# Comparison of three field parameters from a 3C-2D test line, Conroe, Texas

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## ABSTRACT

In August of 2003, a 2D seismic test survey was conducted by Veritas for Exxon Mobil along a busy state highway in Conroe, Texas. Two vibrator source lines (line 501, 2 vibrators, 16 sweeps per VP; line 502, 4 vibrators, 4 sweeps per VP) were recorded by two full length receiver lines (line 101; standard 6-geophone array; line 201; Sercel DSUs), and a shorter receiver line (line 102; standard 6-geophone array, podded). In addition, a number of noise spreads were acquired, as well as a variety of tests involving explosive sources and/or different receiver deployments, for example, receiver burial at depths up to ~9 m (30 ft).

In this paper, we present comparisons of stacked sections obtained from shots correlated and vertically stacked in the field to those obtained from shots correlated using a diversity power stack at CREWES. The effects of different source arrays recorded by the same receiver array, and the effects of different receiver arrays for a common source array are also considered.

In general, data quality of the stacks with large amounts of traffic noise can be significantly improved by diversity power stacking repeated shots, especially in the deeper section. Unfiltered 6-geophone arrays provide better images than pods of 6 geophones. High CDP fold results in better images after diversity stacking than low fold.


## INTRODUCTION

### Geology

The Conroe field is located in Conroe, Texas roughly 96 km (60 miles) north of Houston, Texas. The structure can be characterized as a complexly faulted 4-way closure that is likely salt cored. Historically, the primary reservoirs are within the Cocksfield Formation, which is Eocene in age, and at about 1500 m (5000 ft) average depth (Whitson et al., 1975). Deeper reservoirs have been penetrated within the thick (~2134 m; 7000 ft) Wilcox formation which is Paleocene in age. The sands have been described as fluvial - shallow marine in origin for both the Cocksfield and Wilcox Formations. The Conroe field is primarily a gas field, with some downdip oil production from the Cocksfield Formation.

### Acquisition

The Conroe test line consisted of a number of source and receiver lines laid out along ~10 km (6.25 miles) of highway. The primary objective of this 2D line was to de-risk the parameters for a potential 3D survey in a congested gas field/urban environment. The noise source of particular concern in this area is vehicular traffic.

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Some acquisition parameters are listed in Table 1. A number of noise spreads were acquired (lines 103, 104, 105, 106 and 202), as well as receiver tests (lines 107, 203 and 204) and explosive source tests (lines 503, 504 and 505). In this paper, we consider the results from two vibrator source lines (lines 501 and 502) recorded by three receiver lines (lines 101, 102 and 201). Considering just these source and receiver lines, there are a total of 10 seismic lines to be processed (including V, H1 and H2 from multicomponent line 201).

Line 501 was acquired using 2 vibrators and 16 sweeps per vibe point (VP) at an ~33.5 m (110 ft) interval. The shorter line 502 was acquired with 4 vibrators and 4 sweeps per VP at the same shot interval as line 501 (blue dotted lines; Figure 1). Receiver lines 101 (red dotted line; Figure 1) and 201 (green dotted line; Figure 1) extend the full length of the survey. Line 101 consisted of standard 6-geophone strings at a group interval of ~33.5m (110 ft). Line 201 used individual Sercel DSUs (3 component digital geophones) at a station interval of ~16.75 m (55 ft). Line 102 (short red dotted line; Figure 1), used 24 standard geophone strings with six geophones per string (podded) at a group interval of ~67 m (220 ft).

Every sweep in the field was phase rotated 90 degrees from one shot to the next. Each shot was stored on tape as an uncorrelated record. As well, all sweeps for each VP were vertically stacked and correlated in the recorder.

Table 1. Acquisition parameters

| | |
|---|---|
| Source line 501 | 2 x 48000 lb Hemi44; 16 sweeps per VP; ~33.5 m (110 ft) VP interval |
| Source line 502 | 4 x 48000 lb Hemi44; 4 sweeps per VP; ~33.5 m (110 ft) VP interval |
| Exxon Mobil proprietary sweep | 36 Hz stored Sweep |
| Sweep phase rotation | 0, 90, 180, 270 degrees |
| Receiver line 101 | 6-geophones per station; ~33.5 m (110 ft) group interval. |
| Receiver line 102 | 24 geophone strings/station, 6 phones/string, podded; ~67 m (220 ft) station interval |
| Receiver line 201 | 1 Sercel DSU per station; ~16.8 m (55 ft) group interval |
| Offsets | Up to ~10 km (33000 ft) |

