are provided with the following name convention: "[Line#]_stacking_velocity_rms.segy".
- Velocity Data - RMS Migration: The RMS migration velocity as a function of time are provided with the following name convention: "[Line#]_migration_velocity_rms.segy".

The DVD in Appendix B-2 also includes the navigation data for the Phase 1 Chevron lines. The navigation data is provided in ASCII format in the following file: "Navigation-Chevron Reprocessing (Phase 1).txt". This navigation file includes latitude, longitude, line number and shot number data for the Phase 1 lines.

Appendix B-3 includes a DVD with a full IHS Kingdom 8.8 model of the SONGS area. The Kingdom model includes:

1. <u>SURVEYS - Reprocessed Reflection Profiles</u>: The Phase 1 reprocessed 1979 Chevron lines (29 lines) are included. These lines numbers are annotated with the suffix "-R".
2. <u>SURVEYS - Original Processed Reflection Profiles</u>: Original processed reflection profiles are included for the following surveys:
    a. 1970 Western Geophysical [W-2-70-SC]: 24 lines
    b. 1975 Western Geophysical [W-3-75-SC]: 78 lines
    c. 1977 Digicon [8441-Texaco]: 32 lines converted to SEGY format from scanned TIFF file
    d. 1979 Chevron [H-17-79-SC and H-18-79-SC]: 63 lines (original processing)
    e. 1981 Western Geophysical [W-30-81-SC]: 21 lines
    f. 1981 Western Geophysical [W-31-81-SC]: 57 lines
    g. 1982 Western Geophysical [W-5-82-SC]: 62 lines
    h. 1988 Jebco [J-1-88-SC]: 25 lines
    i. 1990 USGS [L-4-90-SC]: 4 lines
3. <u>CULTURE - Base Maps</u>: The following culture maps are included:
    a. Base Map: Basic map showing topographic relief on land and blue background within ocean area
    b. SONGS Location: Location of SONGS
    c. 3-Mile Limit: State-Federal water boundary
    d. Bathymetry (ft): Bathymetric contours in feet (100 ft contour interval)
    e. Bathymetry (m): Bathymetric contours in meters (25 m contour interval)
    f. Gravity Anomaly: Gravity anomaly in mgals (1 mgal contour interval) from satellite altimetry data
    g. Magnetic Anomaly: Magnetic anomaly in gammas (100 gamma contour interval) from University of Texas, El Paso (UTEP), Pan American Center for Earth and Environmental Studies (PACES) online data compilation.
    h. USGS Geologic Maps: Geologic maps presented on 100,000 scale 30x60 minute quadrangles. The following quadrangles are included: Long Beach, Santa Ana, Oceanside, and San Diego.
    i. USGS(2012) Quat F&F Database: Quaternary faults from USGS (2010) faults and folds database
    j. Rivero (2004) Geologic Map: Geologic map presented by Rivero (2004) in his PhD thesis
    k. Rivero-Shaw (2011) Geologic Map: Geologic Map presented in Rivero and Shaw (2011)

## 4.0 References

Sandwell, D. T., and W. H. F. Smith, Global marine gravity from retracked Geosat and ERS-1 altimetry: Ridge Segmentation versus spreading rate, J. Geophys. Res., 114, B01411, doi:10.1029/2008JB006008, 2009.

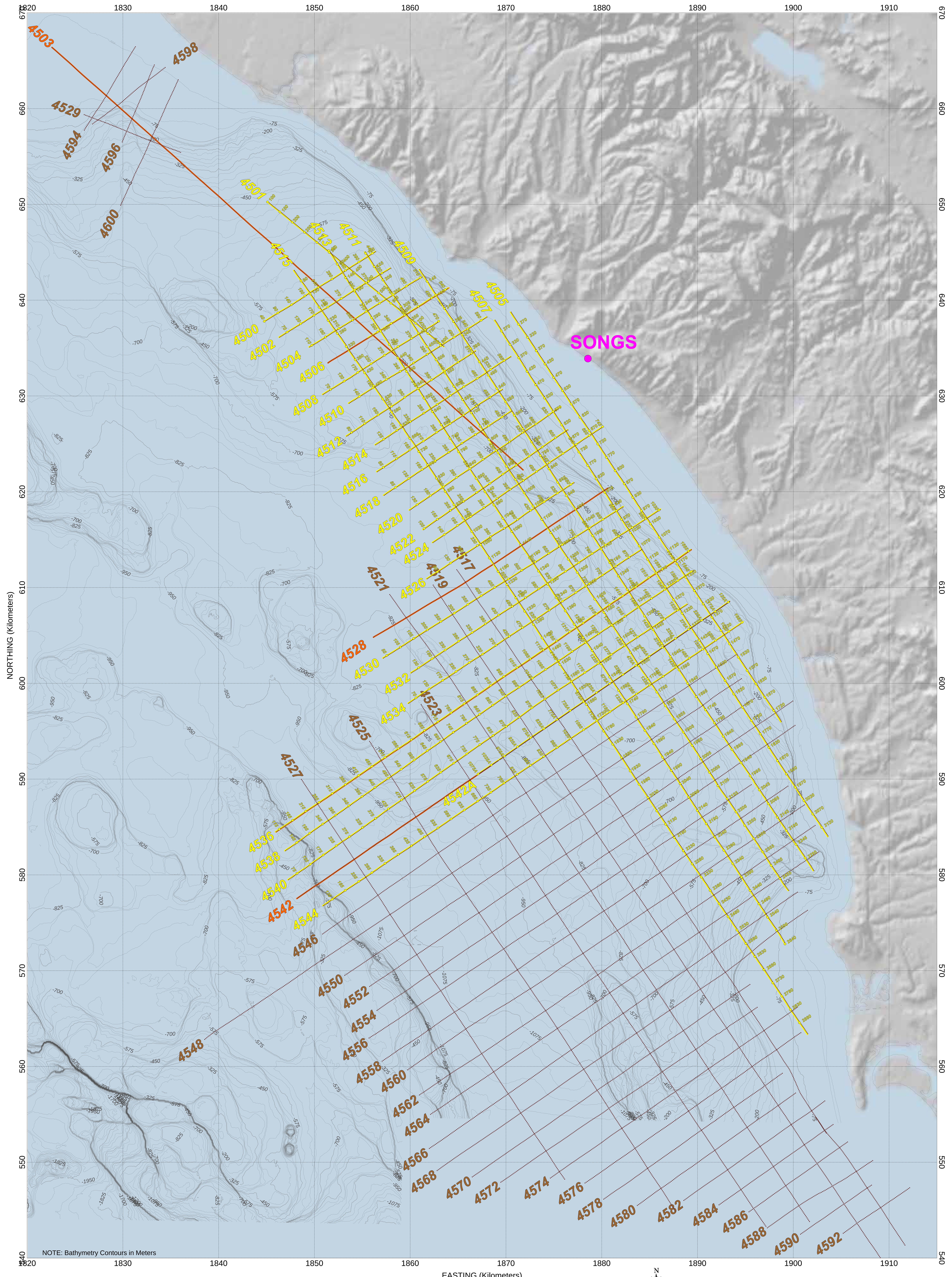
Rivero, Carlos, and John H. Shaw, 2011, Active Folding and Blind Thrust Faulting Induced by Basin Inversion Processes, Inner California Borderlands, in K. McClay, J. Shaw, and J. Suppe, eds., Thrust fault-related folding: AAPG Memoir 94.

Rivero, Carlos, June 2004, Origin of Active Blind-Thrust Faults in the southern Inner California Borderlands, PhD thesis, Harvard University.

USGS, 2010, Quaternary Fault and Fold Database for the United States, updated November 2010, available at [http//earthquakes.usgs.gov/regional/qfaults/].

**TABLE 1**
**PHASE 1 CHEVRON REPROCESSING SUMMARY**

| Line Number | Approximate Line Length (Line-km) | Approximate Line Length Reprocessed (Line-km) | Reprocessed Successfully | Line Not Reprocessed | Comments |
|---|---|---|---|---|---|
| **NE-SW DIP LINES** | | | | | |
| 4500 | 13.67 | 13.67 | X | | |
| 4502 | 13.67 | 13.67 | X | | |
| 4504 | 13.84 | 13.84 | X | | |
| 4506 | 14.84 | 11.10 | X | | Near-shore portion recovered |
| 4508 | 14.34 | 14.34 | X | | |
| 4510 | 17.02 | 17.02 | X | | |
| 4512 | 16.18 | 16.18 | X | | |
| 4514 | 16.91 | 16.91 | X | | Appended to Line 4512 |
| 4516 | 15.68 | 15.68 | X | | |
| 4518 | 16 | 16 | X | | |
| 4520 | 19.17 | 19.17 | X | | |
| 4522 | 18.34 | 18.34 | X | | |
| 4524 | 21.5 | 21.5 | X | | |
| 4526 | 18.34 | 18.34 | X | | |
| 4528 | 29.01 | 0 | | X | File could not be recovered |
| 4530 | 29.67 | 29.67 | X | | |
| 4532 | 31.2 | 31.2 | X | | |
| 4534 | 29.16 | 29.16 | X | | |
| 4536 | 52.4 | 41.47 | X | | Offshore portion recovered |
| 4538 | 51.63 | 51.63 | X | | |
| 4540 | 50.64 | 50.64 | X | | |
| 4542 | 24.68 | 0 | | X | File could not be recovered |
| 4542A | 32.01 | 32.01 | X | | |
| 4544 | 52.96 | 52.96 | X | | |
| **NW-SE STRIKE LINES** | | | | | |
| 4501 | 23.82 | 23.82 | X | | |
| 4503 | 66.07 | 0 | | X | File could not be recovered |
| 4505 | 51.24 | 51.24 | X | | |
| 4507 | 64.17 | 64.17 | X | | |
| 4509 | 75.05 | 75.05 | X | | |
| 4511 | 80.02 | 80.02 | X | | |
| 4513 | 86.67 | 86.67 | X | | |
| 4515 | 23.82 | 23.82 | X | | |
| **TOTAL:** | | **949.3** | **29** | **3** | |




**LEGEND**

1979 Chevron Survey

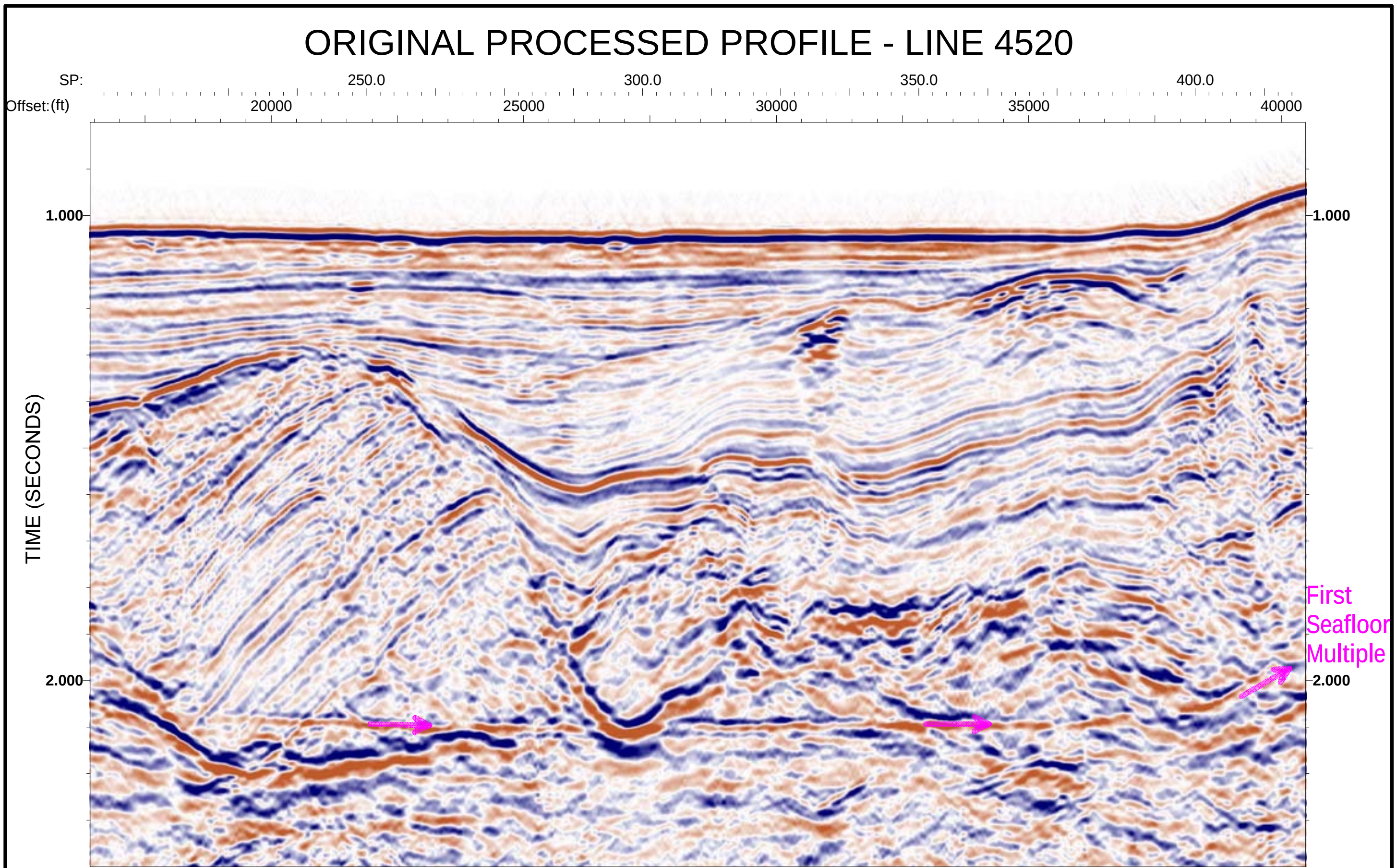
- Phase 1 Reprocessed Line
- Phase 1 Reprocessing attempted however could not be completed, because data could not be recovered
- Phase 1 Reprocessing not attempted

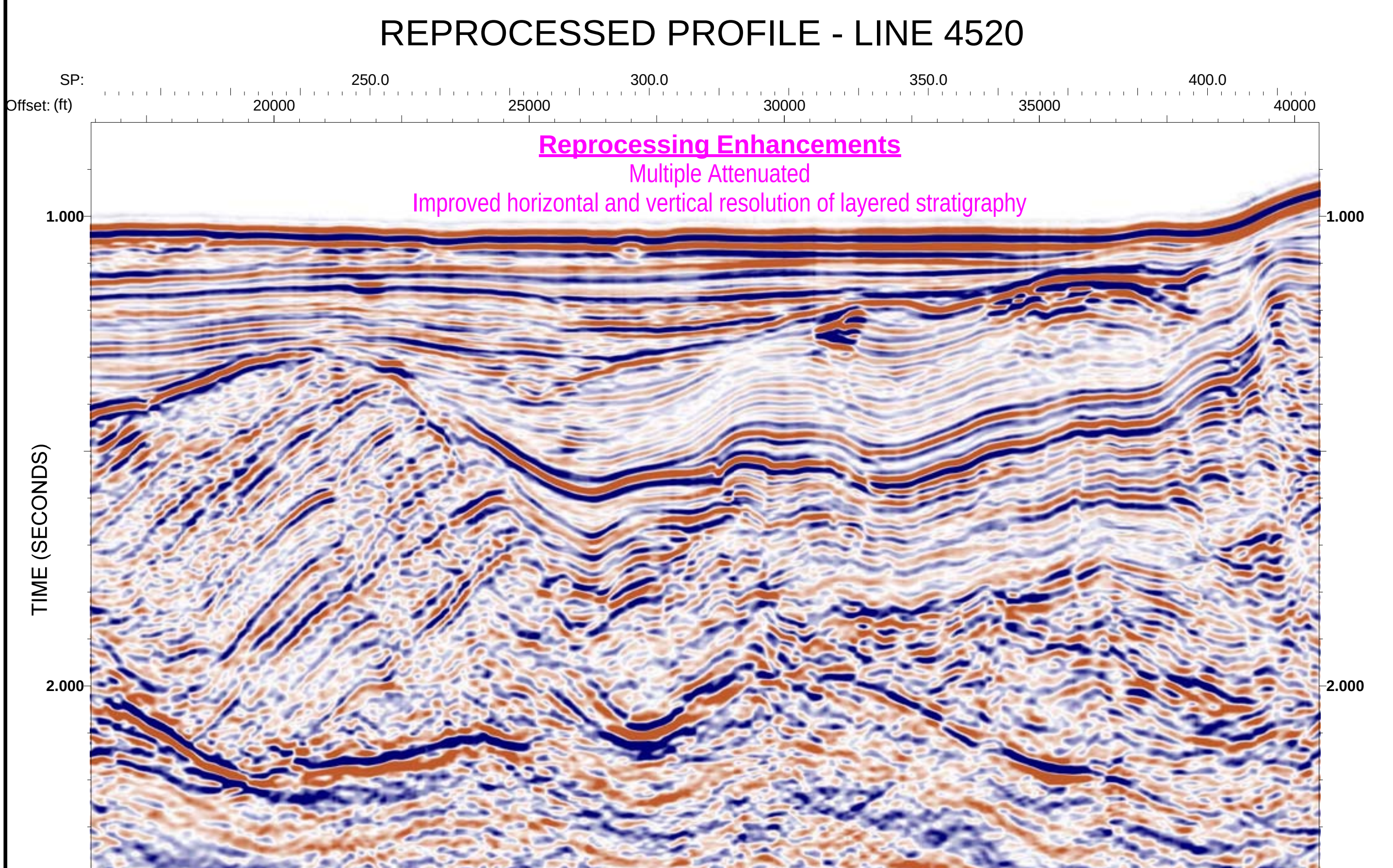
N E S W

0 km 5 km 10 km 15 km 20 km

SCALE: Kilometers

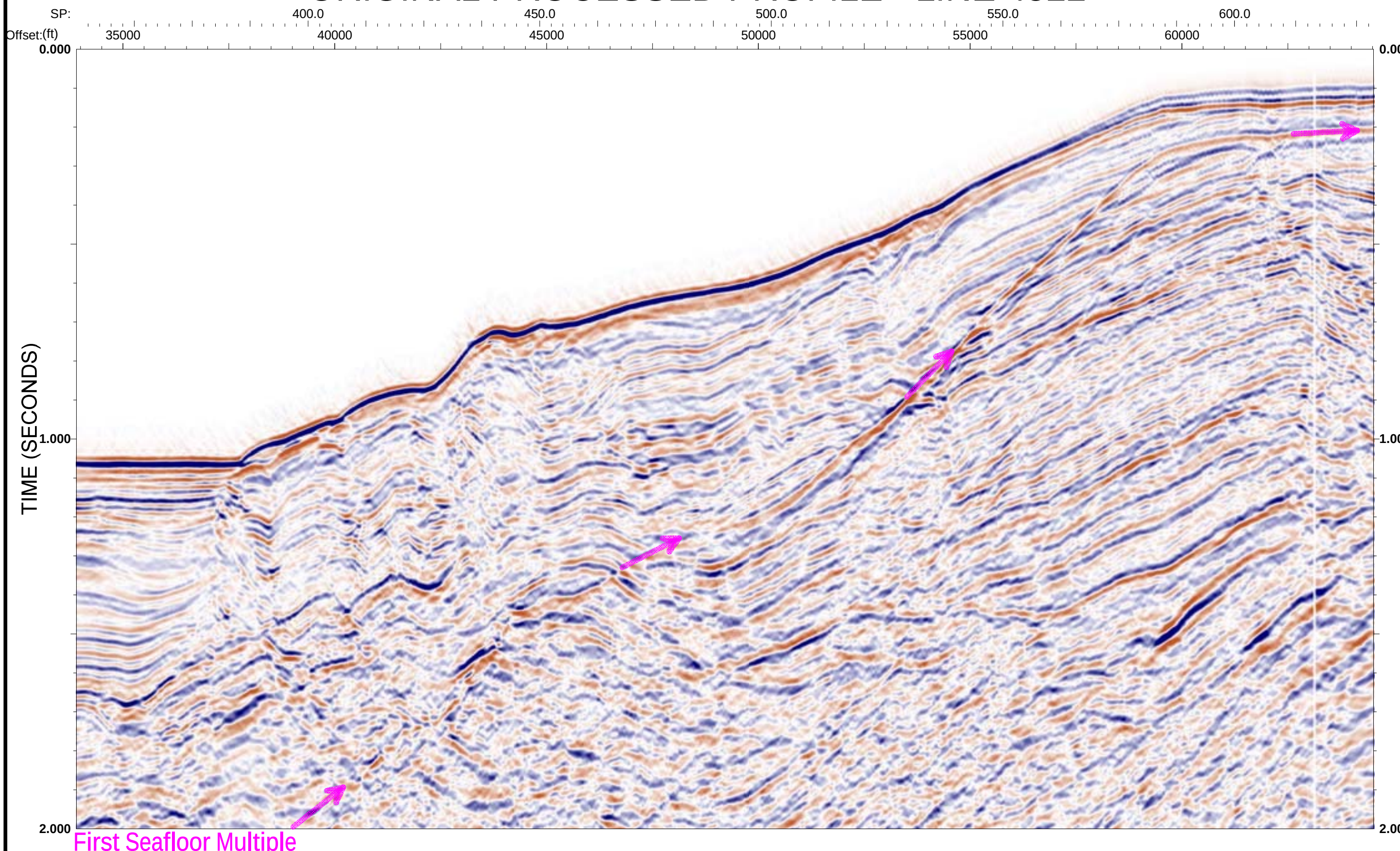
| PHASE 1<br>REPROCESSED SEISMIC REFLECTION LINES<br>1979 CHEVRON SURVEY | SHIP TRACK MAP<br>PHASE 1 REPROCESSED SEISMIC REFLECTION LINES<br>1979 CHEVRON SURVEY | FIGURE<br>1 |
|---|---|---|



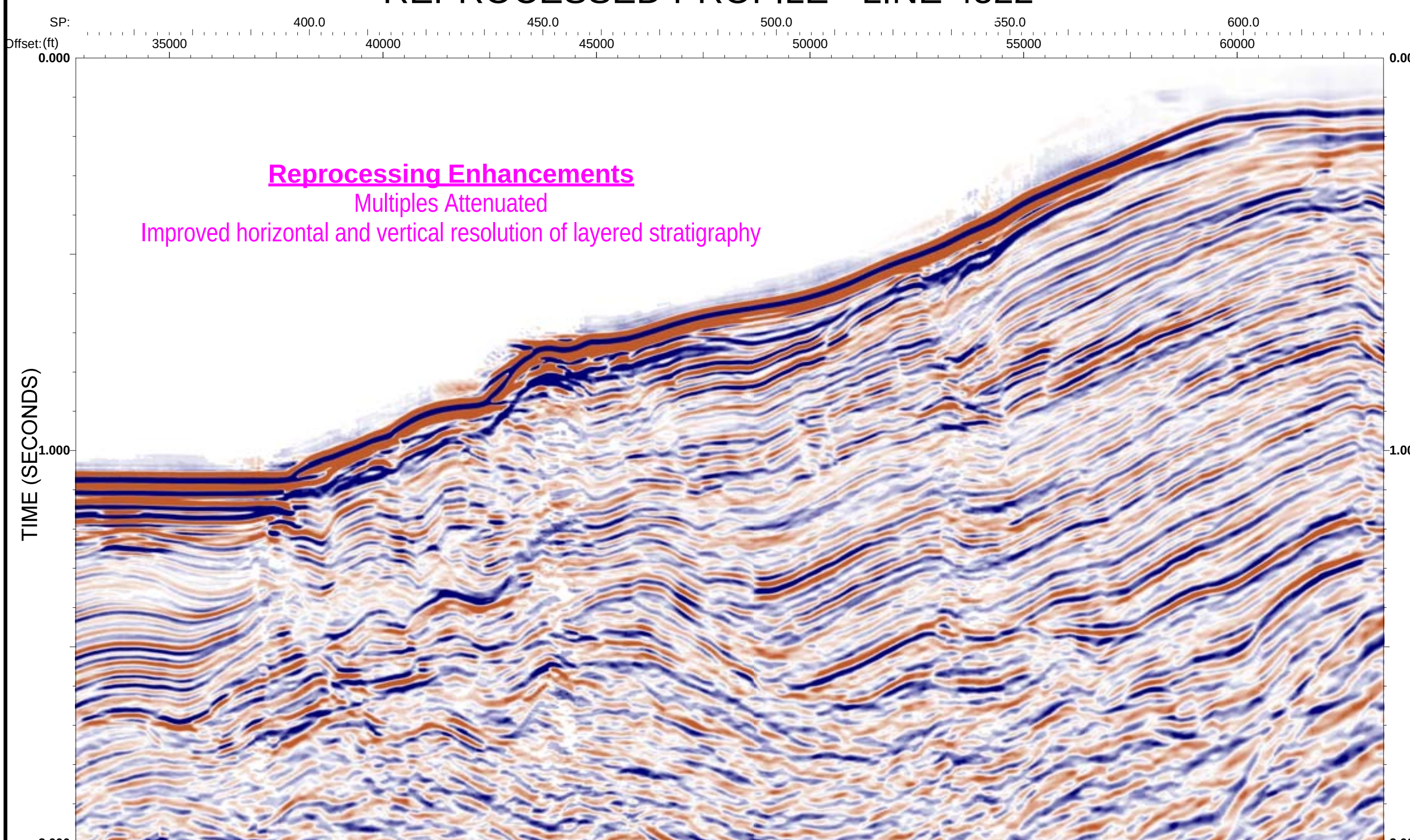




| PHASE 1<br>REPROCESSED SEISMIC REFLECTION LINES<br>1979 CHEVRON SURVEY | LINE 4520 (BLOW-UP)<br>EXAMPLE OF TYPICAL REPROCESSING<br>IMAGE QUALITY IMPROVEMENT | FIGURE<br>2 |
|---|---|---|

# ORIGINAL PROCESSED PROFILE - LINE 4522

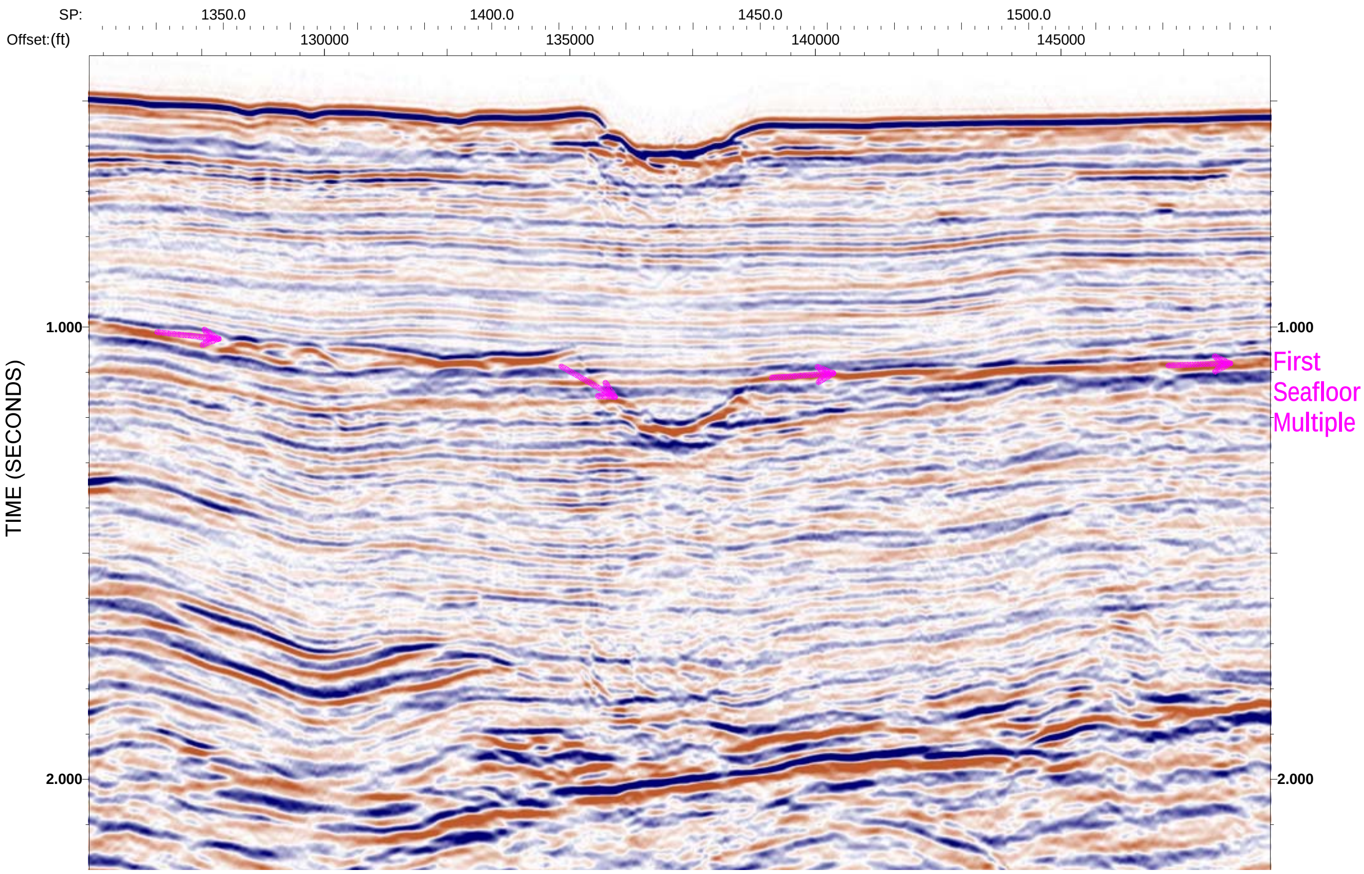



# REPROCESSED PROFILE - LINE 4522

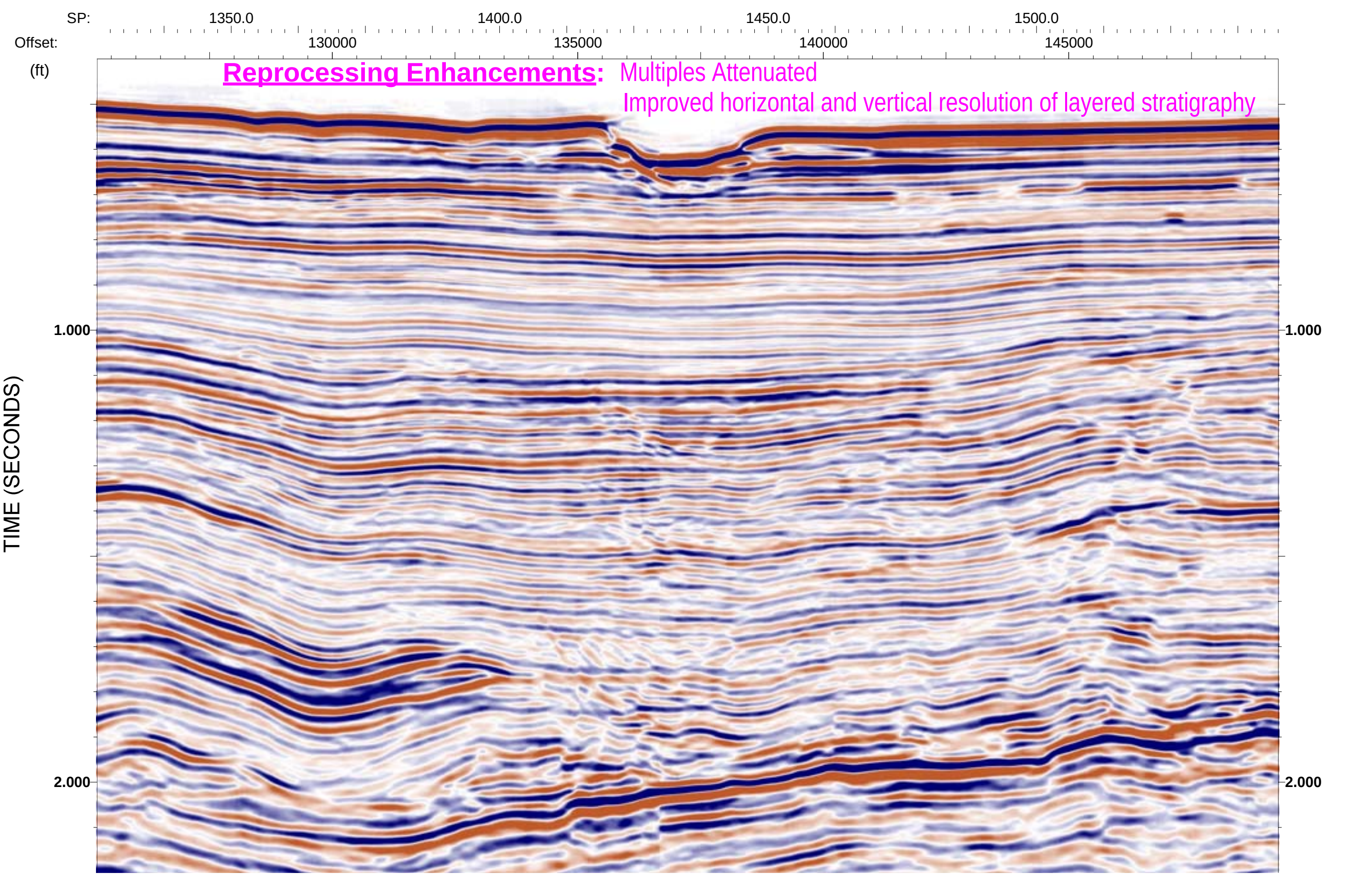



| PHASE 1<br>REPROCESSED SEISMIC REFLECTION LINES<br>1979 CHEVRON SURVEY | LINE 4522 (BLOW-UP)<br>EXAMPLE OF TYPICAL REPROCESSING<br>IMAGE QUALITY IMPROVEMENT | FIGURE<br>3 |
|---|---|---|