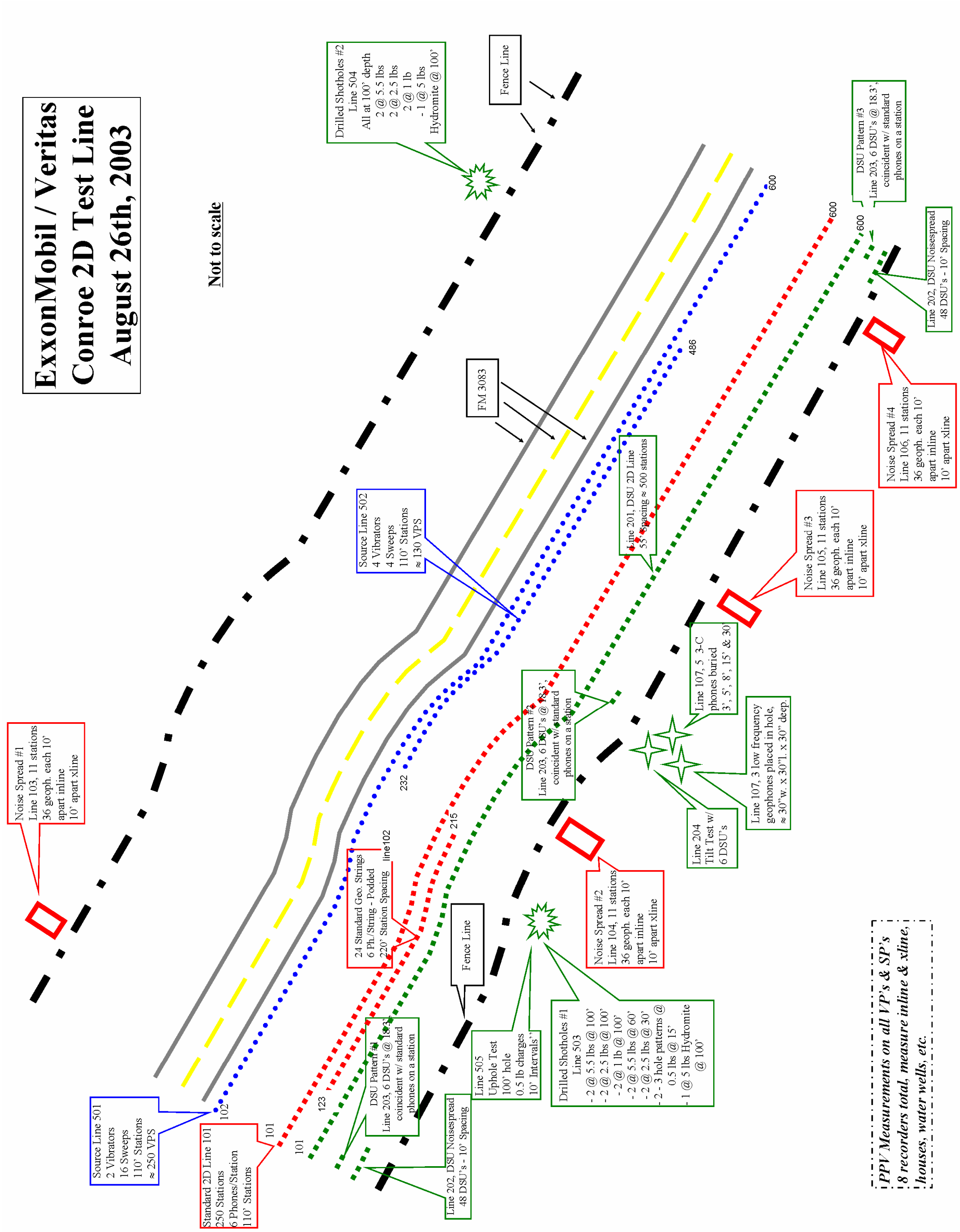



FIG. 1. Conroe 2D test line layout (modified from figure provided by Exxon Mobil).

## INITIAL P-P RESULTS

After initial processing of these seismic data, images are obtained, and these images should represent exactly the same geologic structure. However, the results show that different source and receiver arrays produce different images. The following discussions reveal the reasons for the differences.

### Effect of vertical stacking methods

Figures 2 through 6 show comparisons of images obtained by treating uncorrelated shots records with two different vertical stacking methods. The top image is from shots that were vertically stacked (conventional mean stack) and correlated by the recording system in the field. The bottom image is from uncorrelated shots that were stored in the field, then phase rotated, vertically stacked (diversity power stack) and correlated at CREWES. A diversity power stack weights trace amplitudes based on the trace power in a sliding window, such that relatively more noisy traces contribute less to the output trace amplitudes than would be the case for a conventional mean stack. Diversity stacks are ideal for moving noise sources such as vehicles, but work less well for stationary noise sources.

In all cases, the same processing flow and parameters were used to generate the unmigrated stacks shown, with the exception of refraction statics. The refraction statics solution for each combination of source and receiver lines is similar, but not identical to, other combinations of source and receiver lines, due to slightly differing geometries. So, the main difference between the images in each figure is the processing used to generate vertically stacked shots.

From the results for source line 501, it can be seen that the diversity power stack method has significantly improved the seismic image (black ovals; Figures 2-4). The improvement (if any) is less pronounced for source line 502 (Figures 5and 6). Note that the images obtained from source line 501 and receiver line 102 (Figure 4) image the structure poorly due to a lack of signal at far offsets. No image could be obtained for source line 502 and receiver line 102, because no near offsets were recorded.

While diversity stacking improved the images obtained from source line 501, it should be kept in mind that diversity stacking may distort the offset distribution of amplitudes, which could affect future AVO analysis. Since the main objective for any future 3D survey would be to make a structural image, diversity stacking could be a good choice to overcome a poor signal to noise ratio in the shot records.

### Effect of receiver arrays

Figures 7 through 10 show comparisons of the stacks obtained by recording different source arrays with the same receiver array. The top image is the unfiltered stack obtained from data recorded on the vertical component of single Sercel DSUs (digital seismic units) at each station. The bottom image is for a standard array of six vertical geophones per station.

From these images it can be seen that for the same source effort the geophone array suppresses ground roll much better than a single geophone. The result is improved signal to noise in the deeper section, and more coherent reflections can be seen regardless of the vertical stacking method used. This holds true for both source lines 501 and 502.

### Effect of source arrays

It is difficult to directly compare the effect of source arrays, because 1) CDP fold is significantly higher for line 501 (~210 fold) than for 502 (~72 fold), and 2) line 501 was acquired at night, and so has inherently less traffic noise than 502. Figures 11 and 12 show the results for source lines 501 and 502 recorded on the vertical component of receiver line 201. Figure 11 shows a much better result for line 502 in the middle of the stack, but worse at the edges (probably explainable by CDP fold, traffic volume and a single receiver per station). After diversity power stacking the raw shots, the differences between lines 501 and 502 are less noticeable, but overall, line 501 appears to be a better image based on reflection continuity (Figure 12). Interestingly, some reflections are visible at ~2.3 seconds in the middle of the four vibrator stack (line 502), which are not as prominent on the two vibrator stack (Figure 12).

Figures 13 and 14 show the same source line comparison, but as recorded by receiver line 101. These unfiltered stacks look better than Figures 11 and 12, likely due to the effects of receiver arrays as discussed in the previous section. Again, source line 501 produces a better image (based on continuity of reflections) than 502, but in this case the result holds true for both conventional and diversity power stacked shot gathers.

## INITIAL P-S RESULTS

As for the *P-P* case, the best quality shot records were obtained from diversity power stacking repeated shots. Visually, there appears to be little to no signal on the shot gathers, even after extensive filtering (Figure 15). The receiver stacks and brute CCP stacks are much more encouraging, particularly after radial filtering and Gabor deconvolution (Figures 16 and 17). It should be noted that the stacks shown in these figures have *P*-wave shot statics and scaled *P*-wave receiver statics (based on $V_P/V_S$). The stacks shown represent the first guess at *S*-wave receiver statics. The receiver stack is used to iteratively hand-pick horizons for use as corrections to the initial guess at *S*-wave receiver statics.