# ORIGINAL PROCESSED PROFILE - LINE 4507



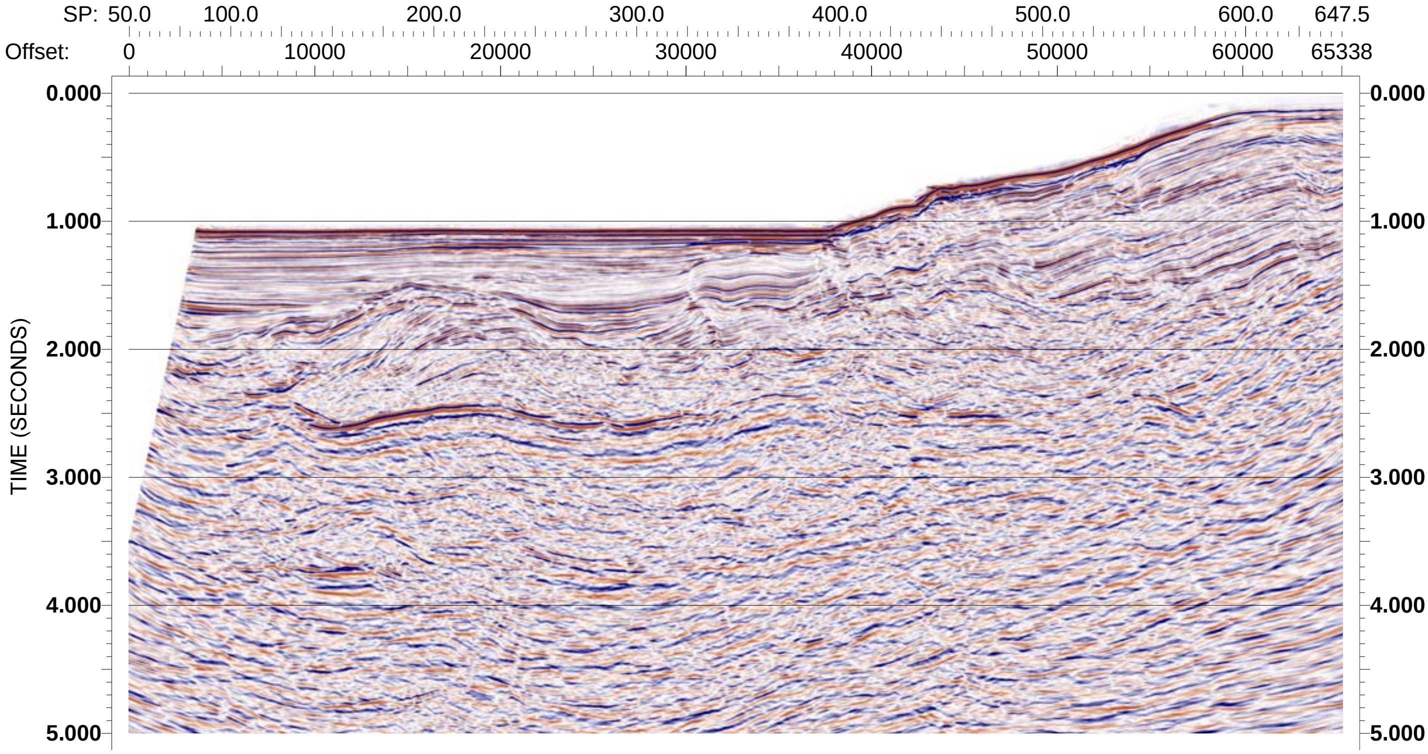

# REPROCESSED PROFILE - LINE 4507



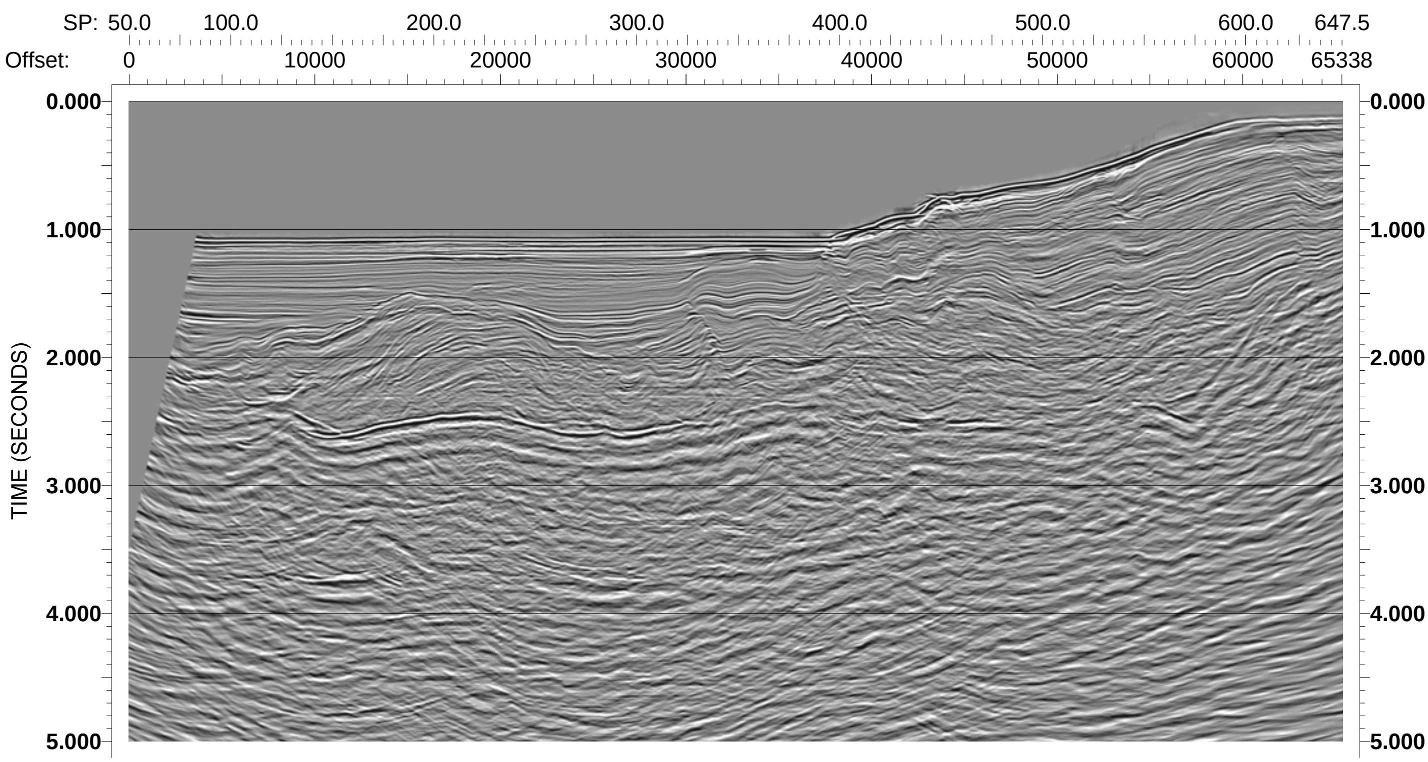

| PHASE 1<br>REPROCESSED SEISMIC REFLECTION LINES<br>1979 CHEVRON SURVEY | LINE 4507 (BLOW-UP)<br>EXAMPLE OF TYPICAL REPROCESSING<br>IMAGE QUALITY IMPROVEMENT | FIGURE<br>4 |
|---|---|---|

# REPROCESSED LINE 4522

Color Profile




Black and White Profile




| PHASE 1<br>REPROCESSED SEISMIC REFLECTION LINES<br>1979 CHEVRON SURVEY | REPROCESSED LINE 4522<br>COLOR AND BLACK AND WHITE PROFILE COMPARISON | FIGURE<br>5 |
|---|---|---|

# APPENDIX A

# REPROCESSING FEASIBILITY EVALUATION

# LINE 4520

# 1979 CHEVRON SURVEY

# APPENDIX A
# REPROCESSING FEASIBLITY EVALUATION LINE 4520
# 1979 CHEVRON SURVEY

## A.1 Introduction

Reprocessing feasibility evaluations were performed on 1979 Chevron survey Line 4520 by Dr. Graham Kent and Geotrace. These evaluations provided information regarding reformatting of original digital data files to facilitate modern reprocessing, survey geometry reconstruction, feasibility to improve image quality, and determination of the optimum reprocessing scheme.

## A.2 Results

The reprocessing feasibility evaluations are documented in the attached reports. Appendix A-1 presents Dr. Kent's report entitled "Viability of the 1979 Chevron Multichannel Seismic (MCS) Dataset for Reprocessing" which is dated August 21, 2011 (updated June 3, 2013). Appendix A-2 presents Geotrace's report entitled "SONGS 2D Reprocessing, Southern California, Chevron H-18-79 Line 4520, Final Report" which is dated October, November 2012.

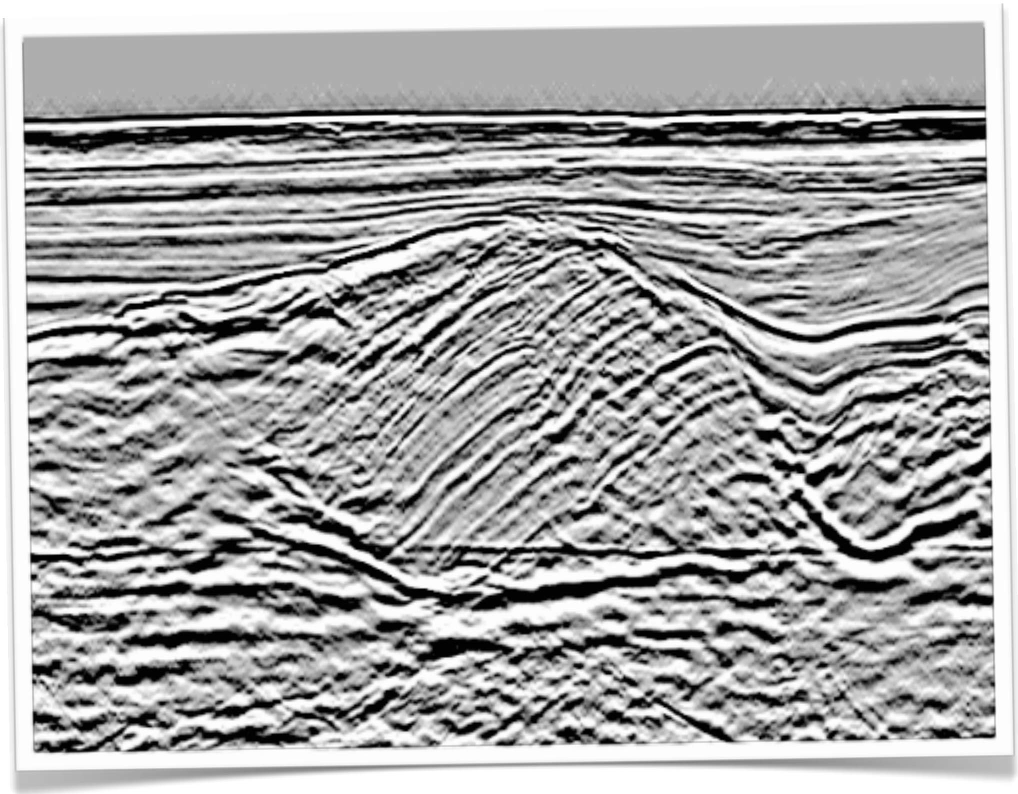
# APPENDIX A-1

# VIABILITY OF THE 1979 CHEVRON MULTICHANNEL SEISMIC (MCS) DATASET FOR REPROCESSING

BY

DR. GRAHAM KENT (UNR)

# *Viability of the 1979 Chevron Multichannel Seismic (MCS) dataset for reprocessing*



*San Onofre Nuclear Generating Station (SONGS)*
*Seismic Hazard Assessment Program*

Dr. Graham M. Kent
Director, Nevada Seismological Laboratory
University of Nevada, Reno

August 21, 2011
—updated June 3, 2013—

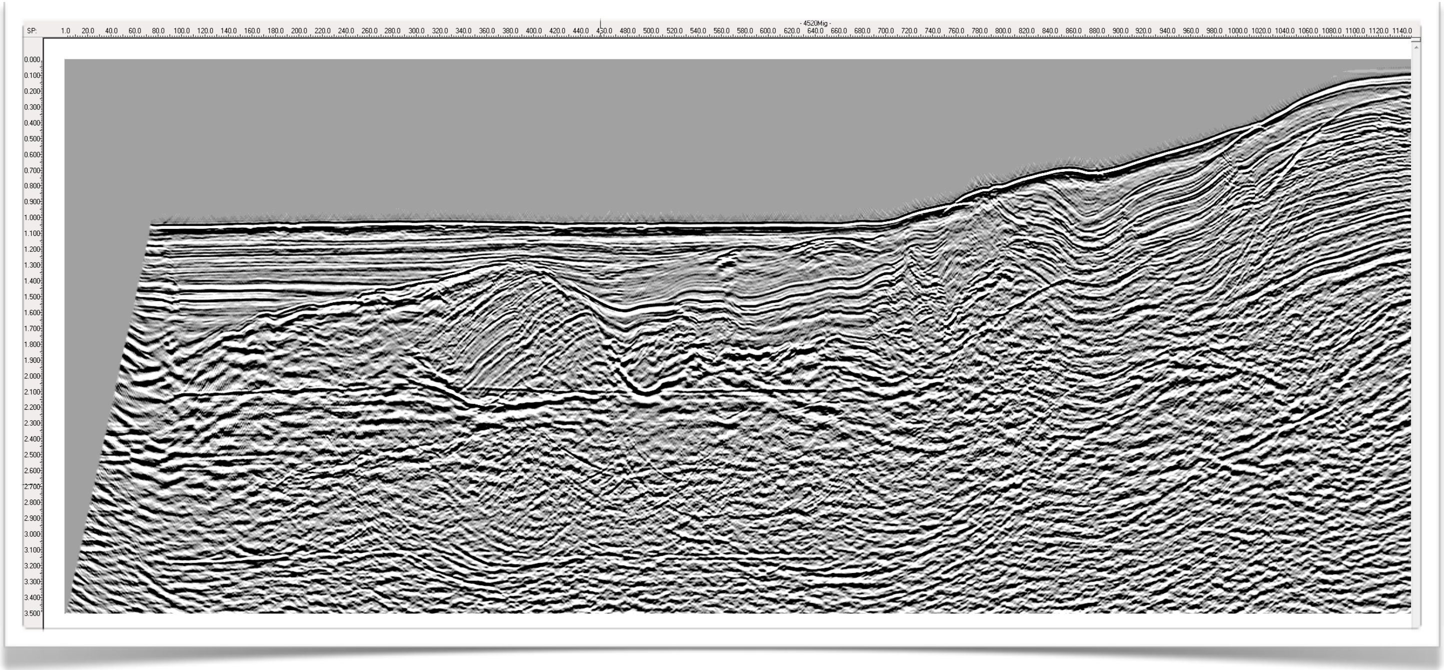
# Data Sleuthing, Recovering Geometry, Processing—and Next Moves

***Executive Summary:*** The geometry from the 1979 Chevron survey, H-18-79, was fully recovered from the archived field data, enabling reprocessing of Line 4520 to test the viability for improvement of image quality — and whether reprocessing of all recovered data is worthy of effort and cost. These vintage multichannel seismic (MCS) data were shot at 110' (~33.5 m) spacing to a 96-channel hydrophone streamer with 110' (~33.5 m) group spacing, providing a nominal fold of 48 traces per common-midpoint (CMP) bin. The coarse receiver spacing limits modern processing approaches for prestack migration, demultiple approaches, etc... due to issues with spatial aliasing (although this may be mitigated to some degree by modern trace interpolation techniques). The approximate 3.2-km-long streamer is also rather limited by today's standards, presenting difficulties in determining significant velocity gradients seen in the shallow crust offshore *SONGS* that will likely inhibit any productive attempt to significantly upgrade image quality for deep structure such as the inferred "blind" thrust that has been postulated to reside offshore San Onofre. Modern acquisition systems with long streamers (8 km or more) and finely spaced receiver groups (12.5 m, 6.25 m or less) would provide the best possible chance of imaging deep structure near the facility. That said, the source waveform and noise characteristics from the 1979 experiment is excellent given its vintage and the reprocessed Line 4520 (in high-res mode) does highlight how the shallow most structure can be better imaged with greater fidelity in the layered sediments; these data, if reprocessed, could potentially provide new targets for future high-res systems, ranging from seismic CHIRP to high quality, high-res MCS. With the background work done thus far, the time to process each of these vintage profiles in a more high-res (limited offset) geo-tech mode, as seen for Line 4520, is < 1 day.

**Multichannel seismic (MCS)** reflection data from a 1979 Chevron survey (H-18-79) offshore southern California has been briefly studied to see if ***(a)*** the experimental geometry can be reconstructed from the field records to move forward with reprocessing, ***(b)*** a cursory evaluation of prestack data to understand the limitations of these older data, and ***(c)*** reprocessing a small amount of data (Line 4520) to verify correct geometry and quality of original imagery — and the potential to do better without having to shoot a new survey (i.e., with modern processing approaches, can we do better?).

The attempt to "back out" the initial geometry of this survey has proved successful, which was uncertain at the beginning due to missing items such as source-receiver ranges, scattered geometry values in various places, and incorrect fold. The original hydrophone group spacing was grabbed from the EBIDIC header; this value was confirmed with the direct water wave arrival times (along with the nearest hydrophone source-receiver range). This analysis was used to set up a credible streamer configuration. The system geometry is a follows: 96-channel streamer with 110 foot group spacing (~33.5 m) and a near offset of ~178 m. To add confusion, 16 "Shot Trace 1" auxiliary channels were also recorded, providing 112 total channels. Unfortunately, these 16 additional "Shot X, Trace 1" channels (duplicate records) can give modern processing packages issues, since identical records in a disk-based, random-access system is <u>less than ideal</u>.

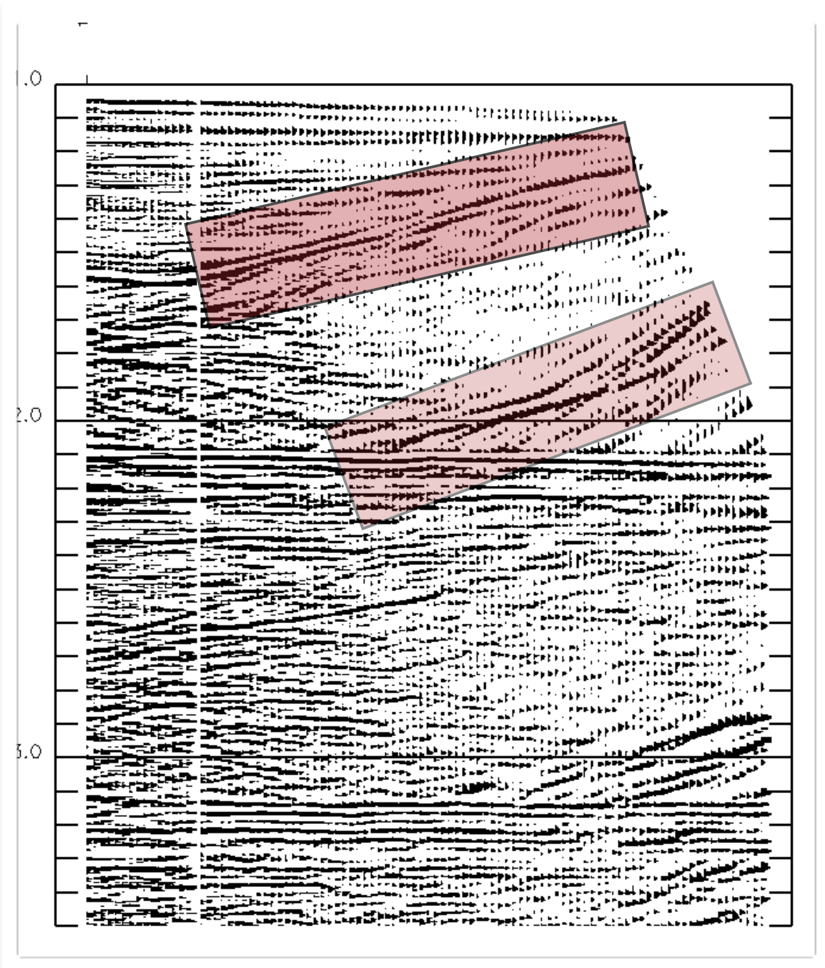
Metadata provided with the prestack SEGY data confirmed a 110' shooting rep-rate, which should have given a nominal fold of 48 traces with 55' common-midpoint bins. The SEGY header values presented a problem: if the "stamped" CMP values were to be believed, the fold was 96, suggesting either binning at twice the natural bin spacing, or a 55' shot spacing (an unrealistic shooting rep-rate)—or perhaps the CMP numbers were just garbage and the Chevron data was archived as shotgather records. Ultimately, the shot times in the header seemed to favor the 2nd interpretation. Line 4520 was processed in both modes, with the lack of coherent hyperbolic reflectors observed in the "CMP" mode, while regathering from shotgather space produced coherent reflections across the re-geometry'd



**Chevron Line 4520—Archived Post-Stack Migrated Image**

CMP gathers. Hence, it was ultimately determined that the Chevron data were archived in shot receiver space (i.e., sequential shotgather records).

Profile 4520 was investigated to verify correct geometry and to see what the quality and nature of these old data were — and whether they would be sufficient or have potential for advanced reprocessing (and outcomes). The limiting factors would be the coarse shot and group spacing 110' or ~33.5 m; both parameters can limit the usefulness of wavefield techniques such as prestack migration in either the shot and/or common-offset domain due to spatial aliasing issues (although this could be mitigated somewhat through trace interpolation schemes, but typically only one of the domains is interpolated, not both!). For example, modern systems that are "tuned" for deep imaging, might shoot at 25 m or 37.5 m intervals and are recorded by streamers with 12.5 m or 6.25 m group spacing. The 3+ kilometer streamer offset is actually pretty good given the vintage of the data (late 70s), but this is considerably less than modern systems that typically tow 6- or 8-km-long streamers (or more), which would have distinct advantages with respect to imaging deeper reflections such as the low-angle, reactivated "blind" thrust proposed for region (offshore San Onofre) and for analysis of first-arrival refractions. The latter point is especially true given the lack of coherent reflectivity one to two seconds beneath the seafloor, and below; un-detected velocity heterogeneities in this region would inhibit quality images at depth. Longer streamers with finely spaced sensors provide access to a new generation of "redatuming to the seafloor" techniques that provide a better way to estimate significant velocity variations through either first-arrival tomographic and/or full-

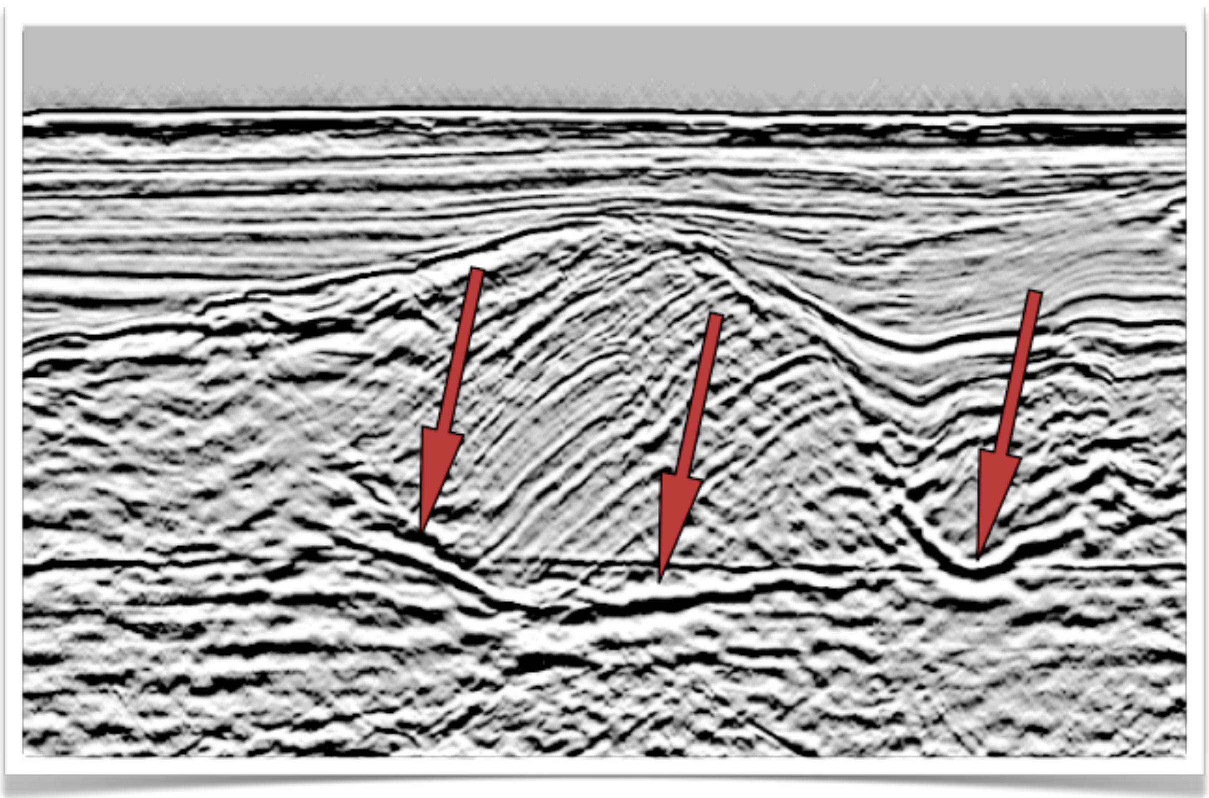



**Example CMP gather** (Line 4520) moved-out at water velocities (1500 m/s). Note the right-to-left dipping events (semi-transparent red boxes) within the gather, which are related to "triplications" from refracted events (high velocity contrast gradient interfaces). Some of the "low frequency" reflections seen within the existing Chevron images are stacked "caustics" from these triplications and not strictly interface reflections—as they are typically mis-located in depth/time (relative to the velocity gradient). These events in the record highlight the need to back-out the complex velocity field before imaging at depth, which is not easily done with these vintage data.

waveform inversion techniques. In all of these respects, the older data from this margin will have only limited outcomes when trying to improve images (and correct spatial geometry) for deeper targets.

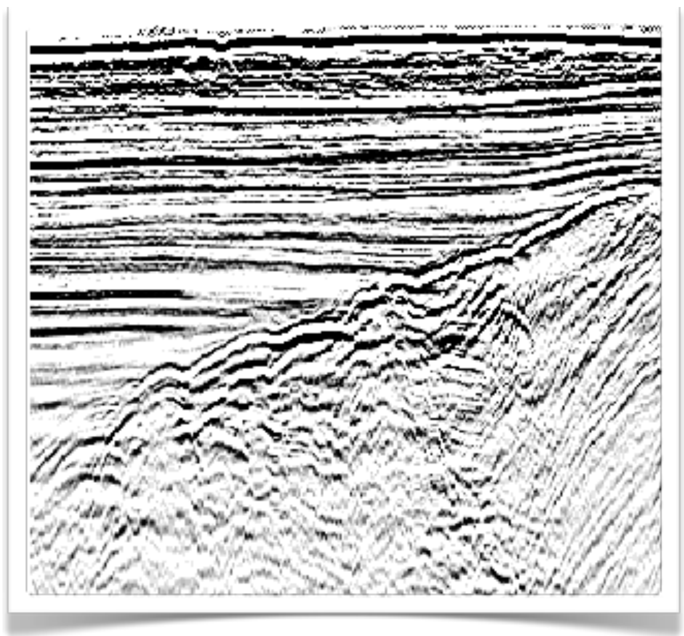
Although more speculative, raw CMP and/or shot gathers do highlight the 3-D nature of these data in that events within the gather itself seem to show fair amount of out-of-plane events or arrivals. Also, likely triplications associated with refractions at velocity jumps, relatively shallow in the crust (1.0 s bsf) appear to be responsible for some of the "lower frequency" events stacked and imaged into the original data. That said, simple reprocessing of these data is unlikely to yield spectacular results at depth. More significant efforts using advanced techniques (with significant issues due to trace spacing in older data) may be better applied to a modern 2-D dataset if access is realistic. This is likely a necessary step before planning any deep penetration, 3-D experiment.

Despite difficulties in providing better images at depth within these vintage data, success was gained through careful reprocessing of the shallow most sedimentary section, above most of the velocity complexities. A wider band of frequencies were kept relative to the original images, and care was taken to include only a few traces per bin to minimize any non-hyperbolic moveout that is common to reflectors in these data. Essentially, can we make better images of recent faulting by turning the high-fold data (in a relatively complex area) into low-fold (or single-channel in the extreme) to get the best images of the sedimentary section. To this

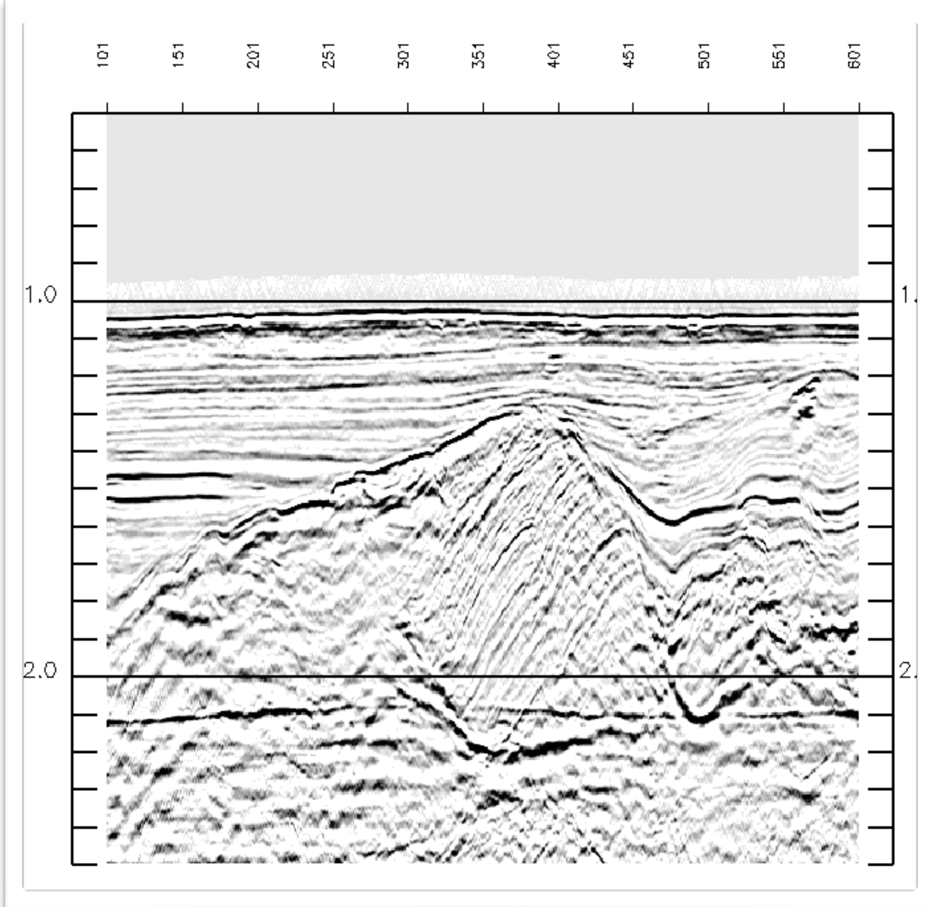


**Low frequency reflections** (Line 4520) from stacking refracted triplications are seen within the final migrated image. These events lack depth sensitivity and as such are a poor proxy for defining the interface where velocity gradients are expected (and their location and extent are required to image more deeply).

end, the new images of the shallow sedimentary section show much more detail, and would likely help identify and/or confirm future targets for more detailed seismic CHIRP and/or conventional "geo-tech" high-res seismic.

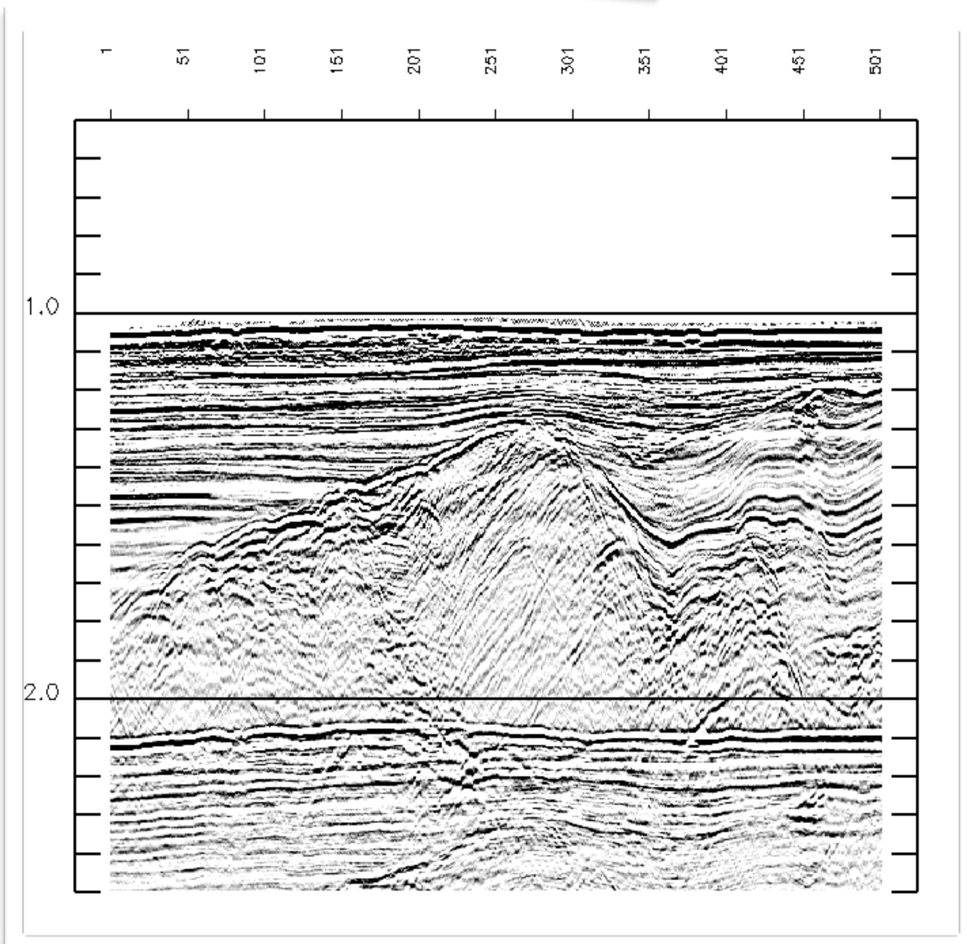
 

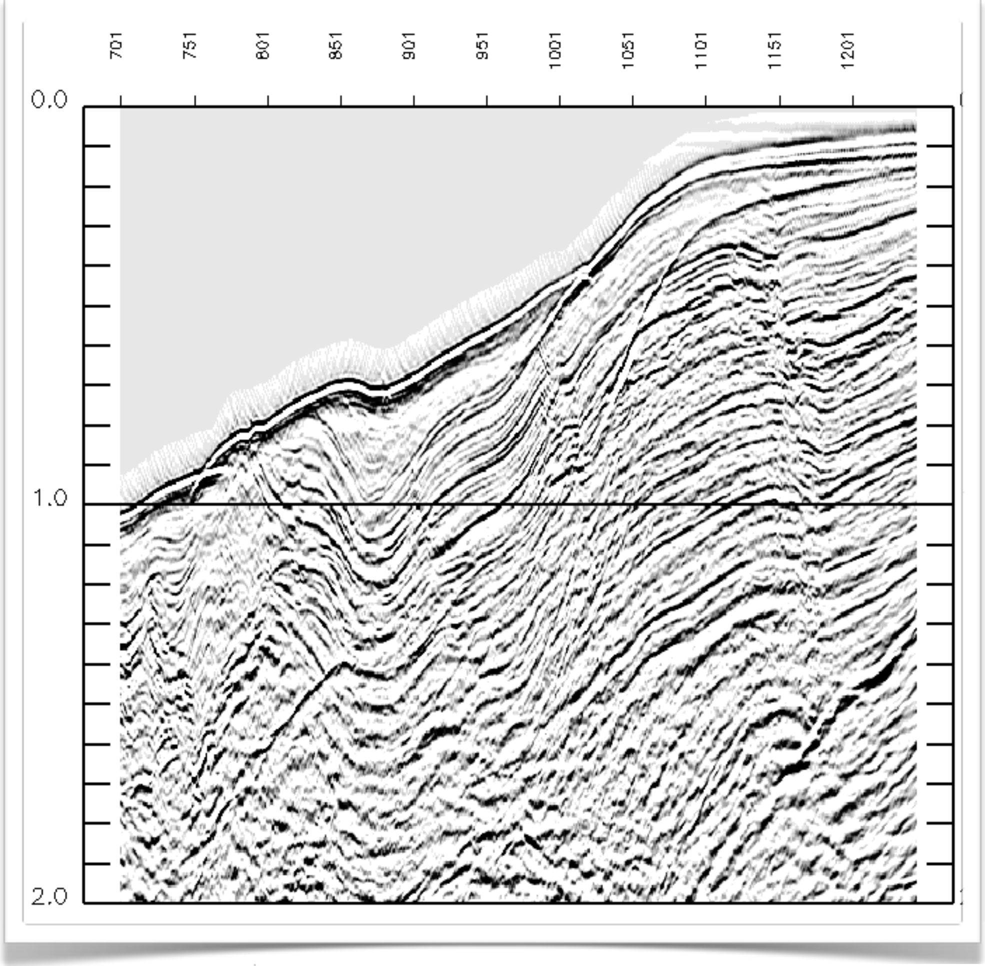
**Example Reprocessed Section** (Line 4520) in high-res mode to try and better image the sedimentary section. Greater frequency content was preserved, and migrated, owing to a stacked section that had twice as many traces than the original trace interpolated data. More detail is seen with this new approach. More imagery is presented for comparison on the next two pages.



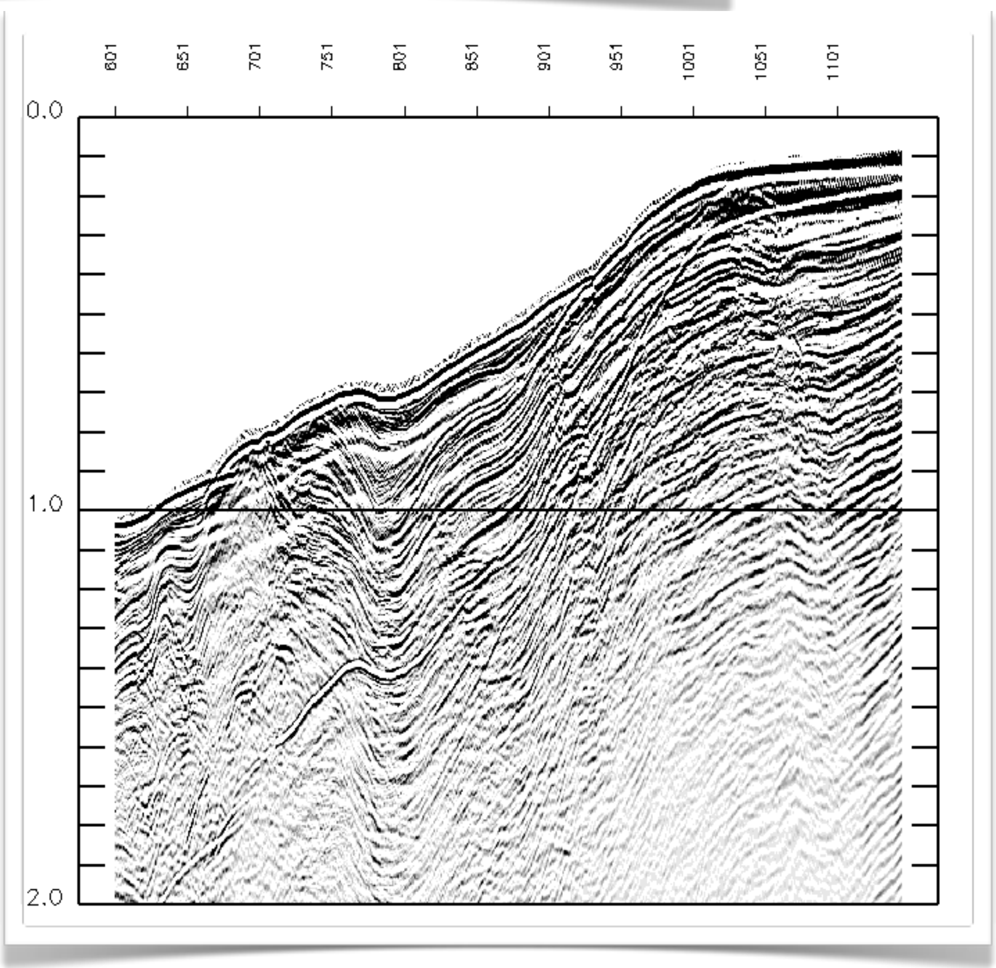

Original

Reprocessed






Original




Reprocessed

# *Appendix—*

## ***Plotting Migrated Data:***

• check migrated image SEGY file

```
SHOT   TR      RP    TR ID  RANGE DELAY NSAMPS    SI   YR DAY HR MIN
                                  SEC
        0     1      1     1  1 -11101     0   2000  4000    0   0  0   0   0
        1268764152******************************** 19481  20983
                  19482l9246****************
        1259884216******************************** 19280  64294
                  19283**********************
          0     0      0     0  0      0     0      0     0     0   0  0   0   0
```

• drats ... # samps wrong in trace header (2000 vs 2066), tape ID header OK

• Fixed, now we can plot migrated section, etc... such are the problems with "old data" and the SEGY "standard"

## ***Geometry Sleuthing:***

• Shot spacing, *h-18-79-sc.txt*

```
19790190000001  33.22241 -117.75220 4520       100    2075807.8   -100934.7   0.0
19790190000002  33.22327 -117.75072 4520       105    2076259.8   -100620.5   0.0
19790190000003  33.22414 -117.74927 4520       110    2076702.5   -100302.8   0.0
19790190000004  33.22498 -117.74786 4520       115    2077133.1    -99996.0   0.0
19790190000005  33.22583 -117.74638 4520       120    2077585.1    -99685.5   0.0
19790190000006  33.22669 -117.74492 4520       125    2078030.9    -99371.3   0.0
```

—110' per shot—

• revisit EBCIDIC header

**** WESTERN GEOPHYSICAL COMPANY SEISMIC STREAMER
96 GROUPS GROUP INTERVAL 110.0 FT
EACH GROUP CONSISTS OF 40 HYDROPHONES IN LINEAR ARRAY
NOMINAL CABLE DEPTH 35 FT GROUP 96 IS NEAR GROUP
WATERBREAK PHONES AT SECTIONS 1, 6, 11, & 31

—110' per group—

• Sweet Sixteen, what is this ?

| *SHOT* | *TR* | *RP* | *TR* | *ID* | *RANGE* | *DELAY* | *NSAMPS* | *SI* | *YR* | *DAY* | *HR* | *MIN* | *SEC* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *97* | *1* | *1* | *1* | *6* | *0* | *0* | *4096* | *2000* | *83* | *300* | *22* | *38* | *22* |
| *97* | *1* | *1* | *2* | *9* | *0* | *0* | *4096* | *2000* | *83* | *300* | *22* | *38* | *22* |
| *97* | *1* | *1* | *3* | *9* | *0* | *0* | *4096* | *2000* | *83* | *300* | *22* | *38* | *22* |
| *97* | *1* | *1* | *4* | *9* | *0* | *0* | *4096* | *2000* | *83* | *300* | *22* | *38* | *22* |
| *97* | *1* | *1* | *5* | *8* | *0* | *0* | *4096* | *2000* | *83* | *300* | *22* | *38* | *22* |
| *97* | *1* | *1* | *6* | *8* | *0* | *0* | *4096* | *2000* | *83* | *300* | *22* | *38* | *22* |
| *97* | *1* | *1* | *7* | *8* | *0* | *0* | *4096* | *2000* | *83* | *300* | *22* | *38* | *22* |
| *97* | *1* | *1* | *8* | *8* | *0* | *0* | *4096* | *2000* | *83* | *300* | *22* | *38* | *22* |
| *97* | *1* | *1* | *9* | *8* | *0* | *0* | *4096* | *2000* | *83* | *300* | *22* | *38* | *22* |
| *97* | *1* | *1* | *10* | *8* | *0* | *0* | *4096* | *2000* | *83* | *300* | *22* | *38* | *22* |
| *97* | *1* | *1* | *11* | *8* | *0* | *0* | *4096* | *2000* | *83* | *300* | *22* | *38* | *22* |
| *97* | *1* | *1* | *12* | *8* | *0* | *0* | *4096* | *2000* | *83* | *300* | *22* | *38* | *22* |
| *97* | *1* | *1* | *13* | *8* | *0* | *0* | *4096* | *2000* | *83* | *300* | *22* | *38* | *22* |
| *97* | *1* | *1* | *14* | *9* | *0* | *0* | *4096* | *2000* | *83* | *300* | *22* | *38* | *22* |
| *97* | *1* | *1* | *15* | *9* | *0* | *0* | *4096* | *2000* | *83* | *300* | *22* | *38* | *22* |
| *97* | *1* | *1* | *16* | *9* | *0* | *0* | *4096* | *2000* | *83* | *300* | *22* | *38* | *22* |
| *97* | *1* | *1* | *17* | *1* | *0* | *0* | *4096* | *2000* | *83* | *300* | *22* | *38* | *22* |
| *97* | *2* | *1* | *18* | *1* | *0* | *0* | *4096* | *2000* | *83* | *300* | *22* | *38* | *22* |
| *97* | *3* | *1* | *19* | *1* | *0* | *0* | *4096* | *2000* | *83* | *300* | *22* | *38* | *22* |
| *97* | *4* | *1* | *20* | *1* | *0* | *0* | *4096* | *2000* | *83* | *300* | *22* | *38* | *22* |

• throw out 16 (first 16) *Aux* channels and renumber

—Geometry Problem, 96 fold per CMP bin—

• natural binning 55’, 48 fold

• 96 fold prestack;  half # of traces than migrated section

—two choices (1) binned at twice natural binning (no!), (2) archived shotgathers (yes!)

—ultimately the shotgathers were rebinned based on shotgather geometry

• geometry confirmed and 1st S-R offset calculated, 178 m

# —SIOSEIS Appendix—

***Remove 16 Auxiliary traces:***

```
sioseis << !
procs diskin prout diskoa end

diskin
  ipath 4520.sgy ftr 17 ltr 112 forgat 1 end
end

prout
  fno 1 lno 99999 ftr 1 ltr 1 end
end

diskoa
  opath 4520.headerfix.sgy end
end

end
!
```

***Place Correct Navigation ionto Headers:***

```
# Now renum shots starting at 97 and plug back something into RP trace
sioseis << !
procs diskin header prout diskoa end

diskin
  ipath 4520.headerfix.sgy renum 97 ntrcs 96 end
end

header
  17 = 1 end
end

prout
```

```
  fno 1 lno 99999 noinc 10 ftr 1 ltr 1 end
end

diskoa
  opath 4520.headerfix2.sgy end
end

end
!


sioseis << !
procs diskin header prout diskoa end

diskin
  ipath 4520.headerfix2.sgy retrac 1 end
end

header
 17 = 97 - 17 end
end

prout
  fno 1 lno 99999 noinc 10 ftr 1 ltr 1 end
end

diskoa
  opath 4520.renum.sgy end
end

end
!

sioseis << eof
procs diskin header header2 diskoa end

diskin
 ipath 4520.renum.sgy end
```

```
end

header
 l10 = l7 * 33.53
 l10 = l10 + 178
 l10 = l10 - 33.53 end
end

header2
 l6 = 0 l7 = 0 end
end

diskoa
 opath 4520.sg.97.633 end
end

end
eof
```

## ***After Gathering Data***

...

## ***Sample, Stack and Migration Script, low-fold:***

```
sioseis << !
procs diskin nmo stack prout tx2fk fkmigr fk2tx prout diskoa end

diskin
   ipath Songs.4520.g.1.1162 ftr 1 ltr 3 ntrgat 3 end
end

filter
  pass 10 120 ftype 0 dbdrop 48 minpha yes end
end

nmo
  fno  100 lno  100 vtp 1480 1.03 1600 1.4 end
  fno  200 lno  200 vtp 1480 1.03 1650 1.6 end
```

```
  fno  300 lno  300 vtp 1480 1.03 1650 1.6 end
  fno  400 lno  400 vtp 1480 1.04 1700 1.7 end
  fno  500 lno  500 vtp 1480 0.98 1700 1.7 end
  fno  600 lno  600 vtp 1480 0.98 1700 1.6 end
  fno  700 lno  700 vtp 1450 0.98 1700 1.6 end
  fno  800 lno  800 vtp 1480 0.68 1800 1.5 end
  fno  850 lno  850 vtp 1425 0.60 1700 1.3 end
  fno  900 lno  900 vtp 1425 0.47 1700 1.0 end
  fno 1000 lno 1000 vtp 1450 0.16 1750 1.0 end
end

smute
  xsets
    800 0.0 1.05
   1217 0.0 1.62
   2116 0.0 2.12
   2190 0.0 5.00
   interp yes end
end

stack
 new no end
end

prout
   fno 1 lno 99999 ftr 1 ltr 99999 end
end

tx2fk
 twindow hann path1 scratch1 path2 scratch2 end
end

fkmigr
  vel 1480 deltax 16.76 end
end

diskoa
   opath 4520.fk_vz.dither.sgy end
```

```
end

end
!
```

# APPENDIX A-2

# SONGS 2D REPROCESSING

# CHEVRON H-18-79 SURVEY, LINE 4520

# FINAL REPORT

**BY**

**GEOTRACE**

# SONGS 2D Reprocessing

# Southern California

# Chevron H-18-79 Survey, Line 4520

# Final Report

Geotrace Project No.: K1031

| | |
|---|---|
| Date: | October, November 2012 |
| Geotrace Contact: | Brian Sharp |
| Addressees: | Steve Duke (GeoPentech), Graham Kent (University of Nevada, Reno) |

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# Table of Contents

# List of Figures and Tables

# 1 Introduction

This report describes a seismic data processing project carried out during the period of October 2012 to November 2012 by Geotrace.

The principal objectives of the processing were as follows:

- Apply current processing methods to an area where noise and multiple are an issue.
- Evaluate if modern processing techniques can improve existing data to a level such that new acquisition is not required.

A particular area of interest is the possibility of the presence of “blind” thrust faults that may lie off the San Onofre Nuclear Generating Station (SONGS).

Acquisition parameters are fully described in Section 2 (Acquisition) and a full inventory of the lines processed is provided in Appendix C. An outline of the processing sequence used is given in Section 4.1.

The development of an appropriate data processing scheme and its application is covered in detail in Section 4. Each section summarises the processing sequence adopted and where appropriate the quality control measures are described.

The report concludes with an assessment of the project in Section 5 (Conclusion). The Appendix section has supporting information relevant to the project.

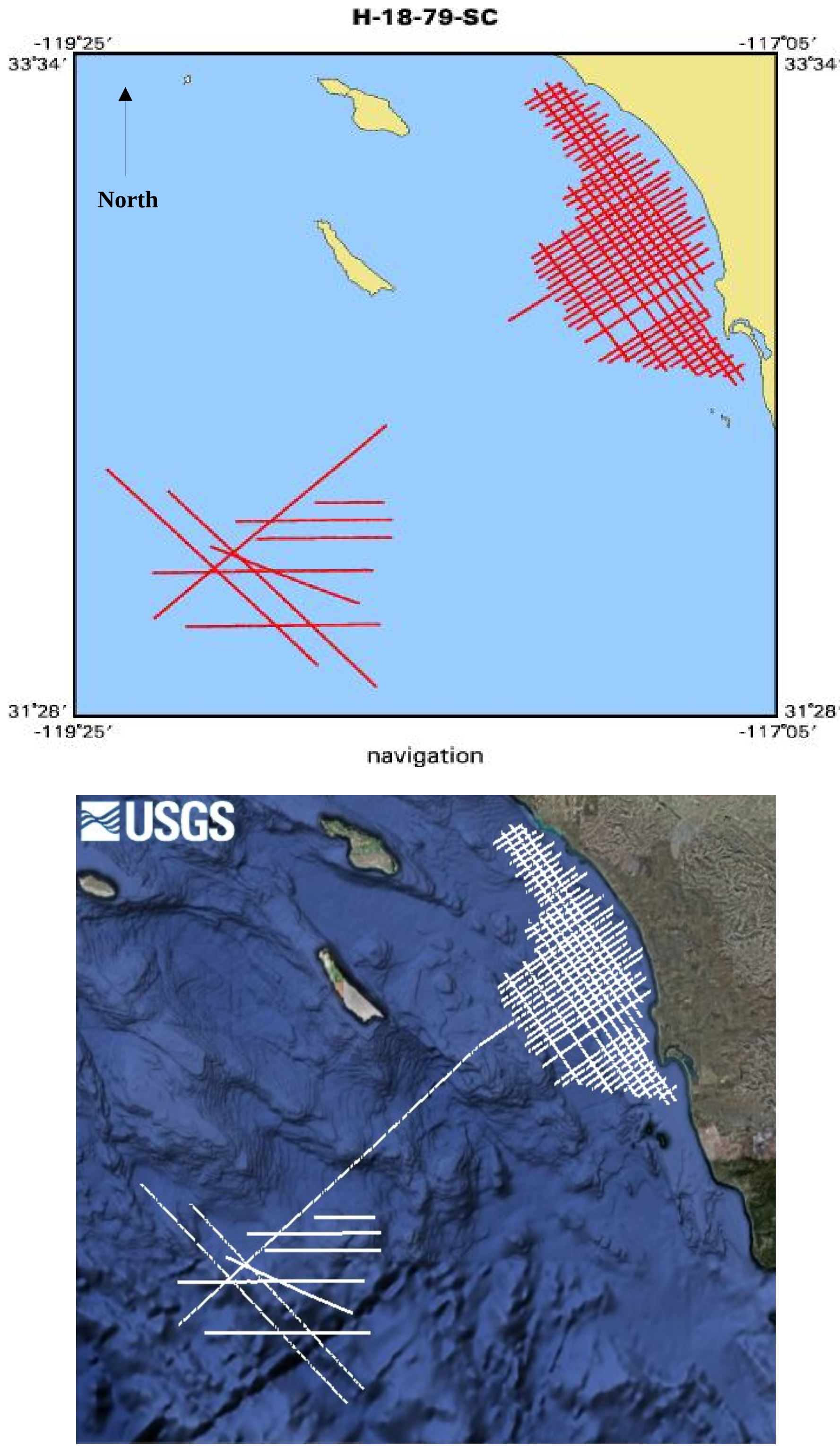


**Figure 1 – USGS SONGS survey location map shown in relation to southern California**

# 2 Acquisition

## 2.1 Survey Specifications

The acquisition specifications for this survey are as follows:

| **Vessel** | Not Available |
|---|---|
| **Year** | 1979 |
| **Source** | Air gun array system |
| **Source depth (metres)** | NA |
| **Volume (cubic inches)** | NA |
| **Array pressure (psi)** | NA |
| **Shot point interval (metres)** | 33.5m |
| **Streamer** | NA |
| **Near offset (metres)** | 178m |
| **Number of Groups** | 96 |
| **Group interval (metres)** | 33.5 |
| **Streamer depth (metres)** | 11m |
| **Streamer length (metres)** | 3216m |
| **Record length (ms)** | 8000 |
| **Sample rate (ms)** | 2 |
| **Recording delay (ms)** | NA |
| **Low cut** | 5 |
| **High cut** | 110 |
| **Format** | NA |

**Table 1 - Acquisition specifications for the H-18-79 survey.**

## 2.2 Comments on Acquisition

From an initial review of the data, the acquisition appears to have had minimal problems   However, since no observers reports or other documentation were supplied, various parameters such as source depth, near offset etc had to be inferred from the data itself.  Visual inspection of the data revealed that it is fairly clean data with minimal noise content.  However this would be expected given the use of a 5hz lo-cut acquisition filter.

# 3 Navigation Data Quality Control

Processed navigation data in UKOOA P1/90 was available with XY and latitude/longitude coordinates for shot point locations. No water depths and coordinates for receivers were present. The spheroid type, projection and geodetic datum used were not available.

## 3.1 Shot location displays

Source locations were displayed to ensure the continuity and visual correct positioning.

## 3.2 Merge with seismic data

Following completion of all processing, the navigation information X and Y coordinates were written to the seismic trace headers.

For the stacked seismic data the coordinates were assigned based on the nearest corresponding CDP to the shot location.

# 4 Processing Scheme

## 4.1 Production Processing

Below is a brief summary of the processing applied to the data.

**Production Processing Flow**

Preliminary Processing:

- Input from supplied SEGY
- Remove auxiliary channels
- Bad shot and trace edits
- Apply zero phase filter derived from data
- Spherical divergence correction
- Interpolate dead or weak channels
- Preliminary 500m velocity analysis
- 2:1 channel interpolation form 33.5m to 16.75m
- 2:1 shot interpolation from 33.5m to 16.75m

Pre-migration Processing:

- Surface related multiple elimination (SRME)
- Drop interpolated channels
- Confirm preliminary 500m prelim velocity analysis
- First pass high resolution radon demultiple
- Drop interpolated shots

Migration Processing:

- Kirchhoff pre-stack time migration for velocity analysis
- Migration velocity analysis (500m interval)
- Final Kirchhoff pre-stack time migration, 3.2km half aperture; dip limit tapered from 60 degrees

Post Migration Processing:

- Second pass high resolution radon demultiple
- Cranvel automated velocity analysis (67m interval)
- NMO correction with final autopicked velocities
- Ensemble balancing
- 5 – 35 degree angle stack
- Waterbottom mute
- Signal : Noise Enhancement
- Gun and cable static correction

Final Deliverable/Archive Production:

- Final Full Angle Volume (AGC)
- Final Velocity Volume
- Processing Reports

## 4.2 Preliminary Processing

### 4.2.1 Input from SEG-D

Raw field data was read and reformatted from the supplied SEG-Y to Geotrace internal format. The trace length was 8190ms at 2ms sample rate.

### 4.2.2 Remove Auxiliary Channels

The first sixteen channels were auxiliary, and not necessary for processing. These were removed.

### 4.2.3 Navigation Merge

Supplied navigation data was merged with the seismic.

### 4.2.4 Low Cut Filter

Upon inspection of preliminary raw shot records, negligible low frequency noise contamination was evident and the acquisition low cut filter of 5Hz (18dB/Octave) was confirmed.