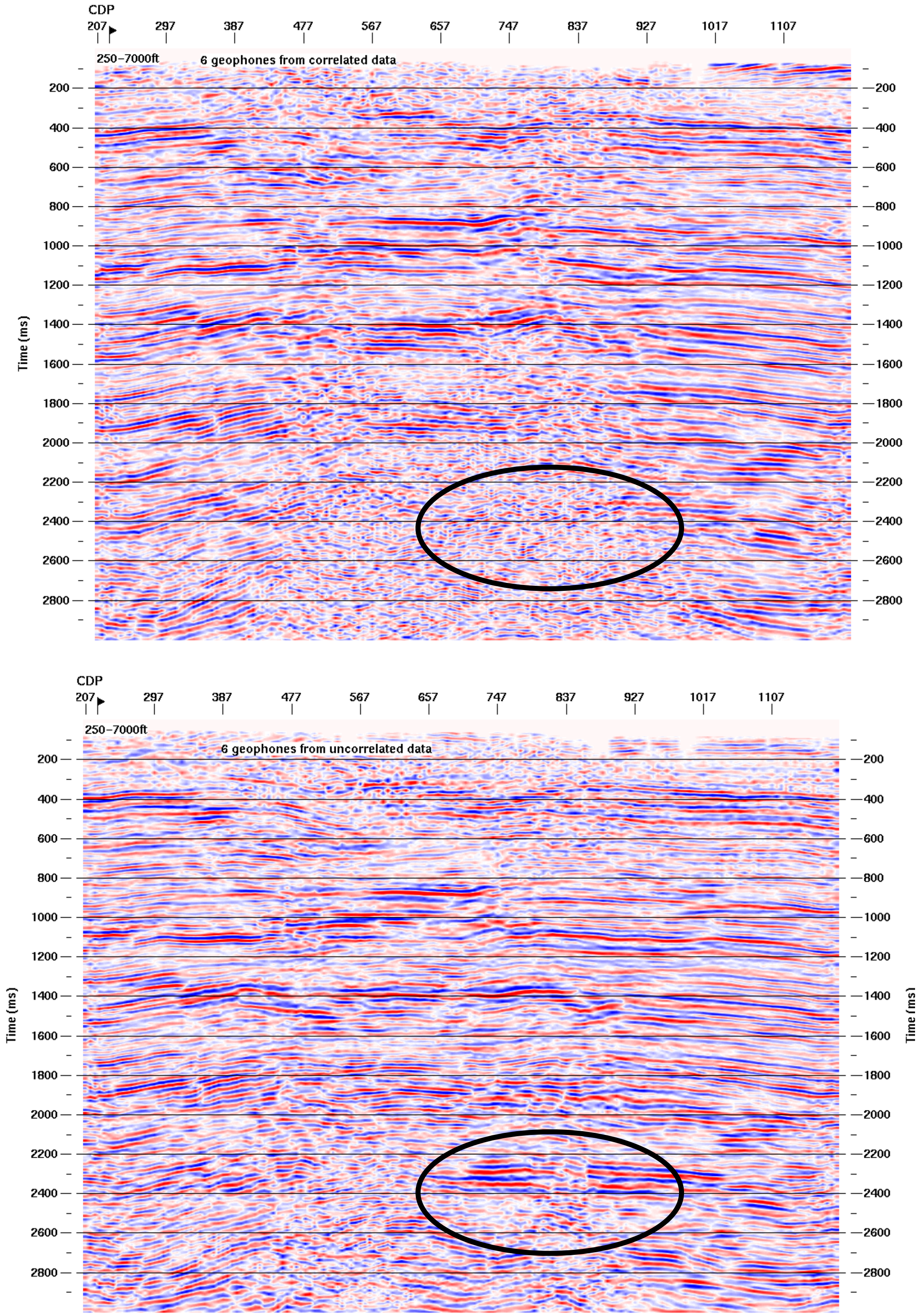



FIG. 2. Source line 501 (2 vibrators, 16 sweeps per VP) and receiver line 101 (geophone array, six per station), using shots vertically stacked and correlated in the field (conventional mean stack; top) and shots vertically stacked and correlated at CREWES (diversity power stack; bottom).