### 4.2.5 Bad Shot and Trace Edits

Trace editing was performed according to information from the Observer's logs, as well as quality control measures employed by Geotrace.

Following the initial reading of the SEGD field tapes, the following suite of quality control displays were produced for each line:

- Near trace gather
- Areal attribute displays depicting absolute amplitude measured within two windows for every trace.
- Areal attribute displays depicting frequency content and areal attribute display depicting flagged anomalous frequencies.
- Areal attribute display for spike detection.
- Displays of brute stacks an CDPs using a single brute velocity function

Analysis of these displays identified poor S/N quality data areas (swell, seismic interference or other types of noise), noisy or spiky channels, shot time shifting. Appropriate shot and channel edits were created.

### 4.2.6 Recording Delay Correction

No recording delay was initially specified. A review of the data appears to confirm the belief that no recording delay was used.

### 4.2.7 Apply Zero Phasing Filter Derived from Far-Field Signature

A far field signature was not supplied to Geotrace.. As a result, a far field signature was derived from the data.

A filter was derived from the far field signature (created from the data) to convert to a zero phase equivalent. This incorporated a receiver ghost notch for an averaged receiver ghost of the nominal streamer depth and the removal of the bubble pulse apparent in the source signature.

To check the derived filters, comparisons were made on near trace gathers of lines before and after their application.

The filter coefficients are specified in Appendix E.

### 4.2.8 Resample and Temporal Anti-alias Filter

After internal discussion, it was agreed to keep the acquired sample rate of 2ms in an attempt to retain as much signal as possible. As such, no filtering was applied

### 4.2.9 Spherical Divergence Correction

A $T^2$ type spherical divergence compensation gain was chosen to compensate for the decrease in seismic wave amplitude due to the geometrical spreading of the wave front.

### 4.2.10 Swell Noise Attenuation

During the QC review of the reformatted data, it was noted that there was only negligible amounts of swell noise. This is likely due to the 5hz lo-cut acquisition filter, as well as the 11m specified cable depth.

Due to this lack of noise, no noise attenuation processing was applied. Should data in addition to the test line be processed, this will be reviewed again as necessary.

### 4.2.11 Preliminary Velocity Analysis

Preliminary velocities were picked at a 500m interval. This corresponds to every thirtieth CDP on the line.

The Geotrace Velocity Work Bench interactive software was used for the analysis displaying NMO corrected CDP gathers, coherency, function stacks and stacks.

## 4.3 Pre Migration Processing

### 4.3.1 Surface-Related Multiple Elimination (SRME)

SRME was employed in order to remove surface related multiple generated from the water bottom. The SRME technique uses the general wave equation boundary condition and makes no assumptions regarding wave behaviour in the earth. No prior model or knowledge of the subsurface is therefore necessary.

A requirement of the technique as implemented is that the shot interval is identical to that of the receivers. While the data as acquired meets this requirement, the sparse channel spacing meant that there was significant aliasing present in both the waterbottom primary and multiple, which can be detrimental to the SRME methodology. To remove this aliasing, both channels and shots were interpolated from 33.5 meters to 16.75 meters.

An iterative three-pass approach to the SRME was used, with the final estimate be subtracted from the input using a least-squares fitting in the X-T domain.

### 4.3.2 Preliminary velocity Analysis Confirmation

Following SRME, a review of the preliminary velocities was performed to see if any locations could be improved.

### 4.3.3 First Pass Radon Demultiple

Parameterisation of the parabolic radon demultiple method principally involved optimisation of the moveout limits to be used in the overall transform and similarly for the multiple model itself. The effectiveness of the Radon process was assessed using a range of multiple models of increasing severity.

A conservative outside trace mute was applied to the CDP gathers prior to Radon to remove excessive NMO stretch. Interpolation (the same parameters used for the SRME) was performed to increase the fold to improve the Radon transform and consequent multiple attenuation. These interpolated traces were dropped immediately after Radon. A wrap around AGC with a 200ms window was applied during the radon demultiple processing, then removed afterwards. The moveout cut values were contoured to follow the waterbottom.

The parameters used are as follows:

**Radon Parameters**
Model design -600ms to +2500ms
Frequency range: 3 - 125 Hz
Dip increment: 8 ms (i.e. one p-trace per 8 ms)
Reference offset: 3360 m
Radon demultiple cut:

| Time (relative to WB) ms | P Move-out (ms) |
|---|---|
| 0 | 2500 |
| 14 | 1680 |
| 218 | 612 |
| 464 | 500 |
| 720 | 240 |
| 956 | 150 |
| 1700 | 100 |
| 8000 | 88 |

## 4.4 Migration processing

### 4.4.1 Migration velocity analysis

The smoothed first pass velocity field was used for the initial pre-stack time migration. This was used to generate a second pass of velocity analysis, which was performed to pick the correct migration velocities at a 500 meter interval.

The same QC measures used in the first pass velocity analysis were implemented here as well.

### 4.4.2 Pre-Stack Time Migration

A 2D curved ray Kirchhoff pre-stack time migration was selected in order to provide the highest data quality overall. Kirchhoff parameterisation tests showed that a 3360 meter migration half-aperture and a 60 degree maximum dip would optimise the image and signal-to-noise content in the data.

## 4.5 Post Migration Processing

### 4.5.1 Second Pass High Resolution Radon Demultiple

Radon demultiple was revisited once better velocity control had been produced after Kirchhoff PSTM. This allowed a much tighter application to be employed. Parameters used are as follows:

Model design -500ms to +1500ms
Frequency range: 3-125 Hz
Dip increment: 8 ms (i.e. one p-trace per 8 ms)
Reference offset: 3343 m
Radon demultiple cut:

| Time (relative to WB) ms | P Move-out (ms) |
|---|---|
| 0 | 1500 |
| 14 | 1380 |
| 200 | 412 |
| 464 | 300 |
| 720 | 140 |
| 956 | 100 |
| 1700 | 88 |
| 8000 | 70 |

### 4.5.2 Cranvel Automated Velocity Analysis (100m Interval)

High density velocity analysis was undertaken using the proprietary Geotrace software technique CRANVEL. Input data for the CRANVEL was preconditioned with various denoise techniques in order to increase the accuracy of the auto-picking. The migration velocity field was also used as a reference for the CRANVEL.

### 4.5.3 NMO Correction

The CRANVEL high density velocity field was used for final $6^{th}$ order normal move-out correction.

### 4.5.4 Diffracted Multiple Attenuation (FDNA)

To help suppress remnant multiple energy pass of FDNA was applied. Parameters are as follows:

Trace window: 15
Start time (near offset): WB + 2200 ms
Start time (far offset): WB + 3300 ms
Frequency range: 16 - 125 Hz

### 4.5.5 Offset Balancing

To help optimize the stack response, offset planes were balanced relative to each other. This is done by first sampling all full fold CDP gathers, creating a pilot ensemble containing averaged RMS values for the line, for each offset. Using this pilot trace, each offset within each CDP is then gained accordingly. Amplitude only Q Compensation

### 4.5.6 Mute and Stacking

After reviewing various displays, an outer trace mute of 35 degrees was chosen. To minimize remnant multiple, a 5 degree, tapering to 2 degrees at depth inside mute was chosen. The data was then stacked, where stack normalisation was by 1/N where N is the number of live samples per CDP ensemble.

### 4.5.7 Post Stack Signal : Noise Enhancement

After stack, several methods were tested for improving the signal : noise ratio.

Firstly a program titled SNIP, a proprietary Geotrace program, was appied. SNIP is a true 3D signal:noise enhancement program that operates by estimating signal over an M x N grid of surrounding traces and rejecting the non-estimated noise.

Signal is determined by finding the dipping plane of maximum semblance that is centered on the outpoint point. Nose is determined through the use of an ampliltude median/trim process within each plane. For this survey a grid of 6 x 6 traces was used with a dip range of +/- 6ms / trace.

Seperately, a program titled DIGISTACK was applied. This processed is performed in two steps. First, coherent components of the seismic are estimated using specified trace and time windows, as well as minimum and maximum amounts of allowable dip. Any data not falling within the allowed parameters is output as a noise record. Data within the allowable parameters is output as a signal record. The parameters used to generate the signal and noise traces were:

| | |
|---|---|
| Window Width: | 25 traces |
| Trace Increment: | 7 |
| Length of Time Window: | 250 ms |
| Time Window Increment: | 36 ms |
| Allowed Dip: | +/- 100 ms |

Following the calculation of the signal and noise records, they are summed back together with a specific relative weight given to the signal trace. For this project a weight of 0.3 was used. Also, to further stabilise the output, a 500ms median AGC was applied after the signal and noise estimation, but before the summing.

### 4.5.8 Gun and cable static

A correction for source and receiver depths was applied to the data. Because the source depth was not specified, the stack section was shifted by an amount that would allow it to best tie with the originally processed stack section. In this case this bulk shift was ~20ms.

### 4.5.9 AGC

After viewing several tests, a 500ms median AGC was applied to both versions of the stack.

### 4.5.10 Output to SEG-Y

After AGC, the stack sections were muted above the waterbottom and taper zone and written to SEG-Y disk file. These files were then delivered via FTP.

## 4.6 Final Deliverables / Archive Production

### 4.6.1 SEG-Y Output

The following seismic data was created as part of the deliverable requirements:

- Final full offset stack with SNIP signal:noise enhancement
- Final full offset stack with DIGISTACK signal:noise enhancement
- RMS migration velocity section

All stacks, CDP gathers and final velocity data was archived in SEG-Y 32bits IBM floating point format, and delivered via FTP.

The archived products are listed in Appendix A.

# 5 Conclusion

The principal objective of this project was to evaluate if modern processing techniques could enhance vintage data to a level so as not to necessitate new acquisition. The primary areas of interest are the proposed “blind” thrust faults that may lie in the area.

Due to the acquisition filters, the data was quite clean in appearance. However, these filters may have possibly harmed low frequency events at depth.

Of particular challenge was determining the velocity gradients at depth. This is again due to the acquisition parameters used. Velocity determination under 3 seconds in particular was rather difficult.

Overall, the final data is quite improved. Demultiple in particular is superior to the original data with nearly all remnants of multiple being attenuated in the stack section.

# Appendix A – Final Deliverables

| Dataset Name/Description | Format | Media (Nos.) |
|---|---|---|
| | | |
| Full Offset Stack with SNIP Signal:Noise Enhancement | SEG-Y | FTP |
| Full Offset Stack with DIGISTACK Signal:Noise Enhancement | SEG-Y | FTP |
| RMS Migration Velocity Section | SEG-Y | FTP |
| | | |
| | | |
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| | | |
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| | | |
| | | |

**Table 2 - Final Deliverables**

# Appendix B – EBCDIC Headers

The EBCDIC headers listed below were used for the final deliverables.

## Full Offset Stack with SNIP Signal:Noise Enhancement

```
C01 PROJECT........ : H-18-79
C02 AREA........... : Offshore Southern California
C03 CLIENT......... : GeoPentech
C04 DATA TYPE.......: FULL OFFSET PSTM STACK
C05 2D-LINE........ : 4520
C06 SHOT POINT..... : 99 - 675
C07 =========DATA ACQUISITION=============================================
C08 VESSEL......... : NA............... DATE SHOT...... : 1979
C09 SOURCE TYPE.... : NA.......... .... SHOT INTERVAL.. : 33.5 M
C10 SOURCE DEPTH .. : NA............... SOURCE VOLUME . : NA
C11 SAMPLE INTERVAL : 2 MS............. RECORD LENGTH.. : 8190 MS
C12 STREAMER TYPE . : NA.......... .... NO OF GROUP.... : 96
C13 GROUP INTERVAL. : 33.5 M........... CABLE LENGTH... : 3216 M
C14 CABLE DEPTH.... : 11 M(+/-1M)....... TAPE FORMAT ... : NA
C15 NEAR OFFSET.... : 175 M............ FOLD COVERAGE.. : 48
C16 GEODETIC DATUM, DATUM: NA; SPH:NA; PROJ: NA ZONE: NA; CM: NA
C17 ==============PROCESSED BY GEOTRACE TECHNOLOGIES INC OCT 2012
C18 =================REPROCESSING==========================================
C19 1)REFORMAT FROM SEGD TO GEOTRACE INTERNAL 2)ZERO PHASE DESIGNATURE
C20 3)500M PRELIM VELOCITY ANALYSIS           4)CHAN INTERP TO 16.75M
C21 5)SHOT INTERP TO 16.75M                   6)ZERO OFFSET EXTRAPOLATION
C22 7)ITERATIVE SRME                          8)DROP INTERP/EXTRAP CHANS
C23 9)HI-RES PARBOLIC RADON                   10)DROP INTERP SHOTS
C24 11)TARGET PSTM                            12)500M PSTM VELOCITY ANALYSIS
C25 13)FINAL PSTM : 3360M APER RADIUS, 90 DEG DIP LIMIT
C26 14)FINAL PARABOLIC RADON                  15)FDNA RESID MULT ATTENUATION
C27 16)AUTOMATED VEL ANALYSIS 134M            17)OFFSET BALANCING
C28 18)INSIDE/OUTSIDE MUTE 05-35 DEG          19)FULL OFFSET STACK
C29 20)500MS MEDIAN AGC                       21)GUN/CABLE STATIC
C30 22)REVERSE POLARITY TO MATCH ORIG         23)WATERBOTTOM/TAPER MUTE
C31 24)WRITE TO SEGY DISK FILE
C32
C33
C34 FIRST CDP : 297; LAST CDP 1544; CDP INT : 16.75 M; SAMPLE INT : 2 MS;
C35 POLARITY : SEG NEGATIVE STANDARD FOR ZERO PHASE WAVELETS
C36 HEADER NAME: BYTE RANGE, FORMAT
C37 CDP: 17 - 20 INT; FFID: 9 - 12 INT; EASTING:73-76 INT; NORTHING: 77-80
INT
C38 SP: 21-25 INT; SUBLINE: 181-184 INT LAT: 81-84 FLT; LONG: 85-88 FLT
C39
C40 END EBCDIC
```

## Full Offset Stack with DIGISTACK Signal:Noise Enhancement

```
C01 PROJECT........ : H-18-79
C02 AREA........... : Offshore Southern California
C03 CLIENT......... : GeoPentech
C04 DATA TYPE.......: FULL OFFSET PSTM STACK
C05 2D-LINE........ : 4520
C06 SHOT POINT..... : 99 - 675
C07 =========DATA ACQUISITION=============================================
C08 VESSEL......... : NA............... DATE SHOT...... : 1979
C09 SOURCE TYPE.... : NA.......... .... SHOT INTERVAL.. : 33.5 M
C10 SOURCE DEPTH .. : NA............... SOURCE VOLUME . : NA
C11 SAMPLE INTERVAL : 2 MS............. RECORD LENGTH.. : 8190 MS
```

```
C12 STREAMER TYPE . : NA.......... .... NO OF GROUP.... : 96
C13 GROUP INTERVAL. : 33.5 M........... CABLE LENGTH... : 3216 M
C14 CABLE DEPTH.... : 11 M(+/-1M)....... TAPE FORMAT ... : NA
C15 NEAR OFFSET.... : 175 M............ FOLD COVERAGE.. : 48
C16 GEODETIC DATUM, DATUM: NA; SPH:NA; PROJ: NA ZONE: NA; CM: NA
C17 ==============PROCESSED BY GEOTRACE TECHNOLOGIES INC OCT 2012=======
C18 =====================REPROCESSING=====================================
C19 1)REFORMAT FROM SEGD TO GEOTRACE INTERNAL 2)ZERO PHASE DESIGNATURE
C20 3)500M PRELIM VELOCITY ANALYSIS           4)CHAN INTERP TO 16.75M
C21 5)SHOT INTERP TO 16.75M                   6)ZERO OFFSET EXTRAPOLATION
C22 7)ITERATIVE SRME                          8)DROP INTERP/EXTRAP CHANS
C23 9)HI-RES PARBOLIC RADON                   10)DROP INTERP SHOTS
C24 11)TARGET PSTM                            12)500M PSTM VELOCITY ANALYSIS
C25 13)FINAL PSTM : 3360M APER RADIUS, 90 DEG DIP LIMIT
C26 14)FINAL PARABOLIC RADON                  15)FDNA RESID MULT ATTENUATION
C27 16)AUTOMATED VEL ANALYSIS 134M            17)OFFSET BALANCING
C28 18)INSIDE/OUTSIDE MUTE 05-35 DEG          19)FULL OFFSET STACK
C29 20)POST STACK S:N ENHANCEMENT VER 1       21)500MS MEDIAN AGC
C30 22)GUN/CABLE STATIC                       23)REVERSE POLARITY TO MATCH
ORIG
C31 24)WATERBOTTOM/TAPER MUTE                 25)WRITE TO SEGY DISK FILE
C32
C33
C34 FIRST CDP : 297; LAST CDP 1544; CDP INT : 16.75 M; SAMPLE INT : 2 MS;
C35 POLARITY : SEG NEGATIVE STANDARD FOR ZERO PHASE WAVELETS
C36 HEADER NAME: BYTE RANGE, FORMAT
C37 CDP: 17 - 20 INT; FFID: 9 - 12 INT; EASTING:73-76 INT; NORTHING: 77-80
INT
C38 SP: 21-25 INT; SUBLINE: 181-184 INT LAT: 81-84 FLT; LONG: 85-88 FLT
C39
C40 END EBCDIC
```

# Appendix C – Lines and SP Ranges

| Line | First Shot Point | Last Shot Point | Line Length (Km) |
| --- | --- | --- | --- |
| 4520 | 100 | 1675 | 19.26 |
| | | | |
| | | | |
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| | | | |
| | | | |
| | | | |

**Table 2 – List of processed lines.**

# Appendix D – Project Personnel

## Geotrace personnel

| | |
|---|---|
| Mark Robinson | Area Manager Far East |
| Brian Sharp | Chief Geophysicist, Team Leader |
| Shelley Van Reeneen | Seismic Processing Supervisor |
| Pete Brown | Seismic Processing Supervisor |

## Client representatives

| | |
|---|---|
| Steve Duke | GeoPentech |
| Dr. Graham Kent | Nevada Seismological Laboratory, University of Nevada, Reno |

# Appendix E – Designature Coefficients

The following table shows the designature filter coefficients that were used for the zero-phasing designature. These were generated using PGS Nucleus software.

```
THIS IS A WAVELET LISTING

Header :    Wiener filter


Sample interval (msec) =     2.000000
Number of samples      =   201
Index of time zero     =    26
```

| | | | | | |
|---|---|---|---|---|---|
| -.78156E+02 | .18817E+02 | -.42693E+02 | -.20967E+02 | .16827E+02 | -.20147E+02 |
| -.95517E+02 | -.12228E+03 | -.52728E+02 | .35431E+02 | .52419E+02 | .13180E+02 |
| .14486E+02 | .96768E+02 | .16385E+03 | .11639E+03 | -.88880E+01 | -.82240E+02 |
| -.54864E+02 | .92164E+01 | .39626E+02 | .37228E+02 | .33582E+02 | .24003E+02 |
| -.59186E+01 | -.31204E+02 | -.16429E+02 | .24914E+02 | .46768E+02 | .30057E+02 |
| .79749E+00 | -.12622E+02 | -.75258E+01 | .29604E+01 | .18578E+02 | .32486E+02 |
| .32298E+02 | .16103E+02 | -.49906E+01 | -.10197E+02 | .45678E+01 | .24775E+02 |
| .32805E+02 | .24567E+02 | .86361E+01 | -.33445E+01 | -.42966E+01 | .39040E+01 |
| .15827E+02 | .23487E+02 | .20740E+02 | .82076E+01 | -.51140E+01 | -.91866E+01 |
| -.14250E+01 | .11784E+02 | .19929E+02 | .16817E+02 | .47691E+01 | -.72337E+01 |
| -.10279E+02 | -.20433E+01 | .11089E+02 | .19122E+02 | .16056E+02 | .49503E+01 |
| -.53788E+01 | -.75131E+01 | -.77932E+00 | .93418E+01 | .15428E+02 | .13227E+02 |
| .42227E+01 | -.56766E+01 | -.95095E+01 | -.42861E+01 | .59175E+01 | .12749E+02 |
| .10743E+02 | .18466E+01 | -.68195E+01 | -.90117E+01 | -.38344E+01 | .46758E+01 |
| .10450E+02 | .92667E+01 | .17582E+01 | -.65190E+01 | -.91702E+01 | -.42439E+01 |
| .42287E+01 | .96887E+01 | .82792E+01 | .13248E+01 | -.59673E+01 | -.83562E+01 |
| -.42802E+01 | .31179E+01 | .83082E+01 | .74084E+01 | .11016E+01 | -.58487E+01 |
| -.83072E+01 | -.45269E+01 | .24867E+01 | .73289E+01 | .63914E+01 | .59607E+00 |
| -.56009E+01 | -.77014E+01 | -.43298E+01 | .19059E+01 | .63858E+01 | .58308E+01 |
| .73186E+00 | -.50453E+01 | -.71051E+01 | -.39875E+01 | .17874E+01 | .58871E+01 |
| .53381E+01 | .73433E+00 | -.44488E+01 | -.64128E+01 | -.37479E+01 | .14879E+01 |
| .53026E+01 | .48657E+01 | .60893E+00 | -.41154E+01 | -.58860E+01 | -.34318E+01 |
| .12596E+01 | .46584E+01 | .44013E+01 | .66511E+00 | -.36817E+01 | -.53554E+01 |
| -.31369E+01 | .11879E+01 | .42852E+01 | .39555E+01 | .62566E+00 | -.31647E+01 |
| -.46710E+01 | -.28221E+01 | .97172E+00 | .38605E+01 | .37029E+01 | .66146E+00 |
| -.28675E+01 | -.41924E+01 | -.24320E+01 | .93756E+00 | .33715E+01 | .31701E+01 |
| .60010E+00 | -.24016E+01 | -.36377E+01 | -.22294E+01 | .75531E+00 | .30038E+01 |
| .28258E+01 | .47420E+00 | -.21502E+01 | -.30777E+01 | -.17863E+01 | .64977E+00 |
| .24598E+01 | .23659E+01 | .53286E+00 | -.17168E+01 | -.26657E+01 | -.15906E+01 |
| .61511E+00 | .22004E+01 | .19635E+01 | .26398E+00 | -.15084E+01 | -.20432E+01 |
| -.10921E+01 | .50526E+00 | .15206E+01 | .14088E+01 | .40081E+00 | -.94805E+00 |
| -.17445E+01 | -.12104E+01 | .49229E+00 | .17505E+01 | .10715E+01 | -.61049E+00 |
| -.10568E+01 | -.13781E+00 | -.11751E-01 | -.98376E+00 | -.10389E+00 | .25586E+01 |
| .12558E+01 | -.47594E+01 | .20215E+01 | | | |

# APPENDIX B

# PHASE 1 REPROCESSED SEISMIC REFLECTION DATA

# 1979 CHEVRON SURVEY

# APPENDIX B
# PHASE 1 REPROCESSED SEISMIC REFLECTION DATA
# 1979 CHEVRON SURVEY

## B.1 Introduction

A total of approximately 950 line-km of seismic reflection data along 29 lines from the 1979 Chevron survey were reprocessed during Phase 1. The locations of the lines are shown on Figure 1 and listed on Table 1 of the main text.

## B.2 Results

The Phase 1 reprocessed lines are included in the attached profiles and digital files. Appendix B-1 presents color plots of the original processed and reprocessed reflection profiles. Figures B-1.1 through B-1.22 show the dip lines – even numbered shore-perpendicular Lines 4500 through 4544 (excluding 4528), respectively. Figures B.1-23 through B.1-29 show the strike lines – odd numbered shore-parallel Lines 4501 through 4515 (excluding 4503), respectively. Appendix B-2 includes a DVD with the digital reprocessed data in SEGY format and navigation file in ASCII format, as described in the main text. Appendix B-3 includes a DVD with a full HIS Kingdom 8.8 model of the SONGS area, as described in the main text.