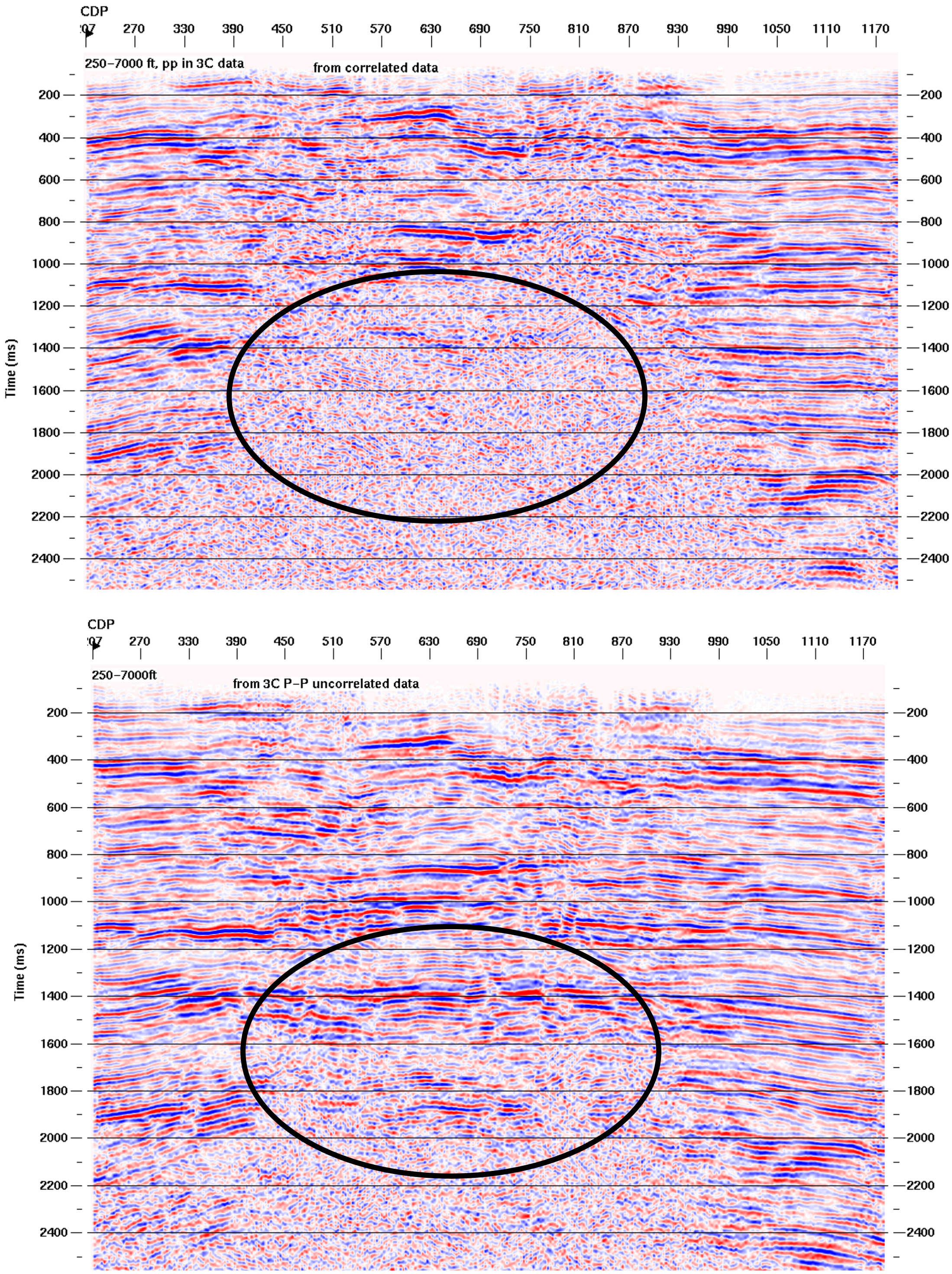
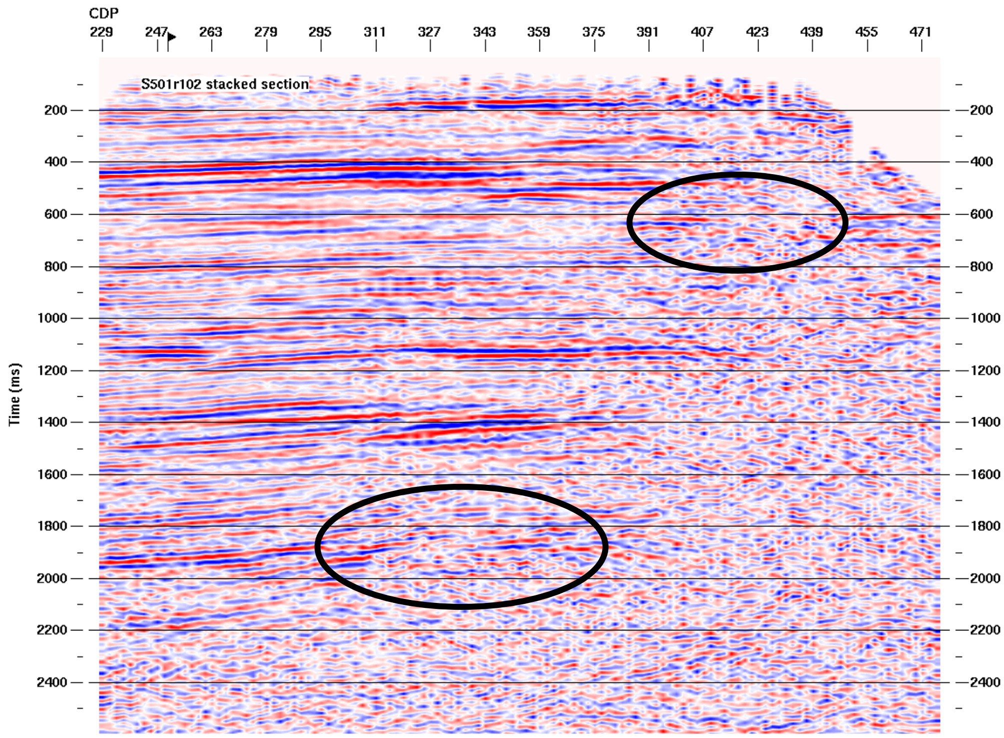