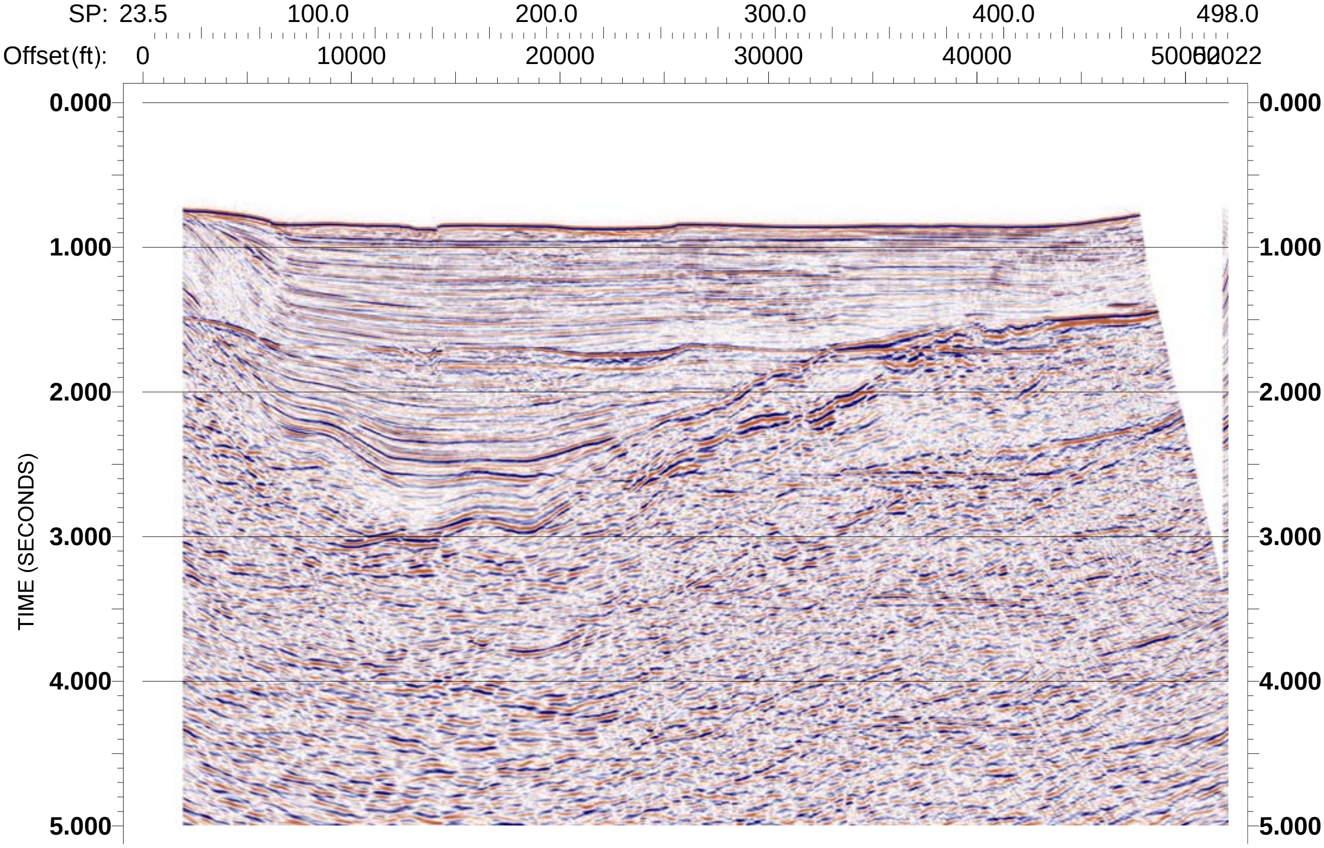
# APPENDIX B-1

# ORIGINAL AND REPROCESSED

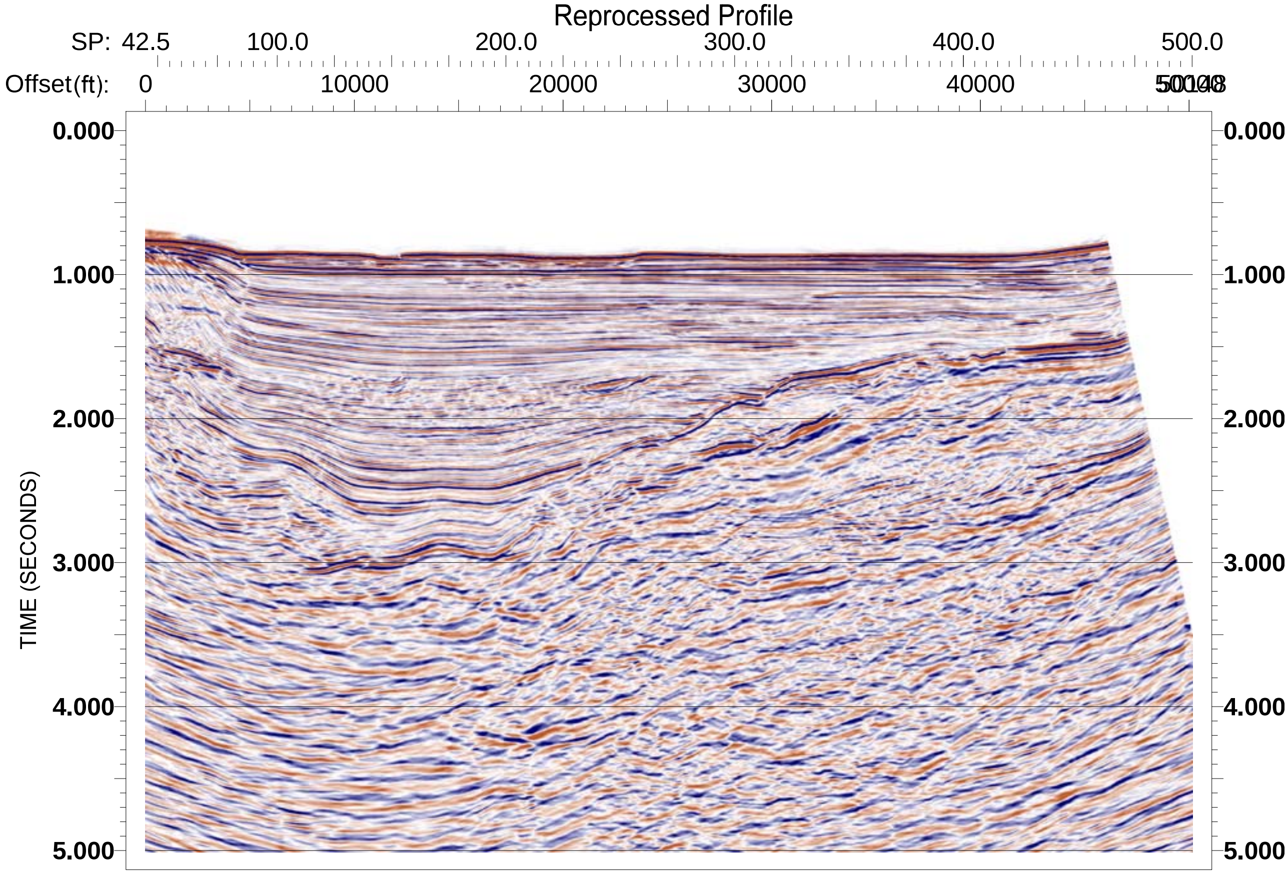
# SEISMIC REFLECTION PROFILES

# LINE 4500

Original Processed Profile



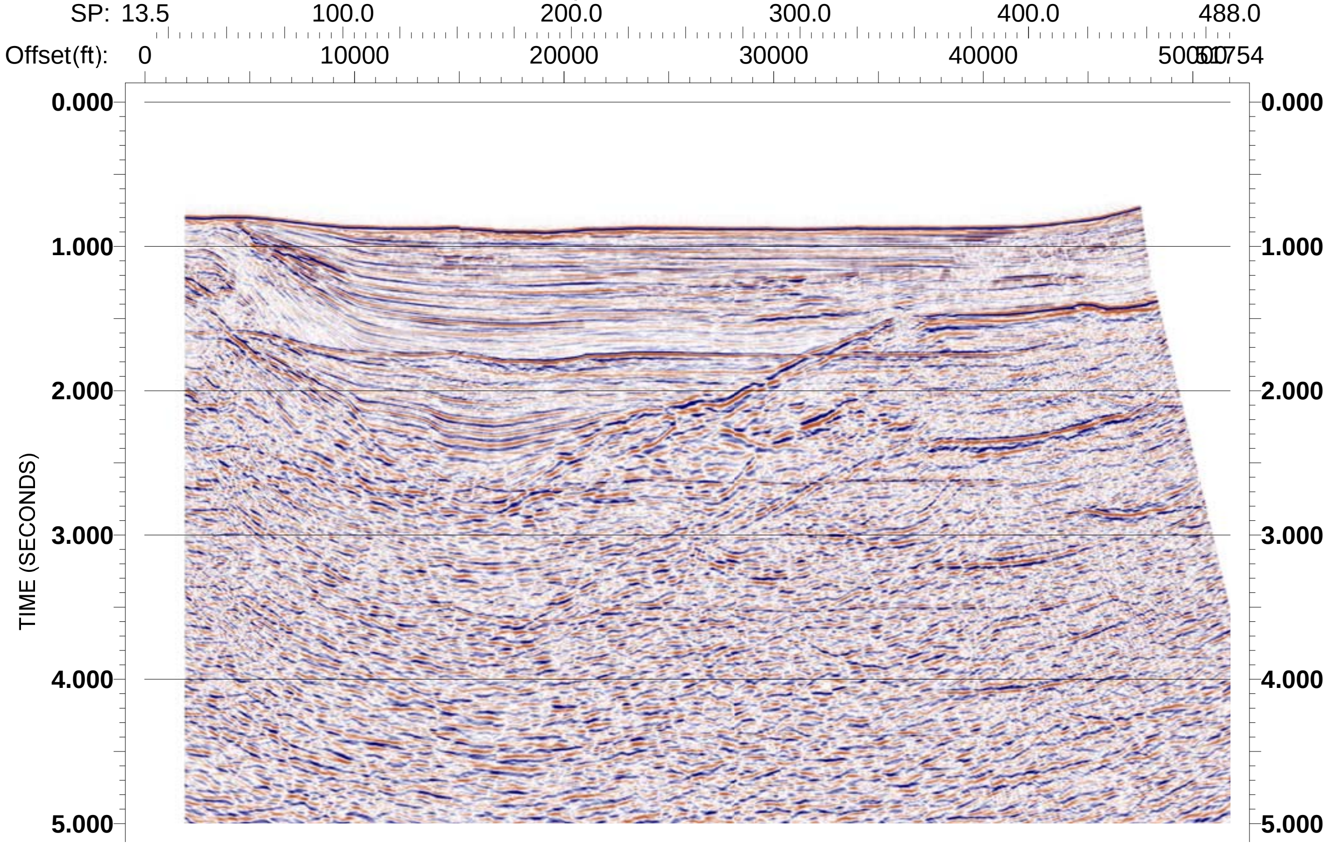

Reprocessed Profile



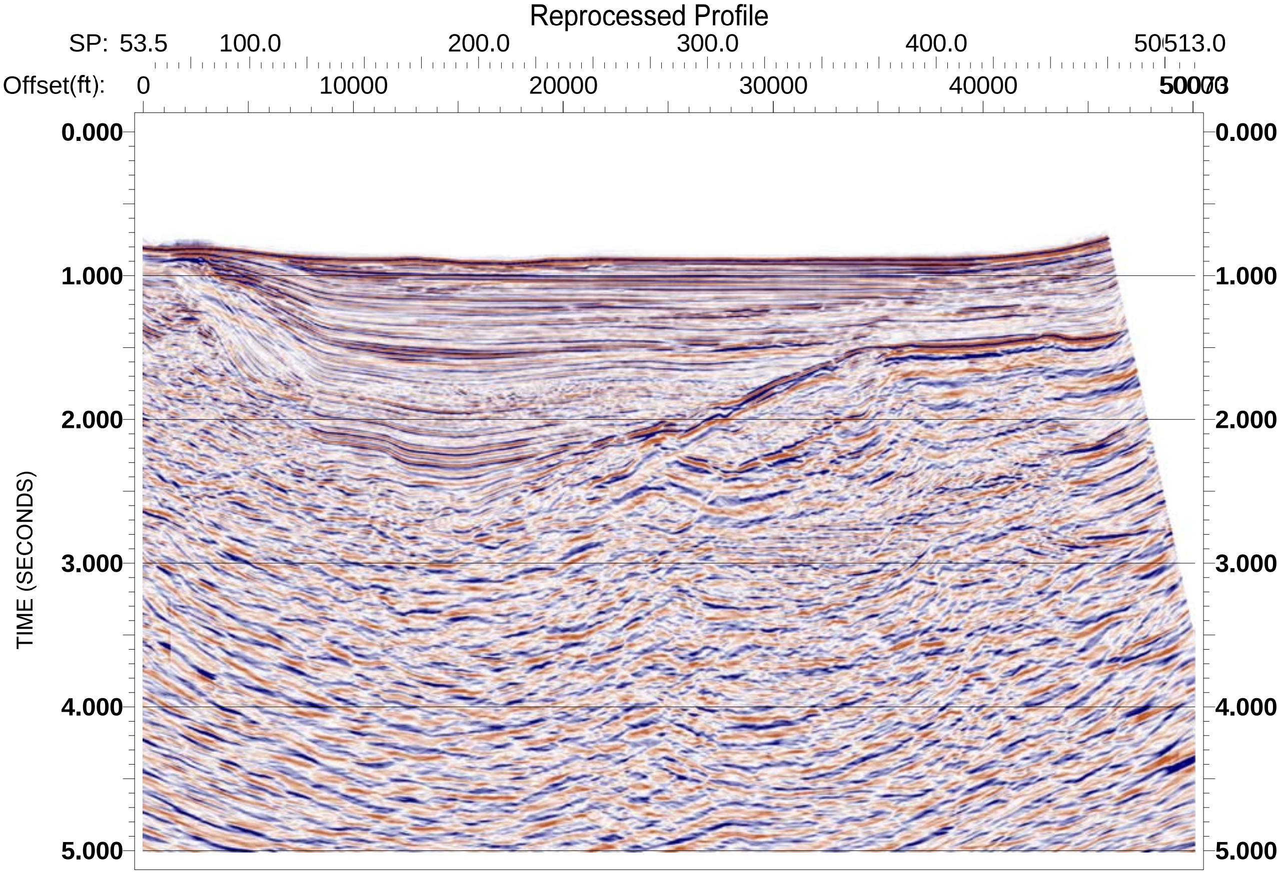

| PHASE 1<br>REPROCESSED SEISMIC REFLECTION LINES<br>1979 CHEVRON SURVEY | LINE 4500 | FIGURE<br>B-1.1 |
|---|---|---|

# LINE 4502

Original Processed Profile




Reprocessed Profile

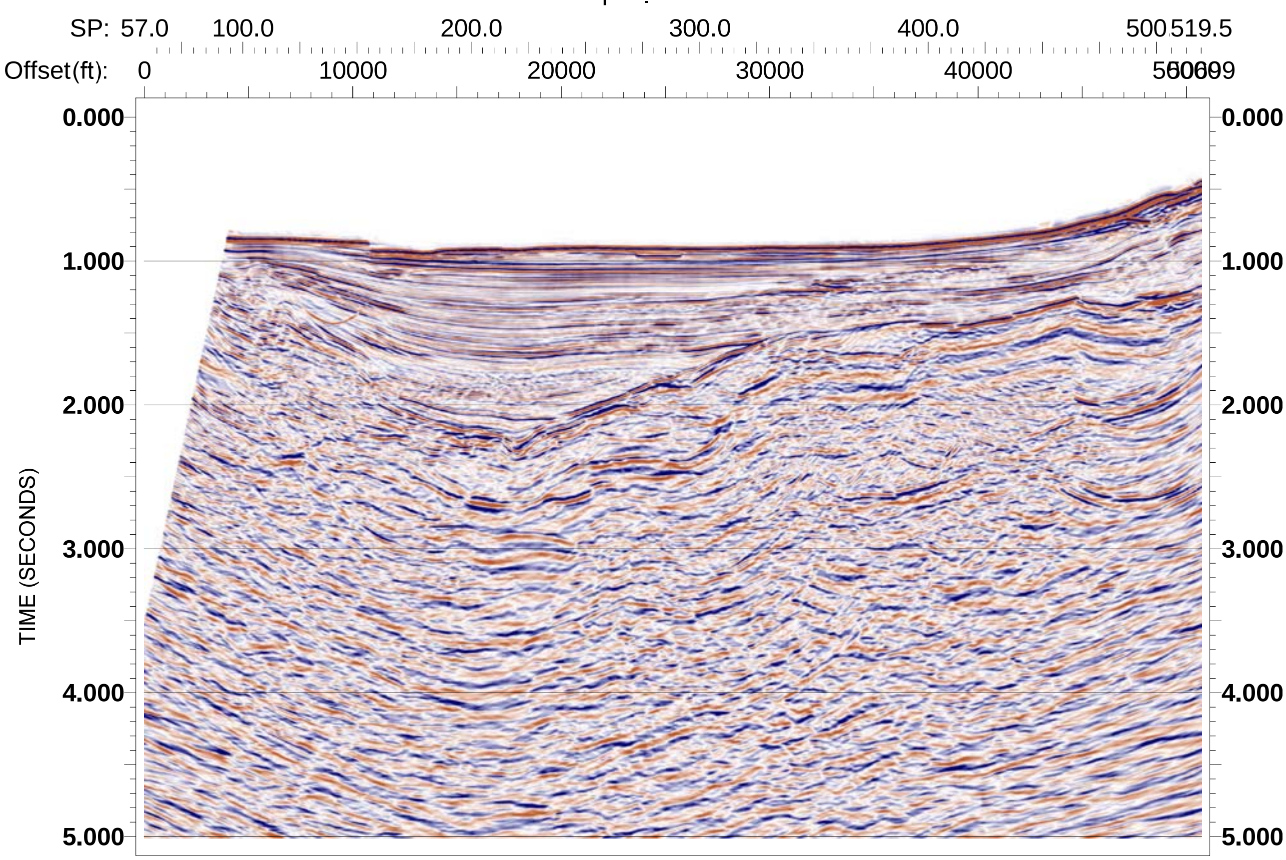



| PHASE 1<br>REPROCESSED SEISMIC REFLECTION LINES<br>1979 CHEVRON SURVEY | LINE 4502 | FIGURE<br>B-1.2 |
|---|---|---|

## LINE 4504

LINE 4504 Original Processed Profile Not Available

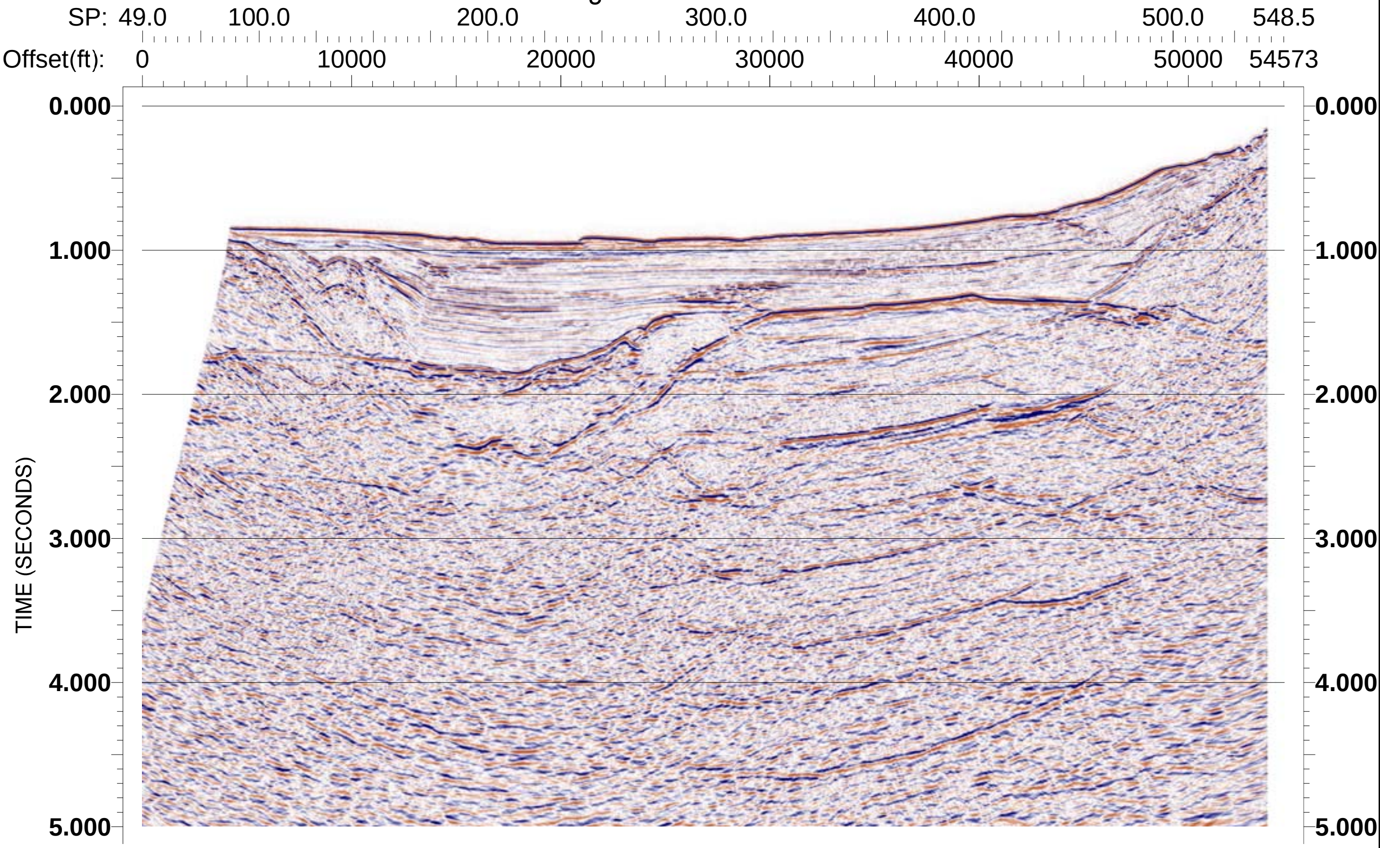
Reprocessed Profile



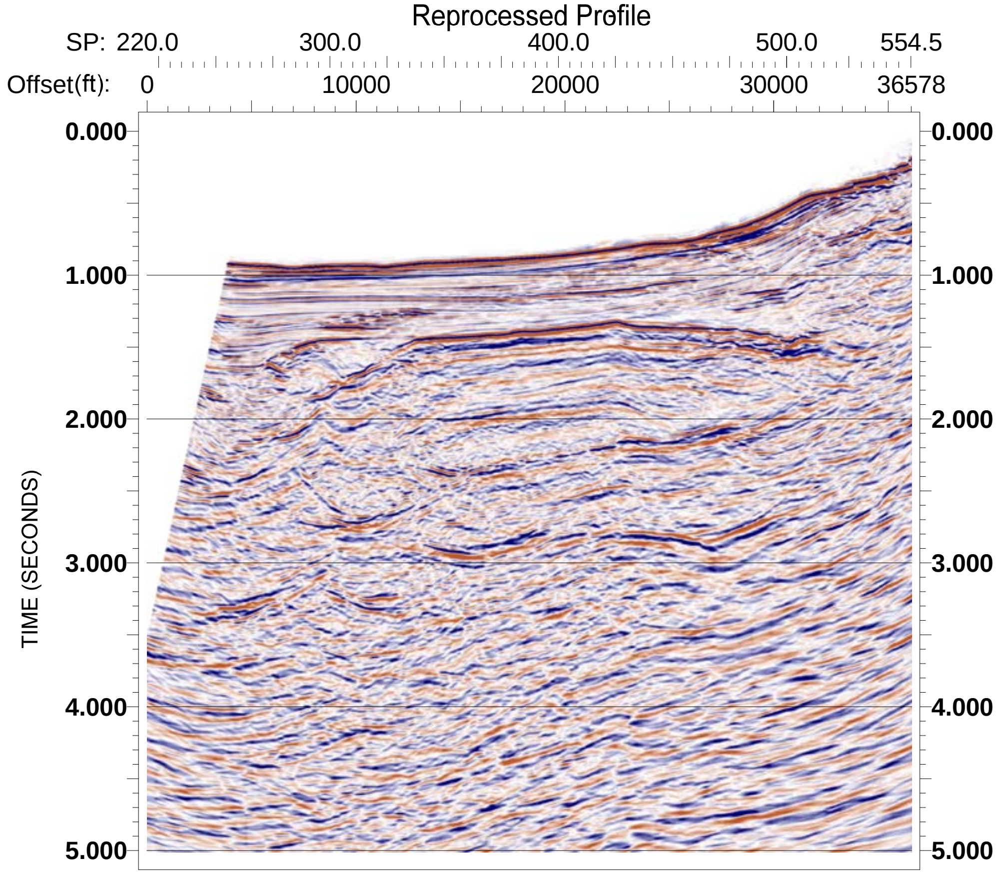

| | | |
|---|---|---|
| PHASE 1<br>REPROCESSED SEISMIC REFLECTION LINES<br>1979 CHEVRON SURVEY | LINE 4504 | FIGURE<br>B-1.3 |

# LINE 4506

Original Processed Profile



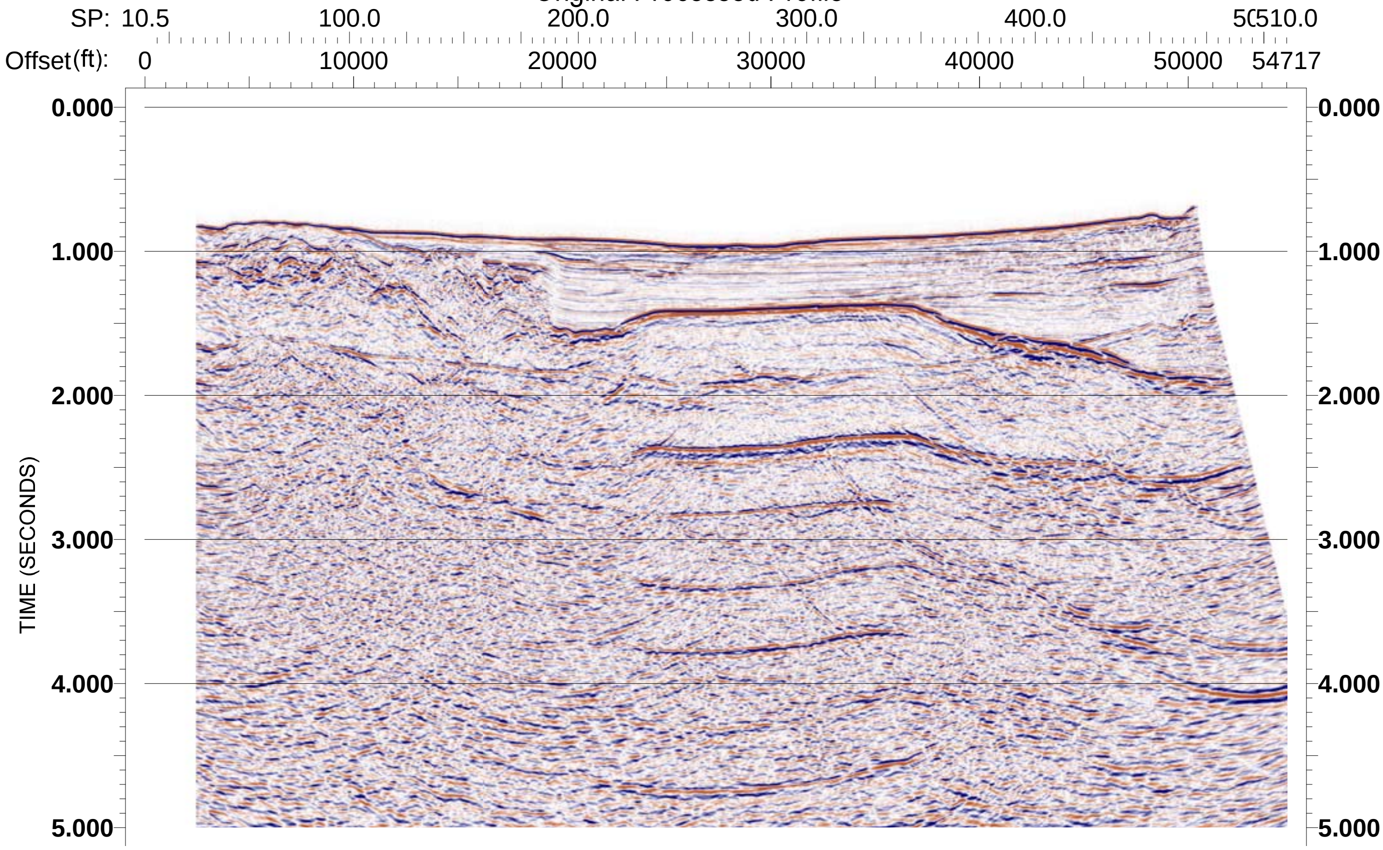

Reprocessed Profile



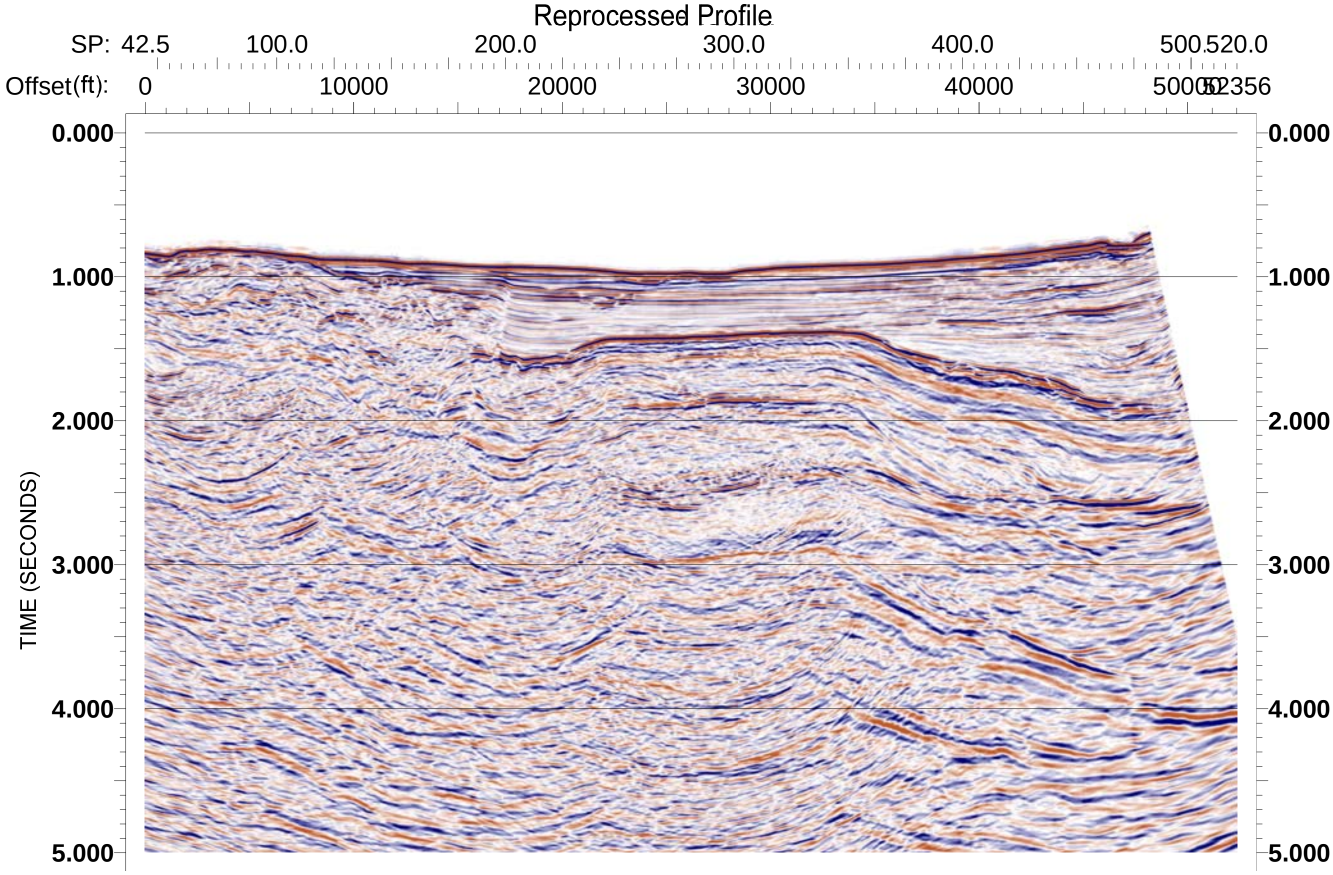

| | | |
|---|---|---|
| PHASE 1<br>REPROCESSED SEISMIC REFLECTION LINES<br>1979 CHEVRON SURVEY | LINE 4506 | FIGURE<br>B-1.4 |

# LINE 4508

Original Processed Profile

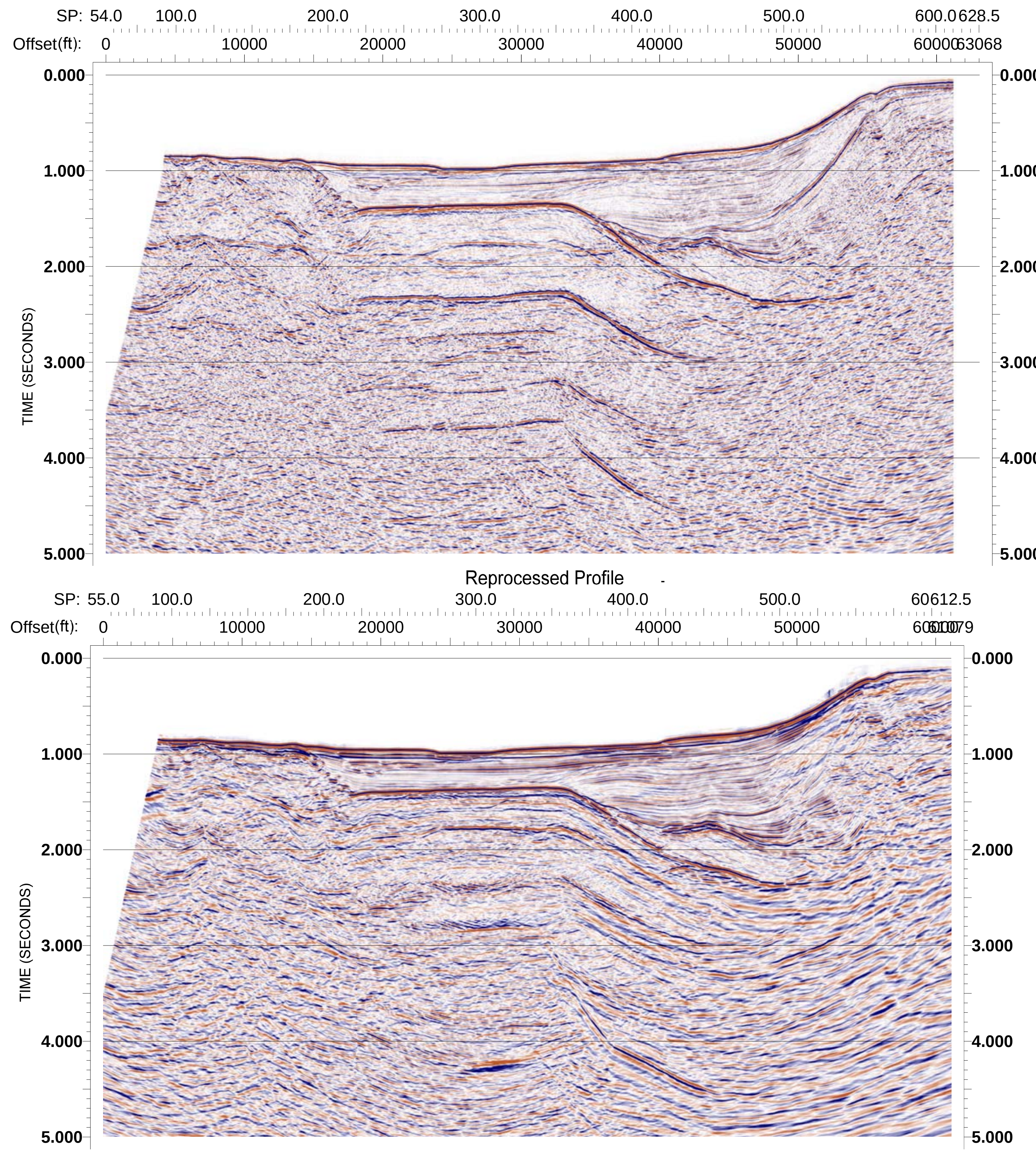



Reprocessed Profile




| | | |
|---|---|---|
| PHASE 1<br>REPROCESSED SEISMIC REFLECTION LINES<br>1979 CHEVRON SURVEY | LINE 4508 | FIGURE<br>B-1.5 |

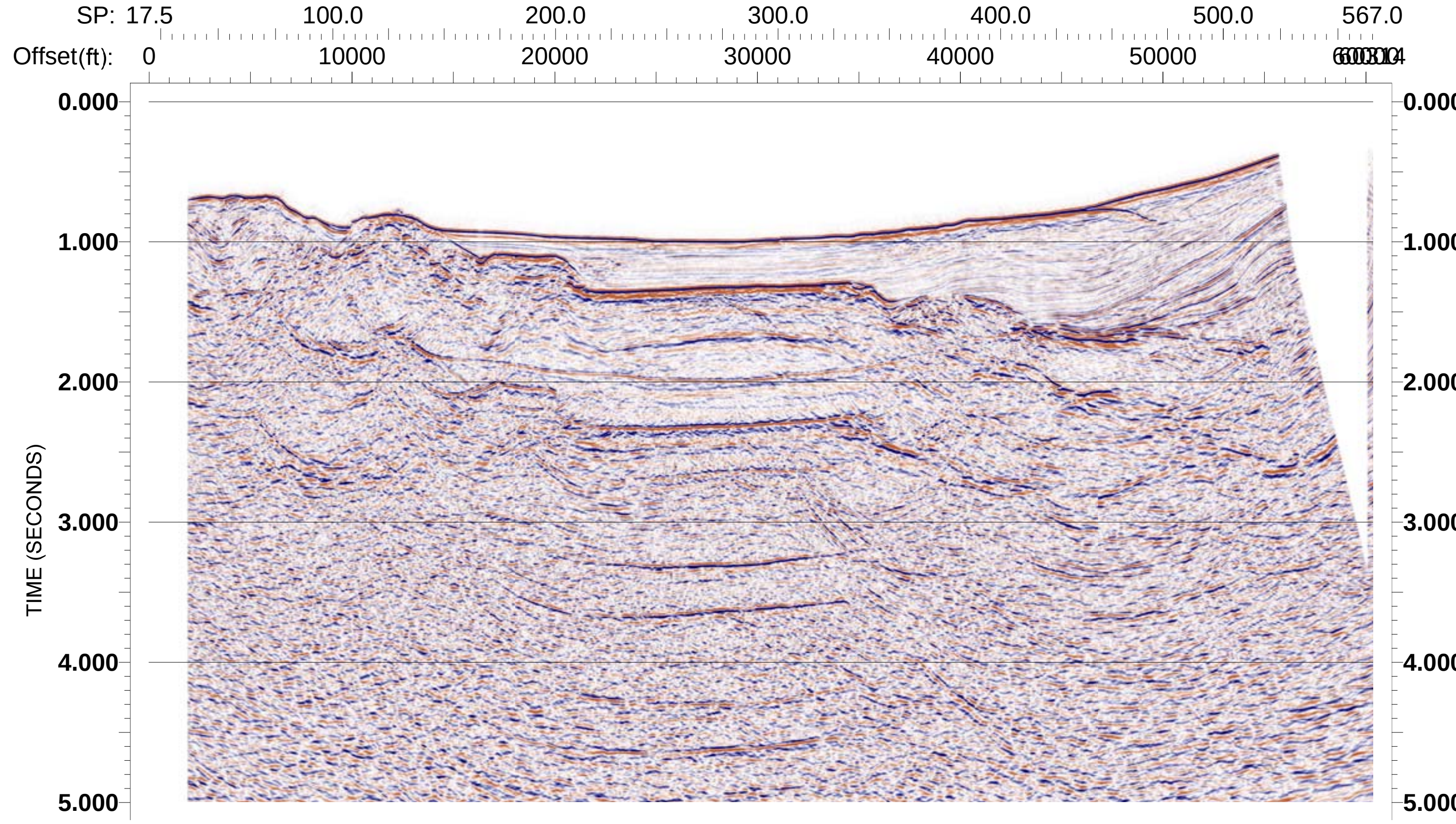
## LINE 4510



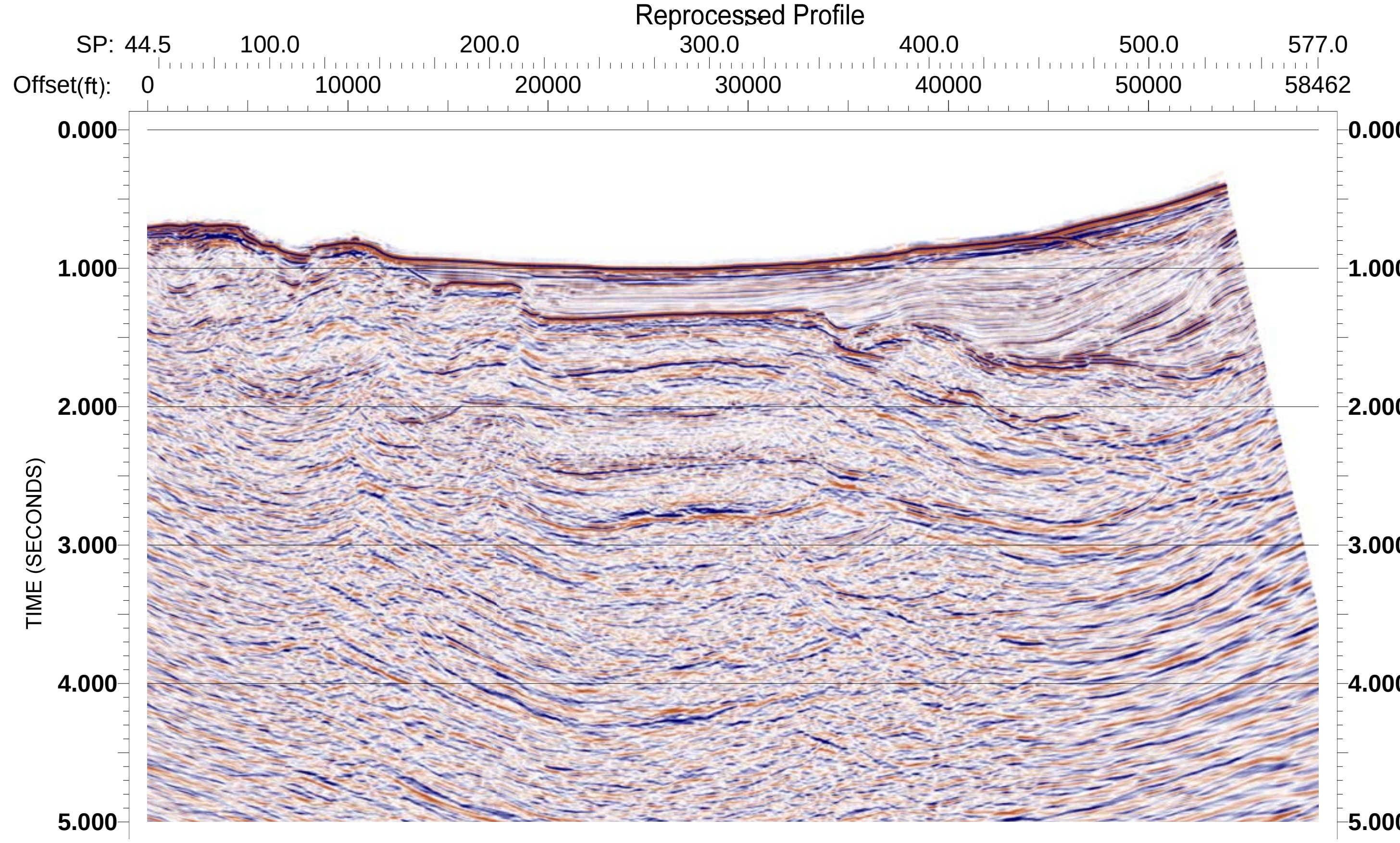

| PHASE 1<br>REPROCESSED SEISMIC REFLECTION LINES<br>1979 CHEVRON SURVEY | LINE 4510 | FIGURE<br>B-1.6 |
|---|---|---|

# LINE 4512

Original Processed Profile

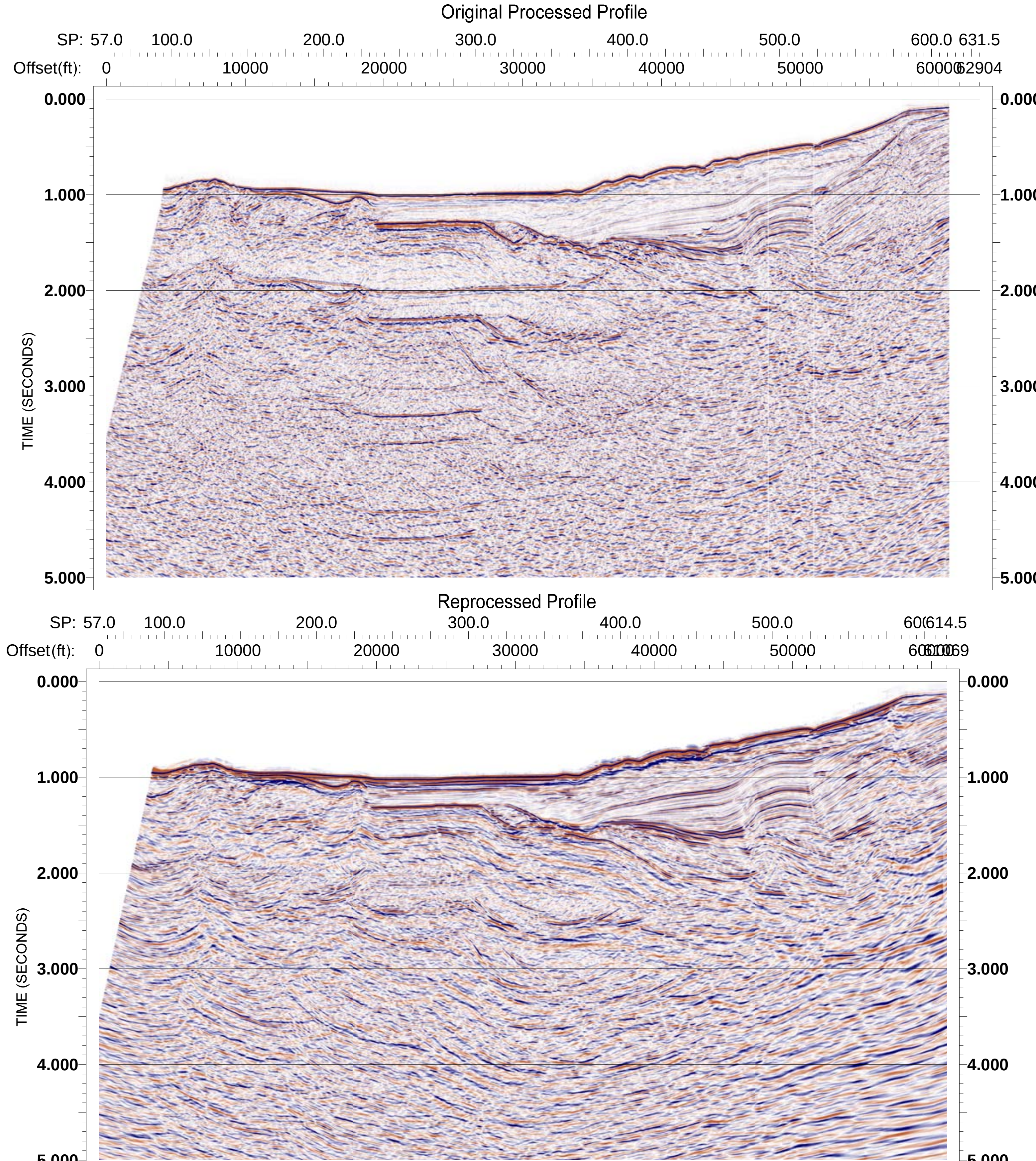



Reprocessed Profile




| | | |
|---|---|---|
| PHASE 1<br>REPROCESSED SEISMIC REFLECTION LINES<br>1979 CHEVRON SURVEY | LINE 4512 | FIGURE<br>B-1.7 |

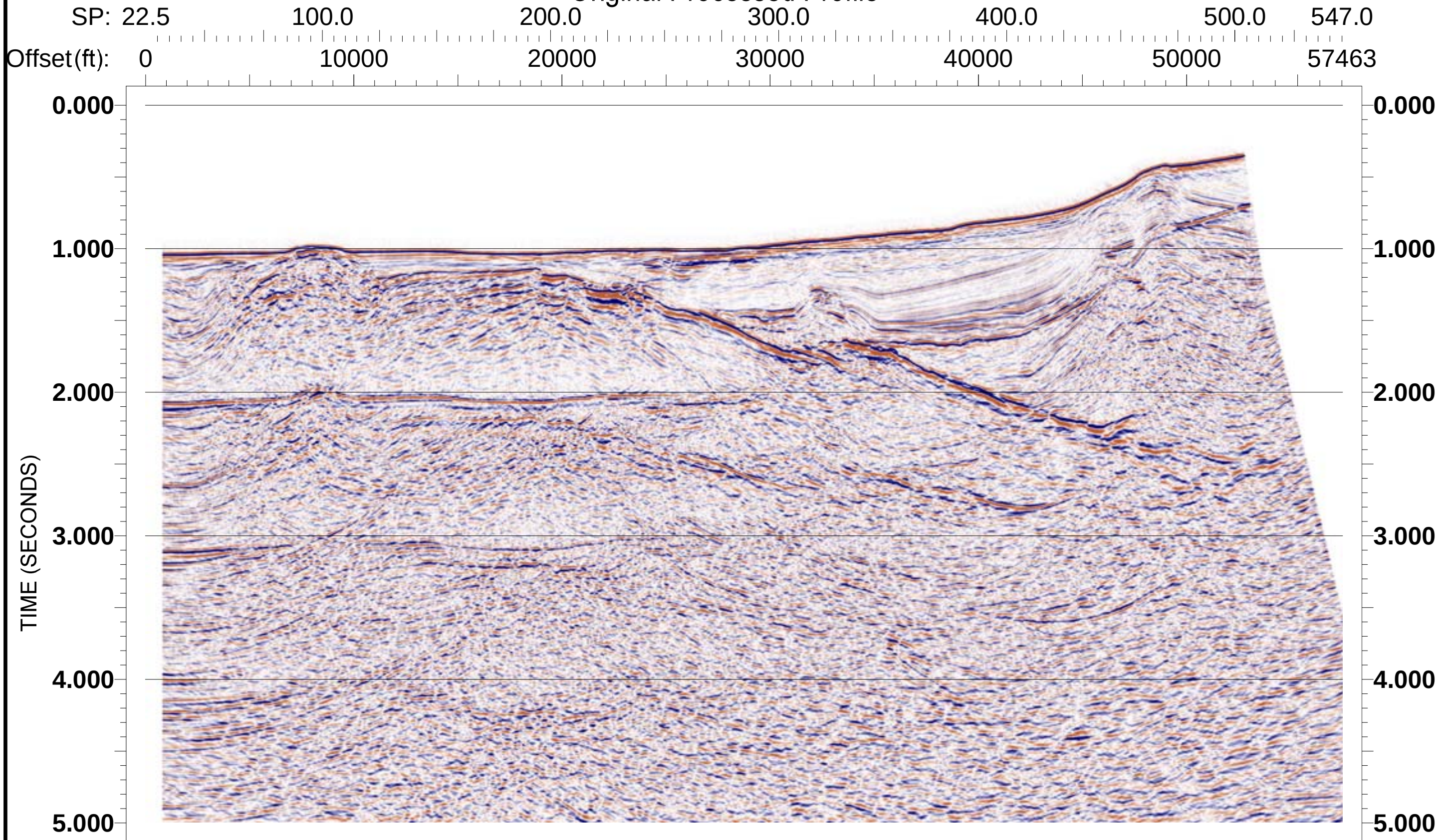
# LINE 4514



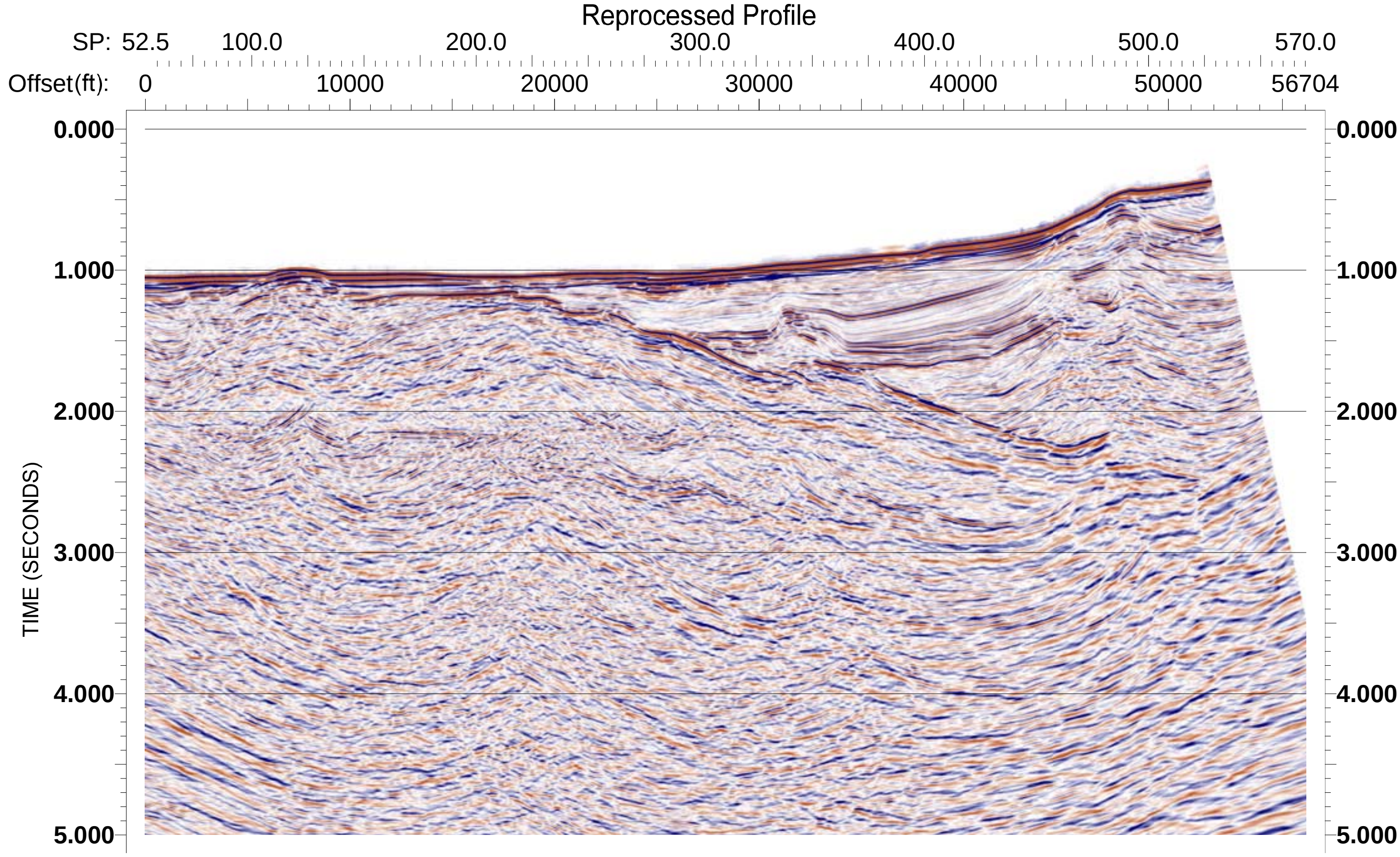

| PHASE 1<br>REPROCESSED SEISMIC REFLECTION LINES<br>1979 CHEVRON SURVEY | LINE 4514 | FIGURE<br>B-1.8 |
|---|---|---|

# LINE 4516

Original Processed Profile



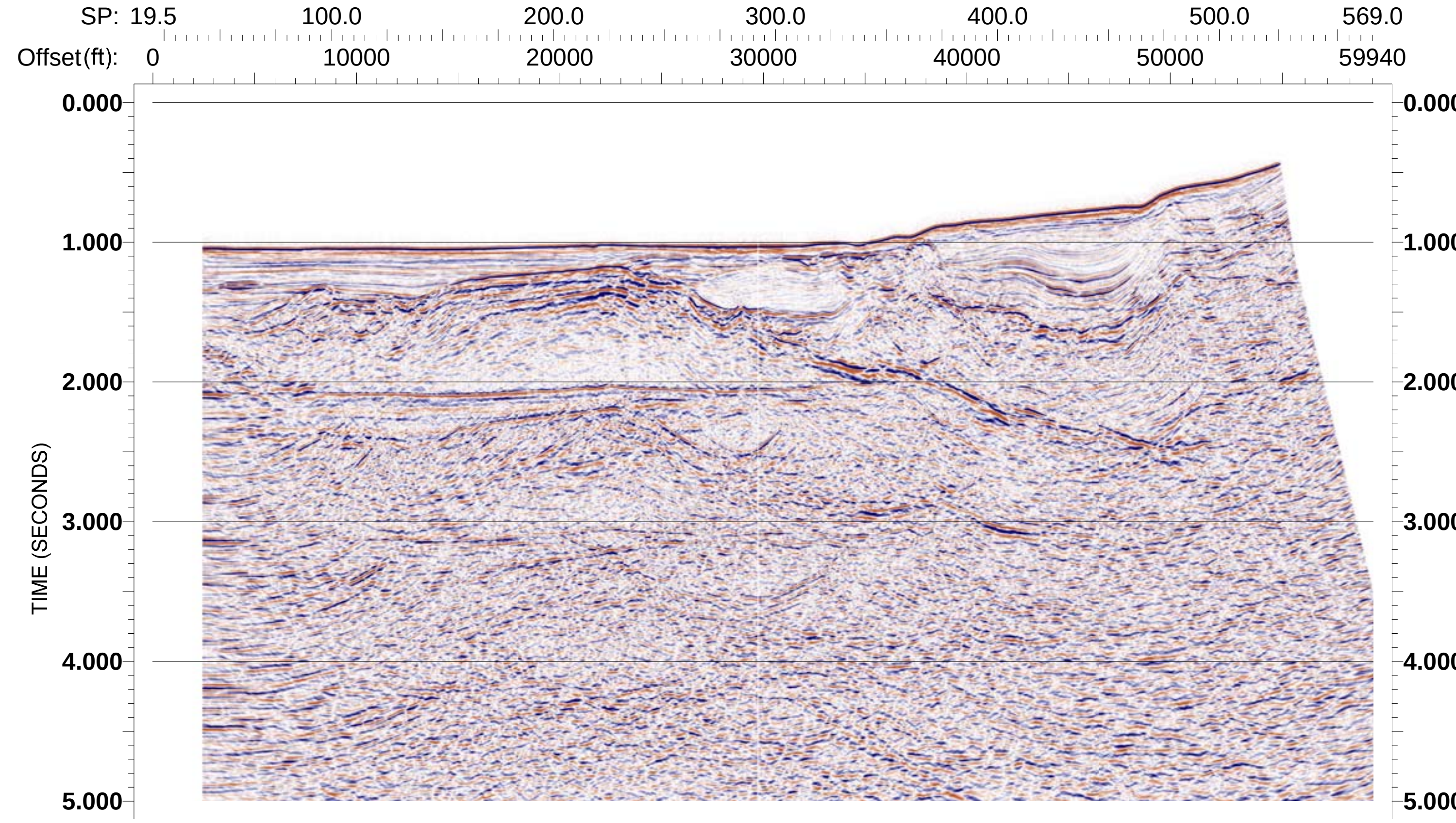

Reprocessed Profile



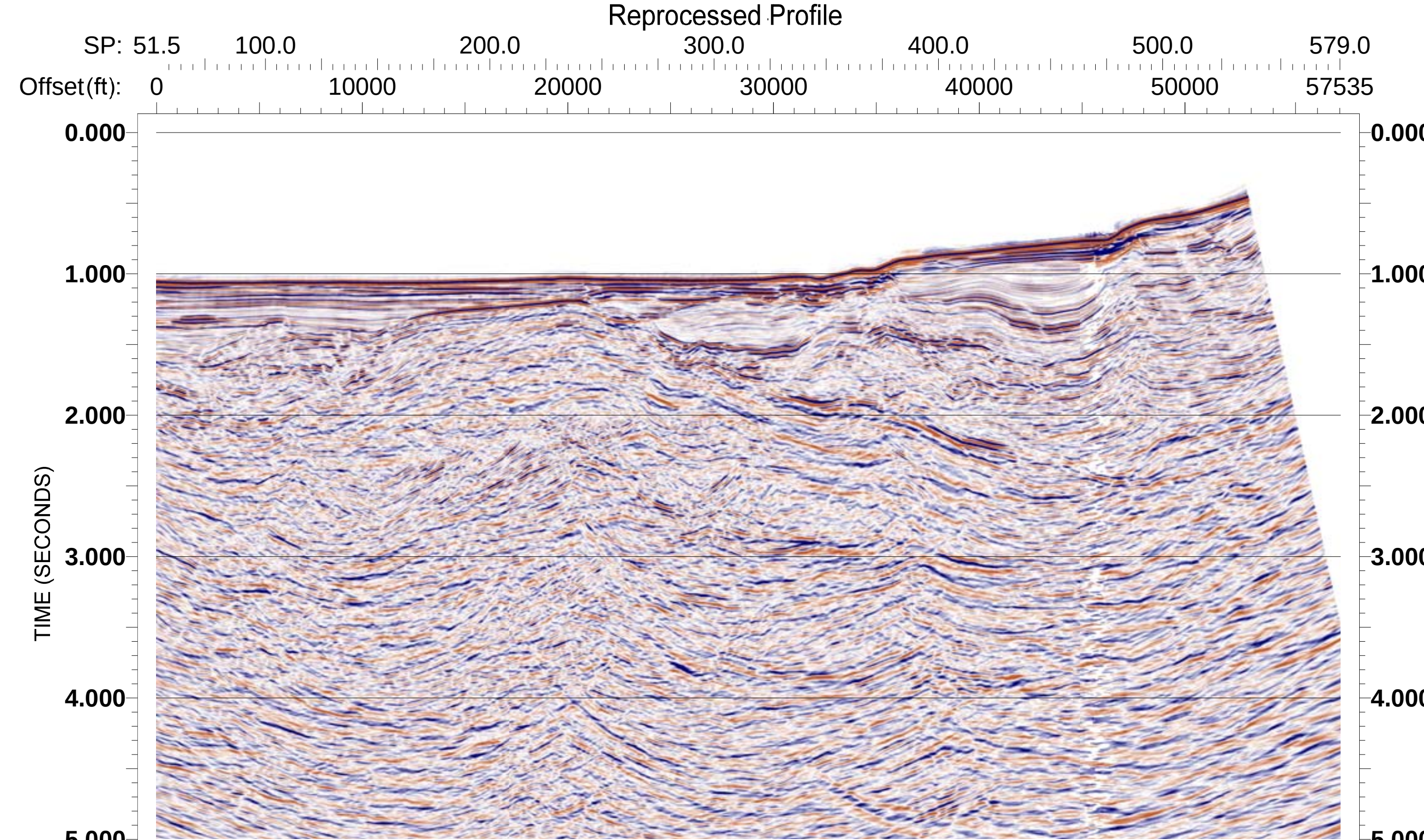

| PHASE 1<br>REPROCESSED SEISMIC REFLECTION LINES<br>1979 CHEVRON SURVEY | LINE 4516 | FIGURE<br>B-1.9 |
|---|---|---|

# LINE 4518

Original Processed Profile



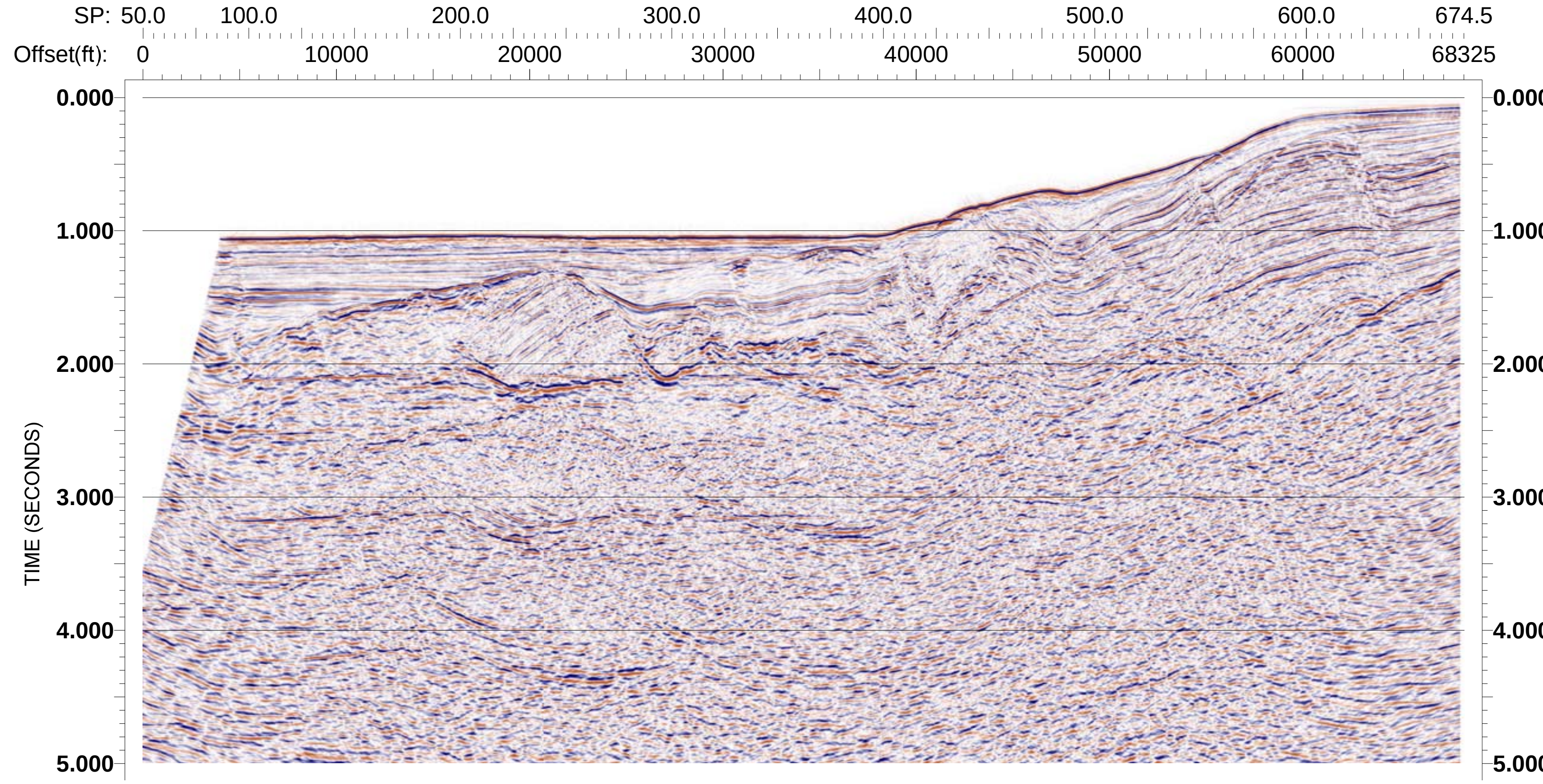

Reprocessed Profile



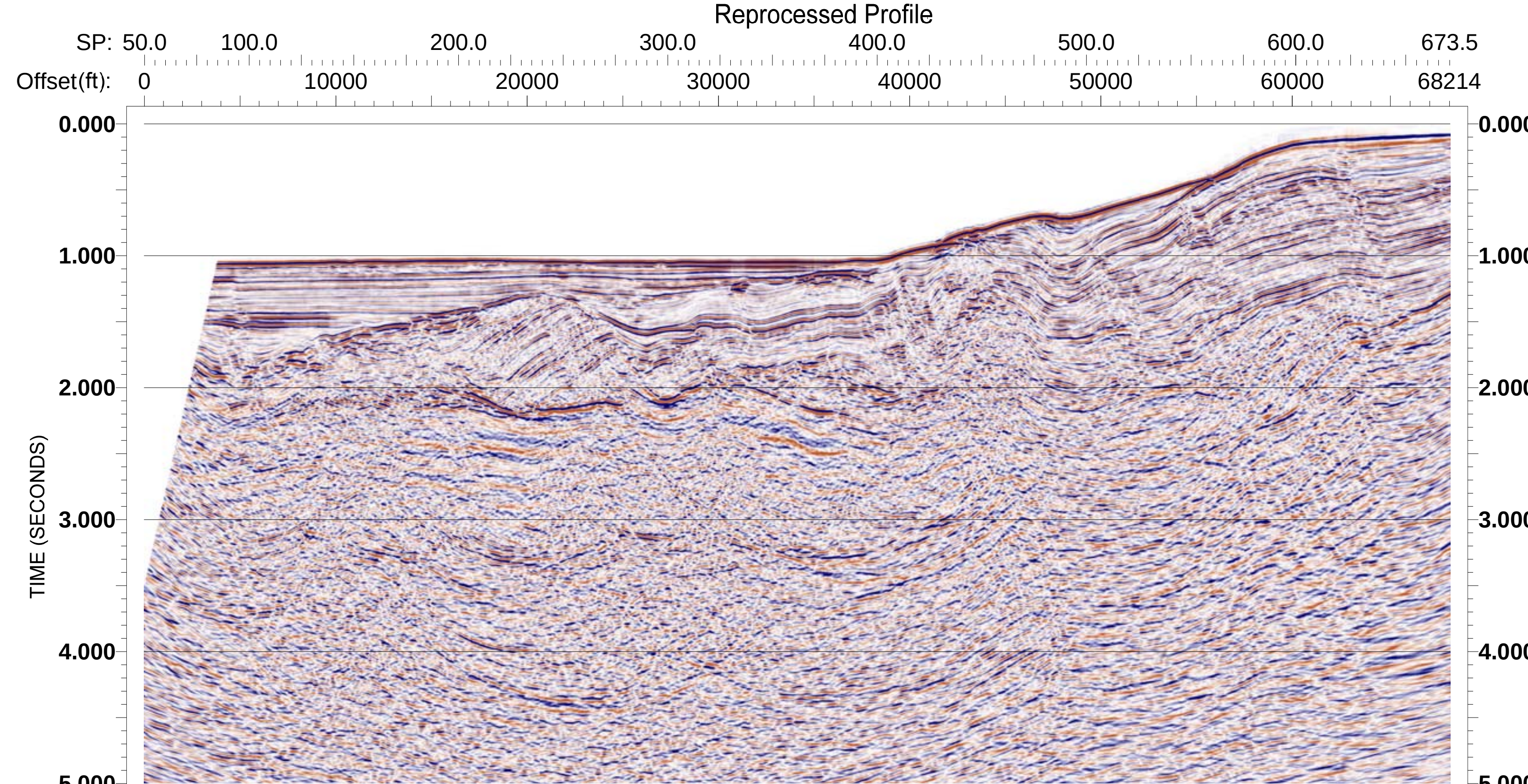

| | | |
|---|---|---|
| PHASE 1<br>REPROCESSED SEISMIC REFLECTION LINES<br>1979 CHEVRON SURVEY | LINE 4518 | FIGURE<br>B-1.10 |