FIG. 3. Source line 501 (2 vibrators, 16 sweeps per VP) and vertical component of receiver line 201 (DSU, one per station), using shots vertically stacked and correlated in the field (conventional mean stack; top) and shots vertically stacked and correlated at CREWES (diversity power stack; bottom).



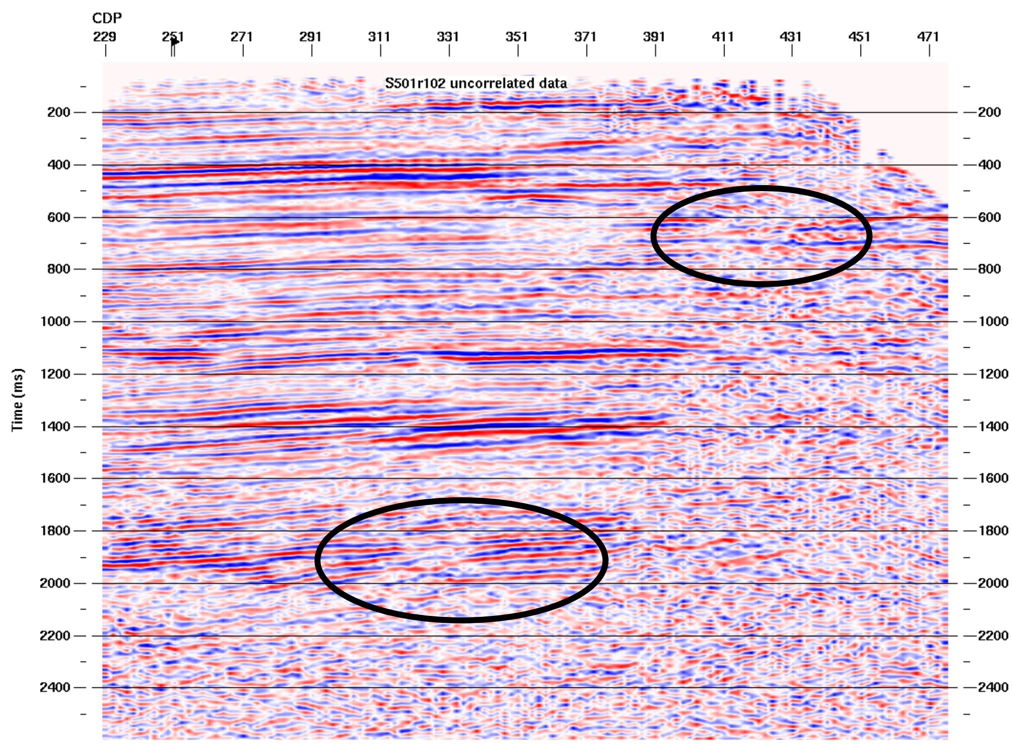




FIG. 4. Source line 501 (2 vibrators, 16 sweeps per VP) and receiver line 102 (geophone array, six per station, podded), using shots vertically stacked and correlated in the field (conventional mean stack; top), and shots vertically stacked and correlated at CREWES (diversity power stack; bottom).