# LINE 4520

Original Processed Profile

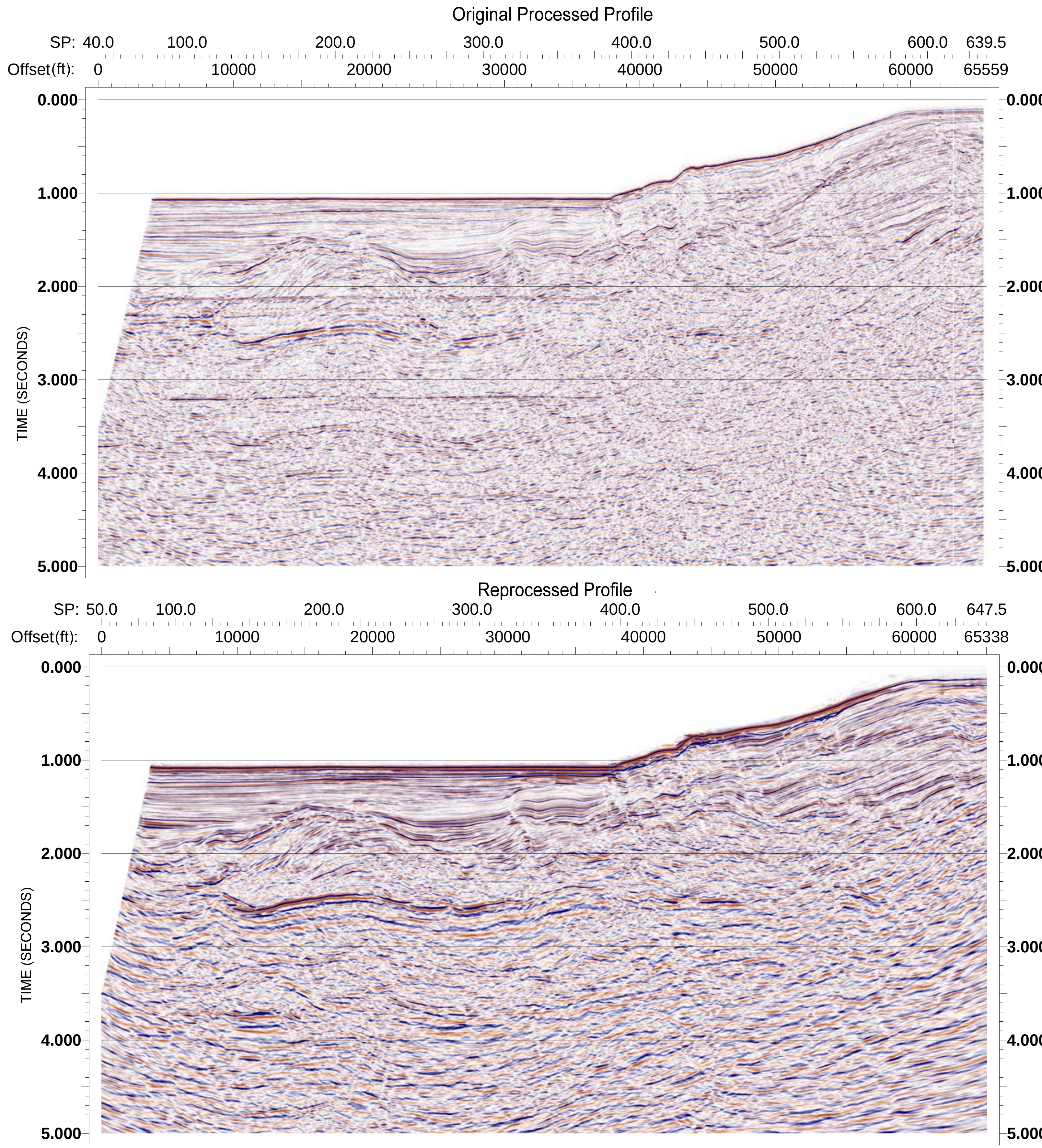



Reprocessed Profile



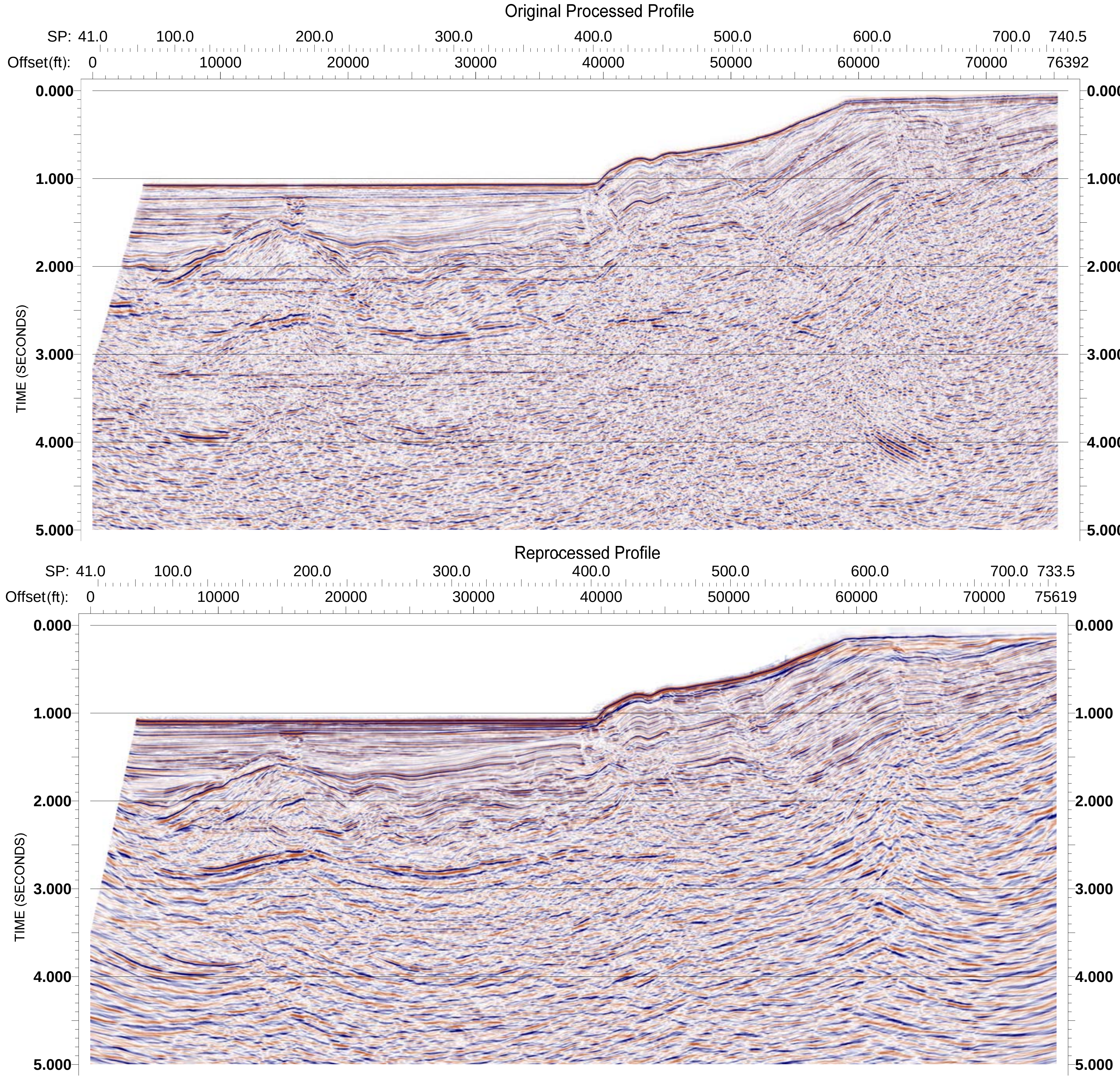

| PHASE 1<br>REPROCESSED SEISMIC REFLECTION LINES<br>1979 CHEVRON SURVEY | LINE 4520 | FIGURE<br>B-1.11 |
|---|---|---|

# LINE 4522




| | | |
|---|---|---|
| PHASE 1<br>REPROCESSED SEISMIC REFLECTION LINES<br>1979 CHEVRON SURVEY | LINE 4522 | FIGURE<br>B-1.12 |

# LINE 4524

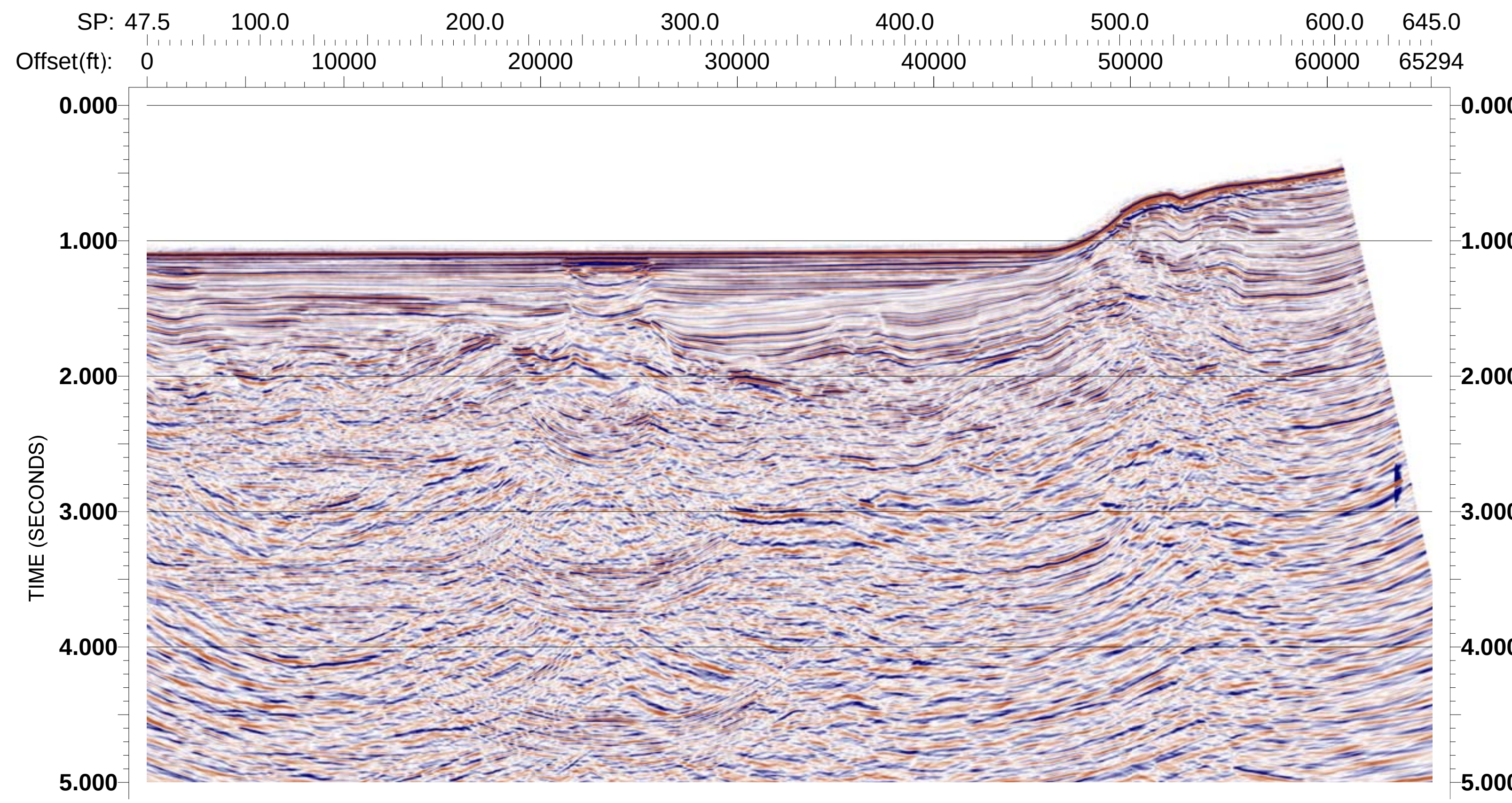



| PHASE 1<br>REPROCESSED SEISMIC REFLECTION LINES<br>1979 CHEVRON SURVEY | LINE 4524 | FIGURE<br>B-1.13 |
|---|---|---|

# LINE 4526

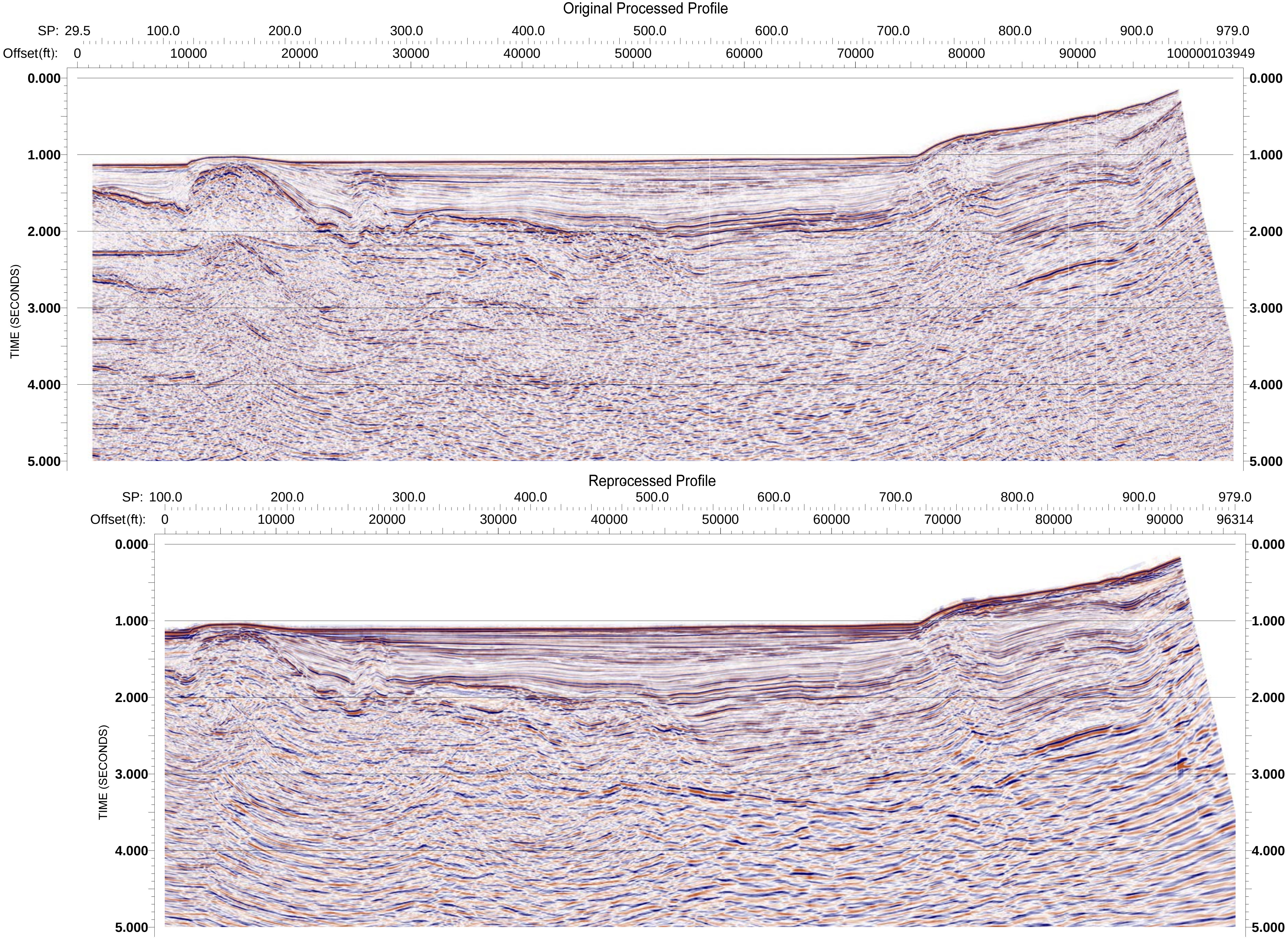
LINE 4526 Original Processed Profile Not Available

Reprocessed Profile




| PHASE 1<br>REPROCESSED SEISMIC REFLECTION LINES<br>1979 CHEVRON SURVEY | LINE 4526 | FIGURE<br>B-1.14 |
|---|---|---|

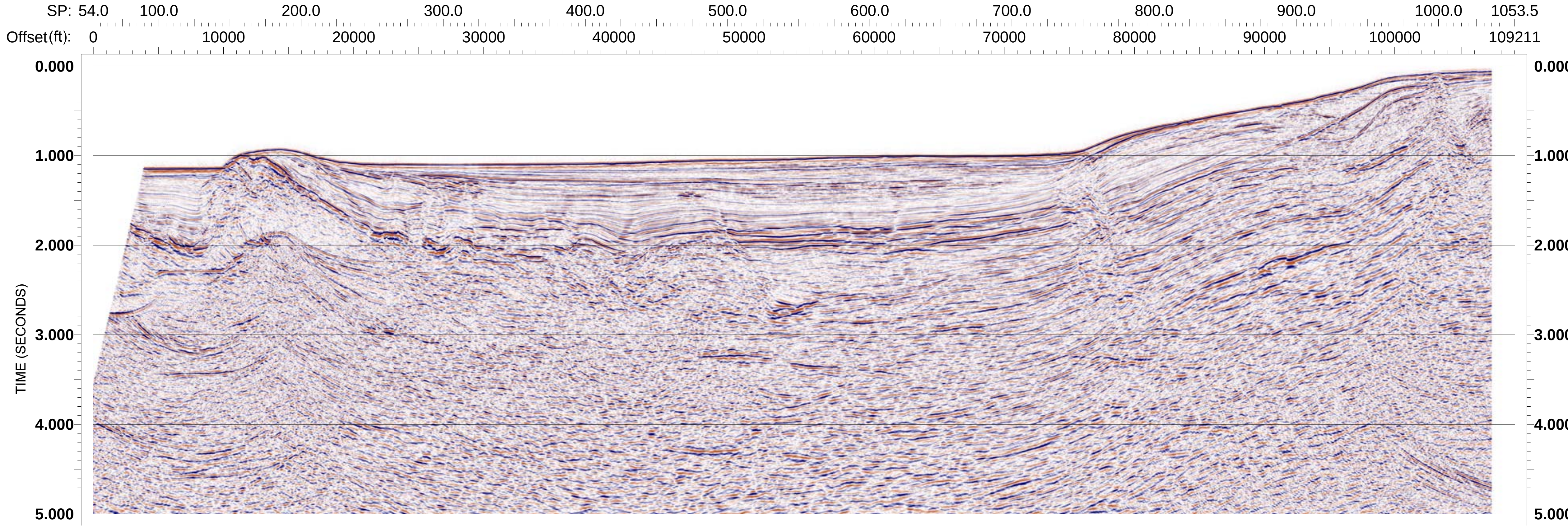
# LINE 4530



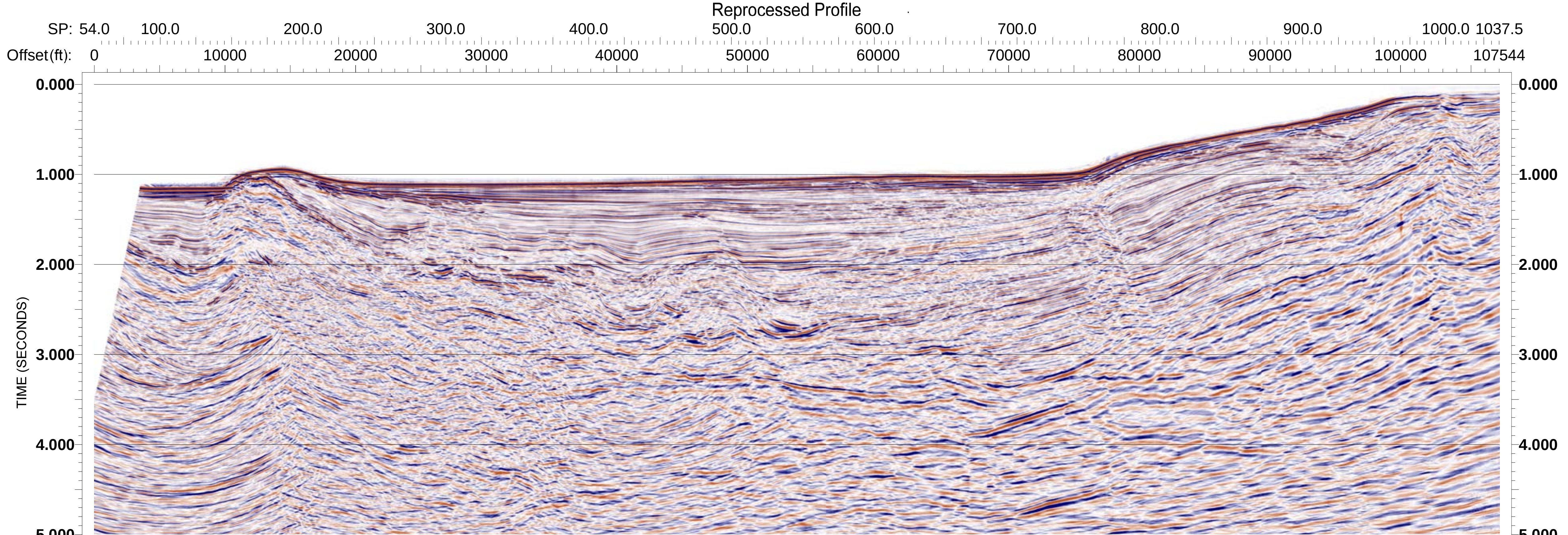

| PHASE 1<br>REPROCESSED SEISMIC REFLECTION LINES<br>1979 CHEVRON SURVEY | LINE 4530 | FIGURE<br>B-1.15 |
|---|---|---|

## LINE 4532

Original Processed Profile

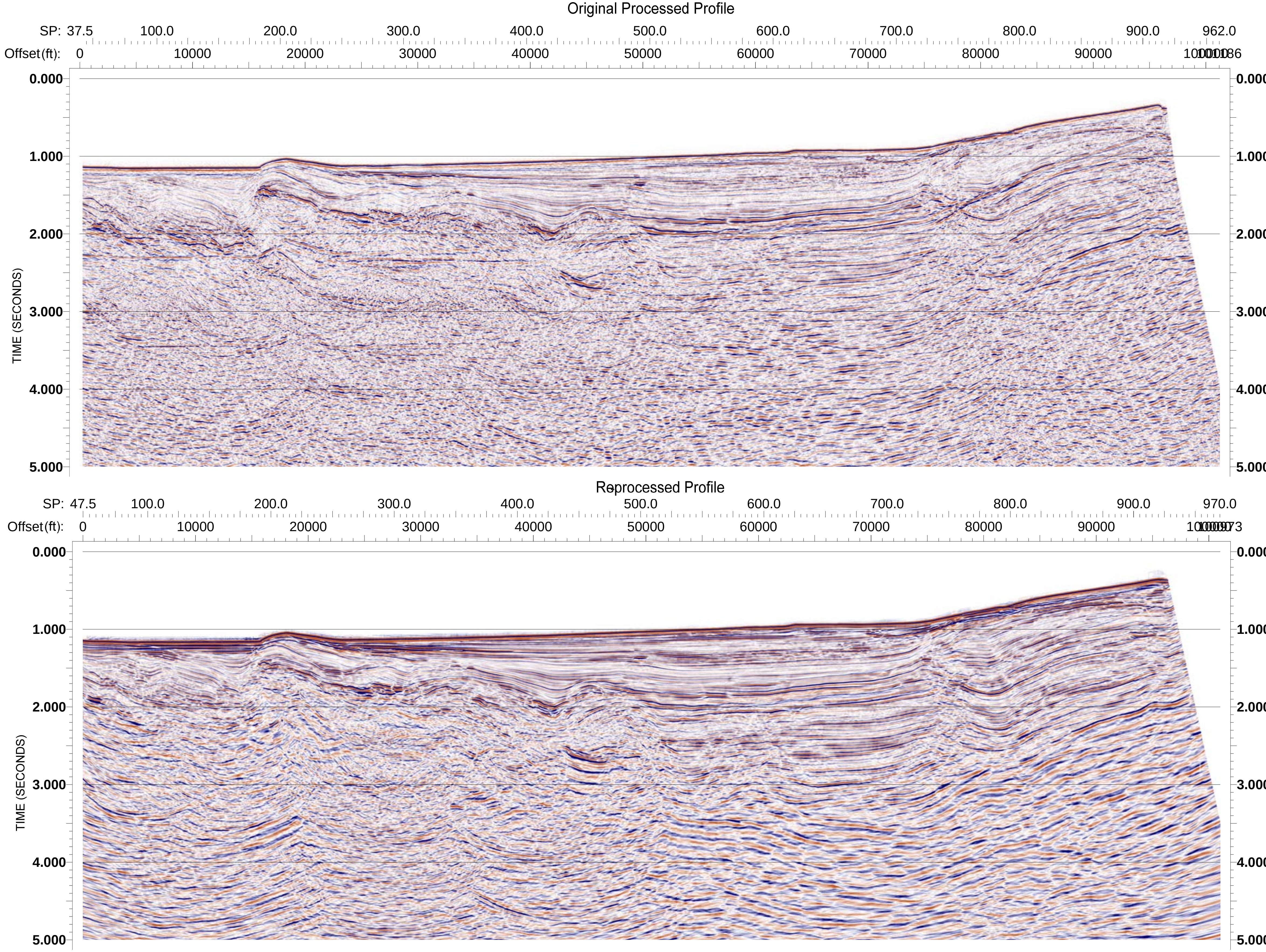



Reprocessed Profile




| PHASE 1<br>REPROCESSED SEISMIC REFLECTION LINES<br>1979 CHEVRON SURVEY | LINE 4532 | FIGURE<br>B-1.16 |
|---|---|---|

# LINE 4534

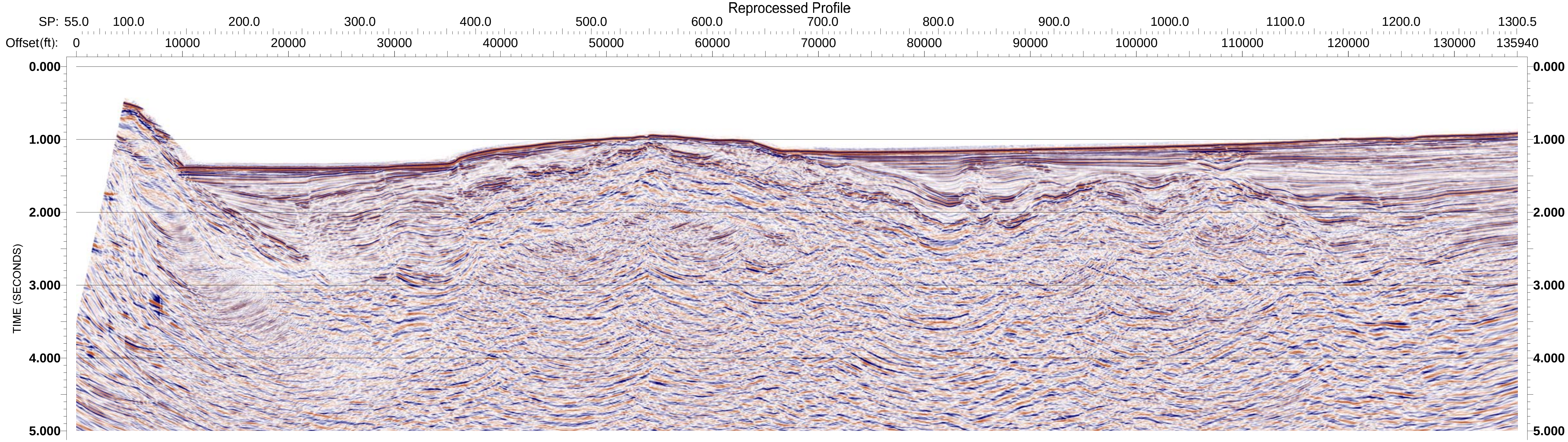



| PHASE 1<br>REPROCESSED SEISMIC REFLECTION LINES<br>1979 CHEVRON SURVEY | LINE 4534 | FIGURE<br>B-1.17 |
|---|---|---|

# LINE 4536

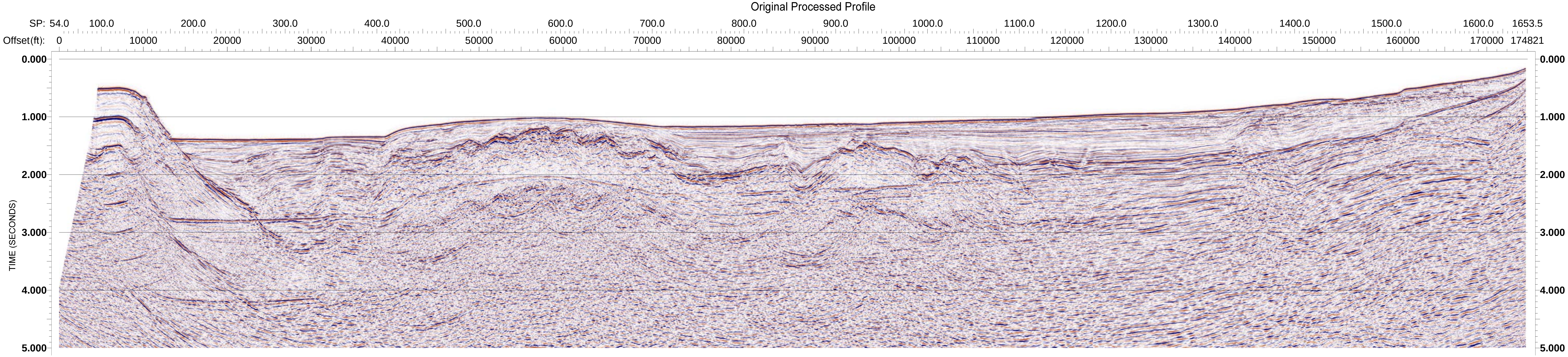
LINE 4536 Original Processed Profile Not Available

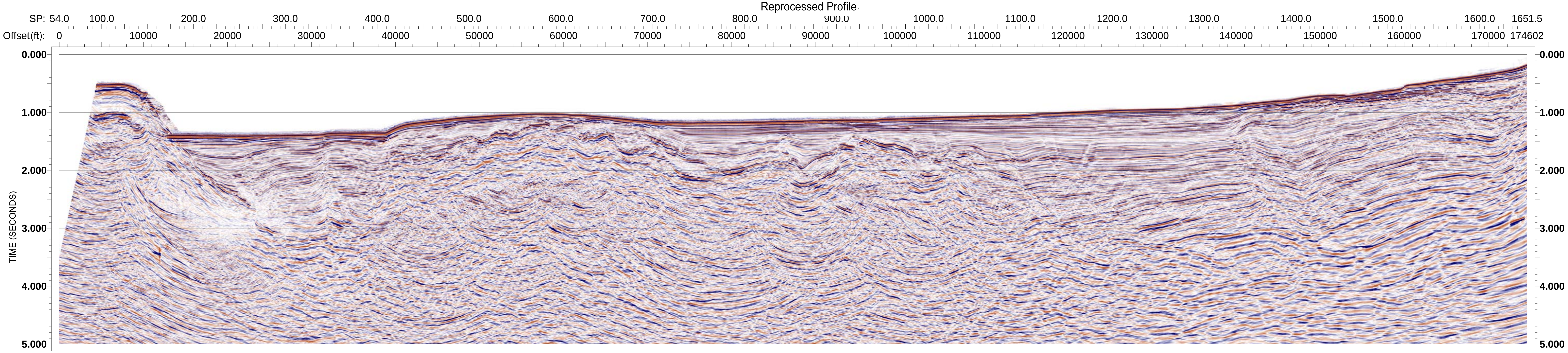
Reprocessed Profile




| PHASE 1<br>REPROCESSED SEISMIC REFLECTION LINES<br>1979 CHEVRON SURVEY | LINE 4536 | FIGURE<br>B-1.18 |
|---|---|---|

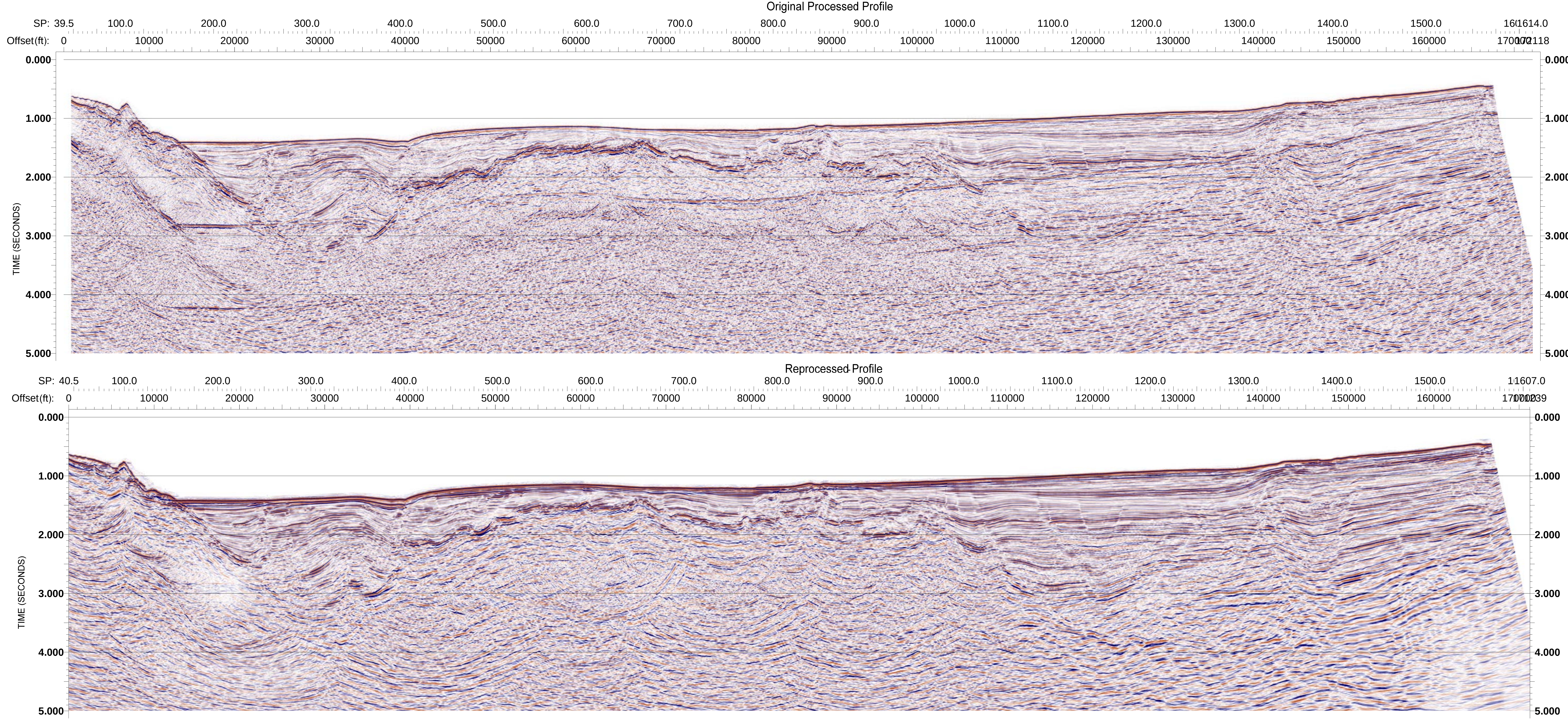
# LINE 4538




| PHASE 1<br>REPROCESSED SEISMIC REFLECTION LINES<br>1979 CHEVRON SURVEY | LINE 4538 | FIGURE<br>B-1.19 |
|---|---|---|

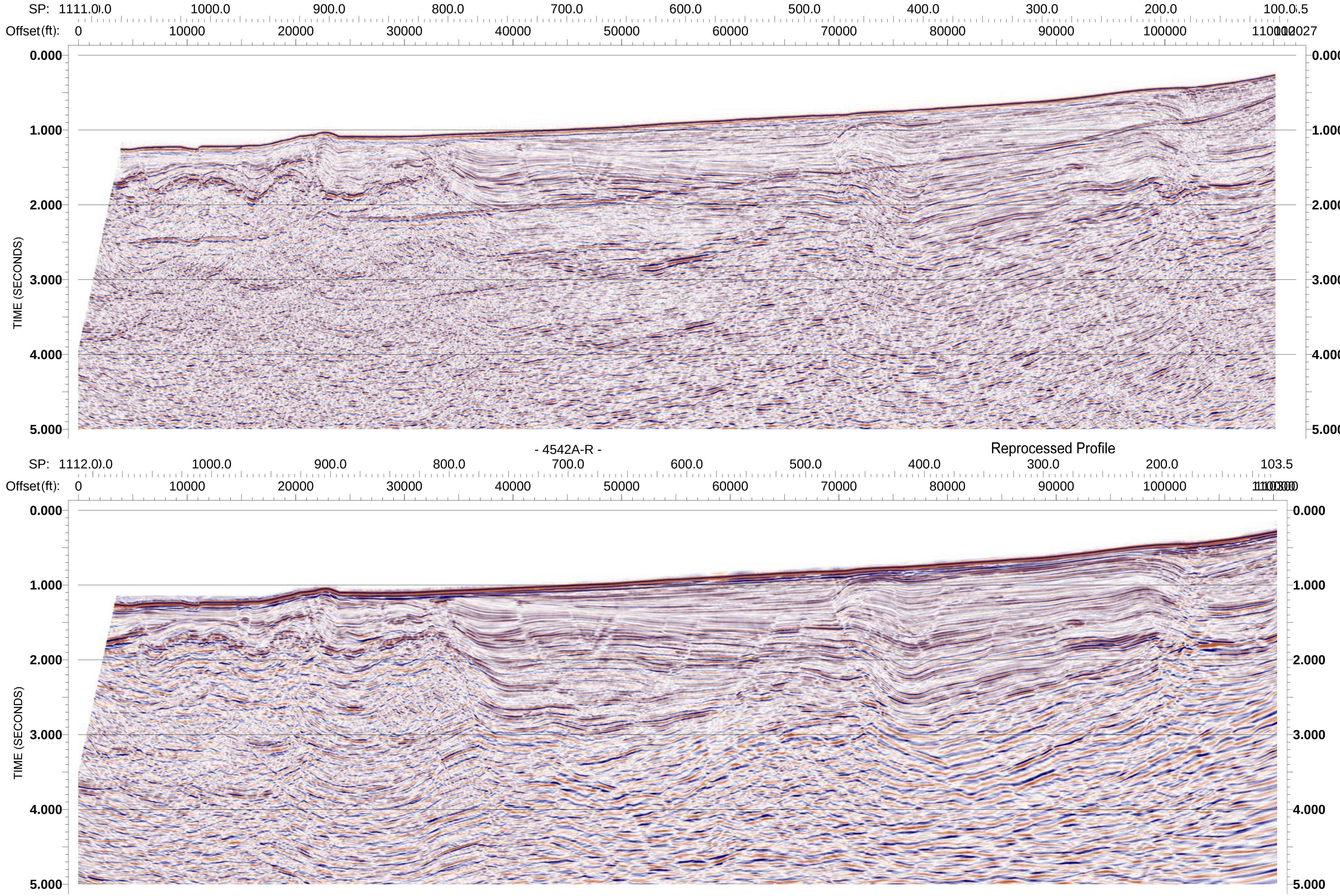
# LINE 4540




| PHASE 1<br>REPROCESSED SEISMIC REFLECTION LINES<br>1979 CHEVRON SURVEY | LINE 4540 | FIGURE<br>B-1.20 |
|---|---|---|

# LINE 4542A

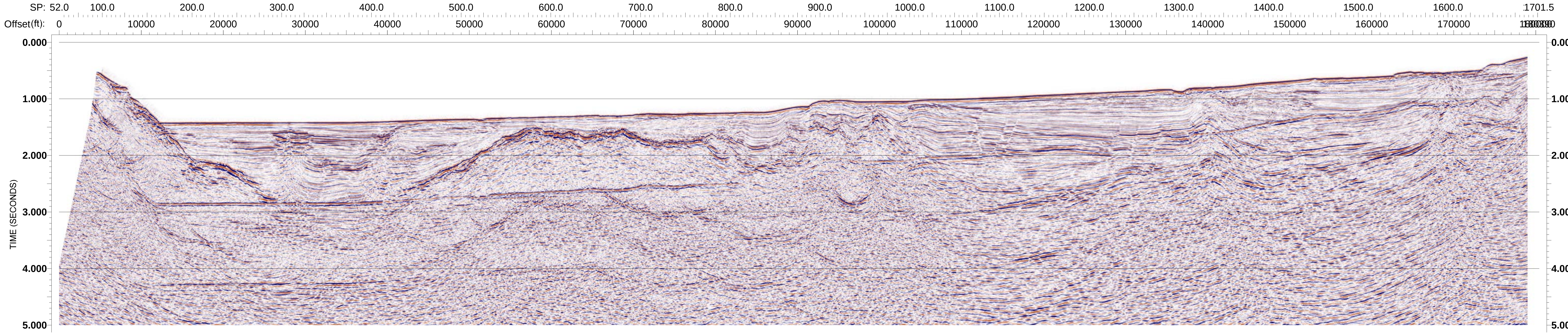
Original Processed Profile



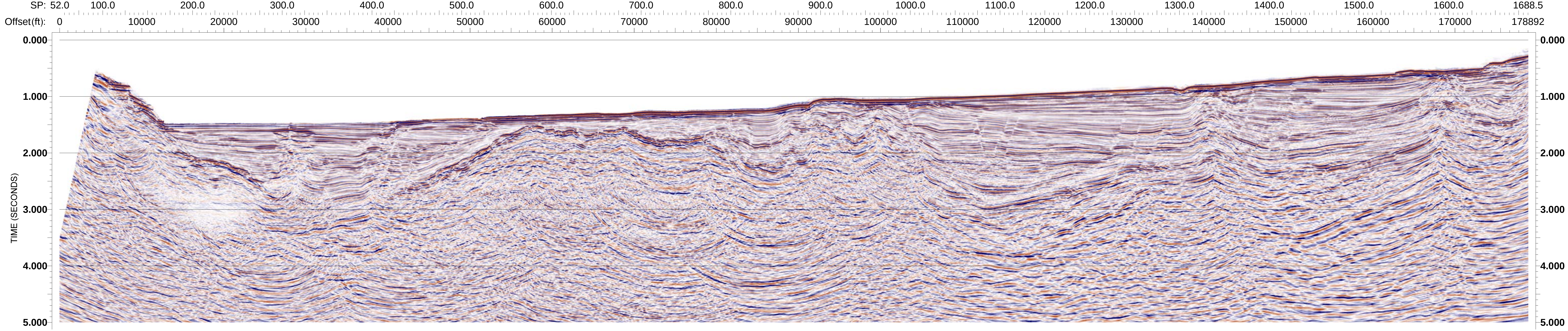

| PHASE 1<br>REPROCESSED SEISMIC REFLECTION LINES<br>1979 CHEVRON SURVEY | LINE 4542A | FIGURE<br>B-1.21 |
|---|---|---|

# LINE 4544

Original Processed Profile



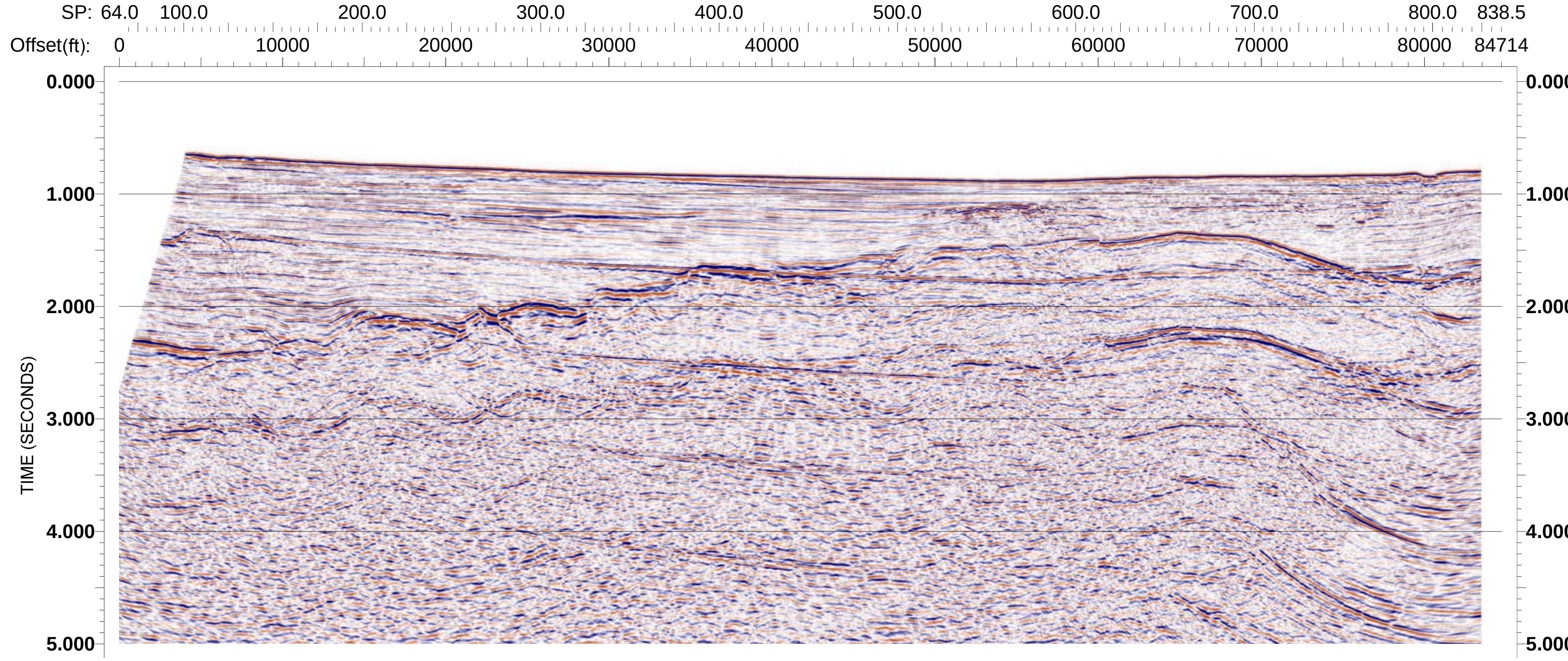

Reprocessed Profile



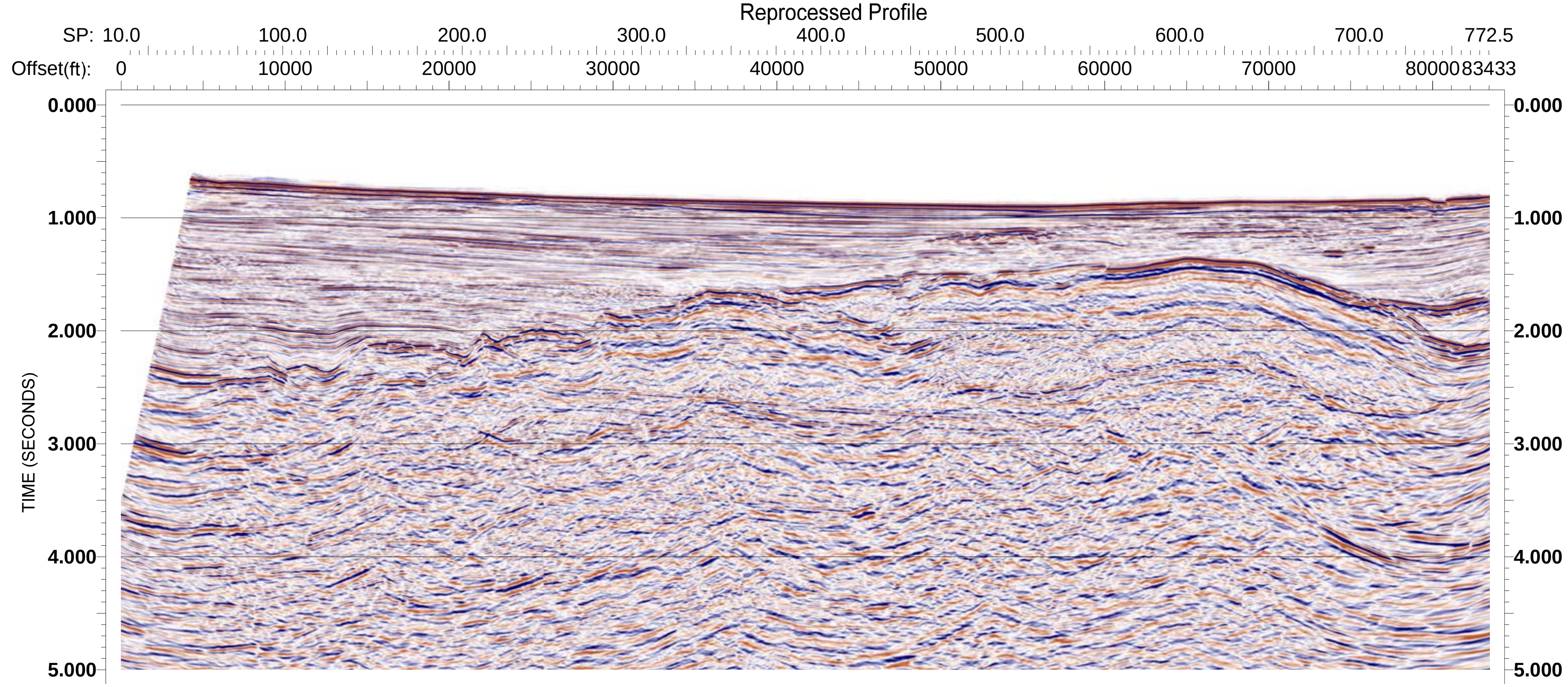

| PHASE 1<br>REPROCESSED SEISMIC REFLECTION LINES<br>1979 CHEVRON SURVEY | LINE 4544 | FIGURE<br>B-1.22 |
|---|---|---|

# LINE 4501

Original Processed Profile

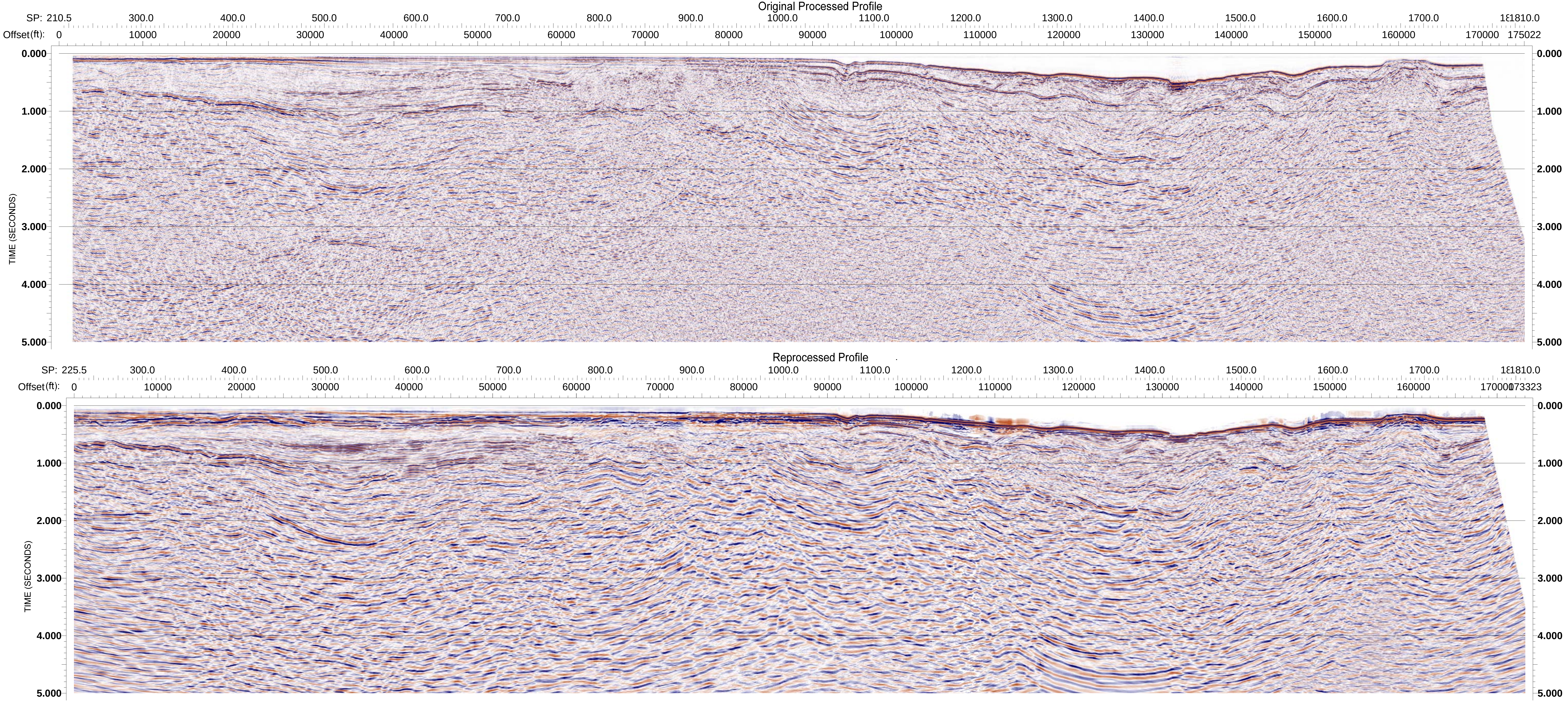



Reprocessed Profile




| | | |
|---|---|---|
| PHASE 1<br>REPROCESSED SEISMIC REFLECTION LINES<br>1979 CHEVRON SURVEY | LINE 4501 | FIGURE<br>B-1.23 |

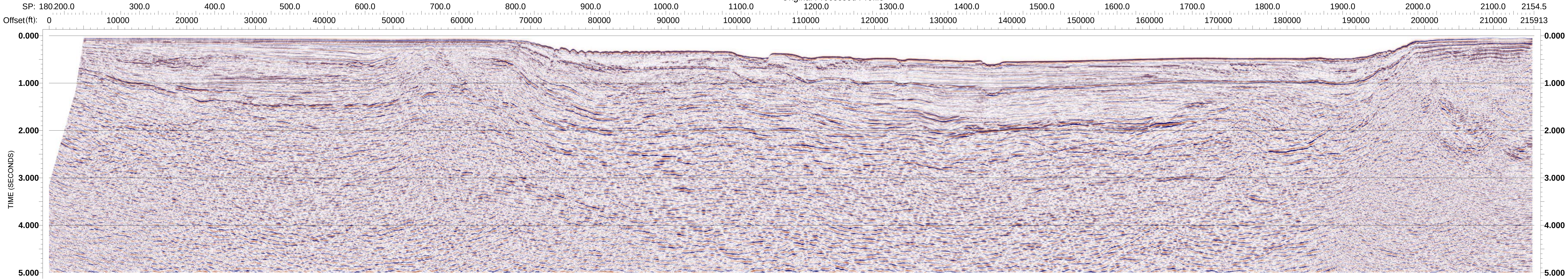
# LINE 4505



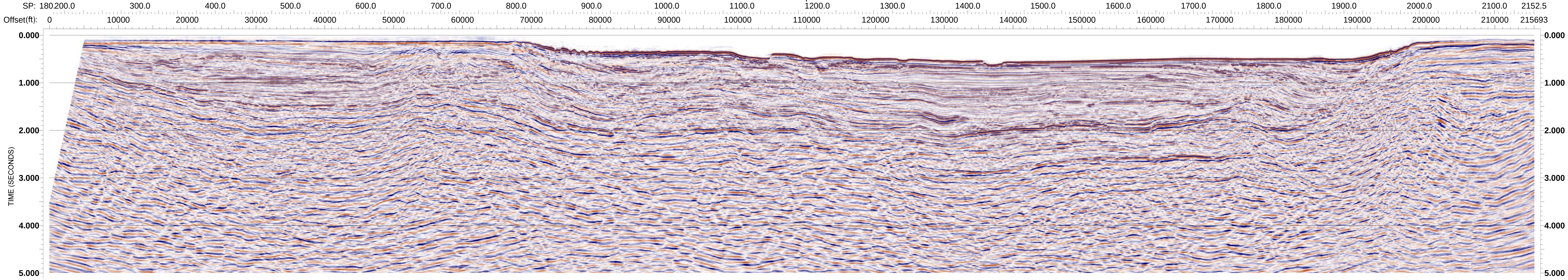

| PHASE 1<br>REPROCESSED SEISMIC REFLECTION LINES<br>1979 CHEVRON SURVEY | LINE 4505 | FIGURE<br>B-1.24 |
|---|---|---|

## LINE 4507

Original Processed Profile




Reprocessed Profile




| PHASE 1<br>REPROCESSED SEISMIC REFLECTION LINES<br>1979 CHEVRON SURVEY | LINE 4507 | FIGURE<br>B-1.25 |
|---|---|---|

## LINE 4509

Original Processed Profile


Reprocessed Profile


| PHASE 1<br>REPROCESSED SEISMIC REFLECTION LINES<br>1979 CHEVRON SURVEY | LINE 4509 | FIGURE<br>B-1.26 |
|---|---|---|


| PHASE 1<br>REPROCESSED SEISMIC REFLECTION LINES<br>1979 CHEVRON SURVEY | LINE 4511 | FIGURE<br>B-1.27 |
|---|---|---|


| PHASE 1<br>REPROCESSED SEISMIC REFLECTION LINES<br>1979 CHEVRON SURVEY | LINE 4513 | FIGURE<br>B-1.28 |
|---|---|---|


PHASE 1
REPROCESSED SEISMIC REFLECTION LINES
1979 CHEVRON SURVEY

LINE 4515

FIGURE
B-1.29

# APPENDIX B-2

# DVD OF

# DIGITAL REPROCESSED DATA (SEGY FORMAT) AND

# NAVIGATION DATA (ASCII FORMAT)

# APPENDIX B-3

# DVD OF

# IHS KINGDOM 8.8 MODEL