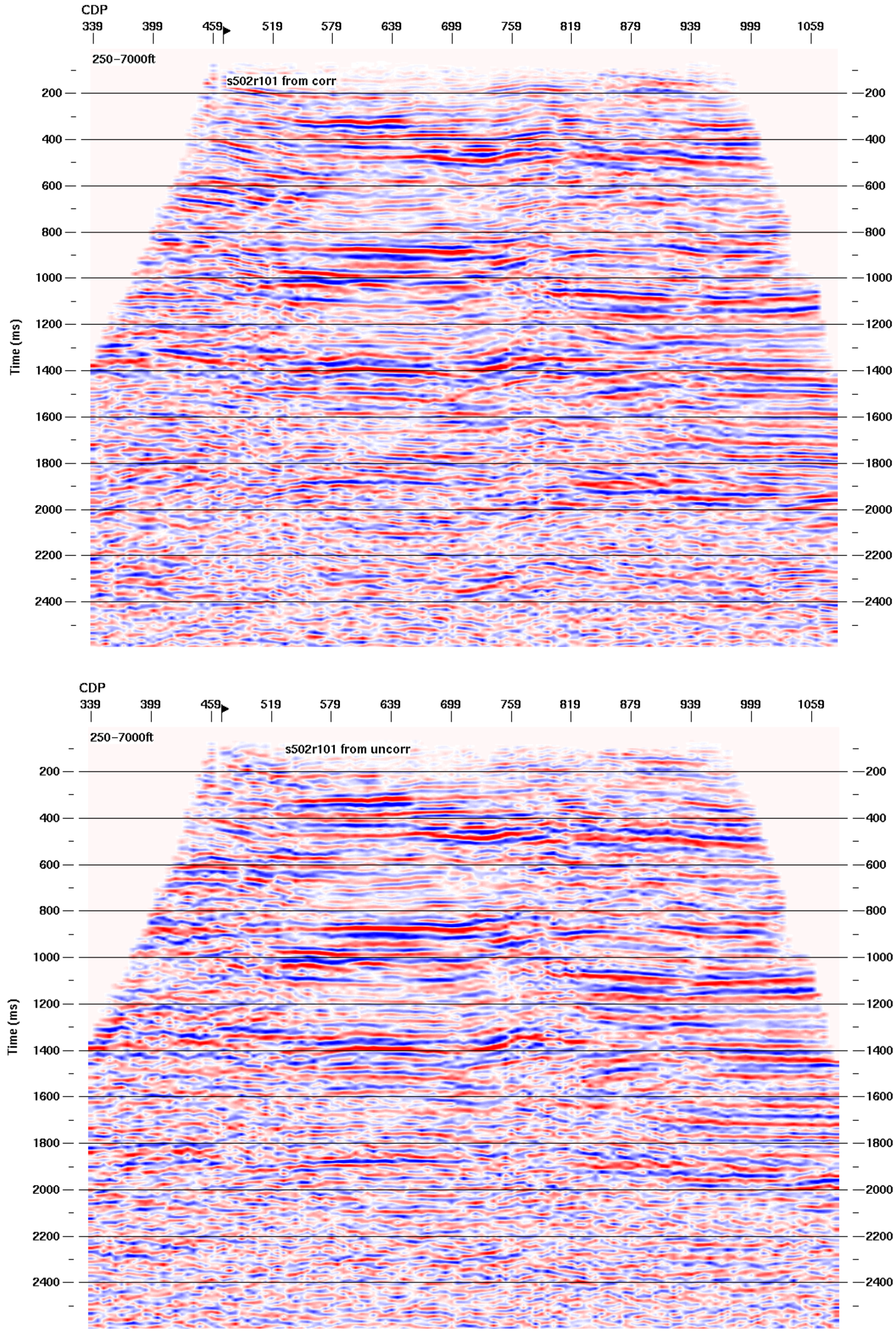



FIG. 5. Source line 502 (4 vibrators, 4 sweeps per VP) and receiver line 101 (geophone array, six per station), using shots vertically stacked and correlated in the field (conventional mean stack; top) and shots vertically stacked and correlated at CREWES (diversity power stack; bottom).

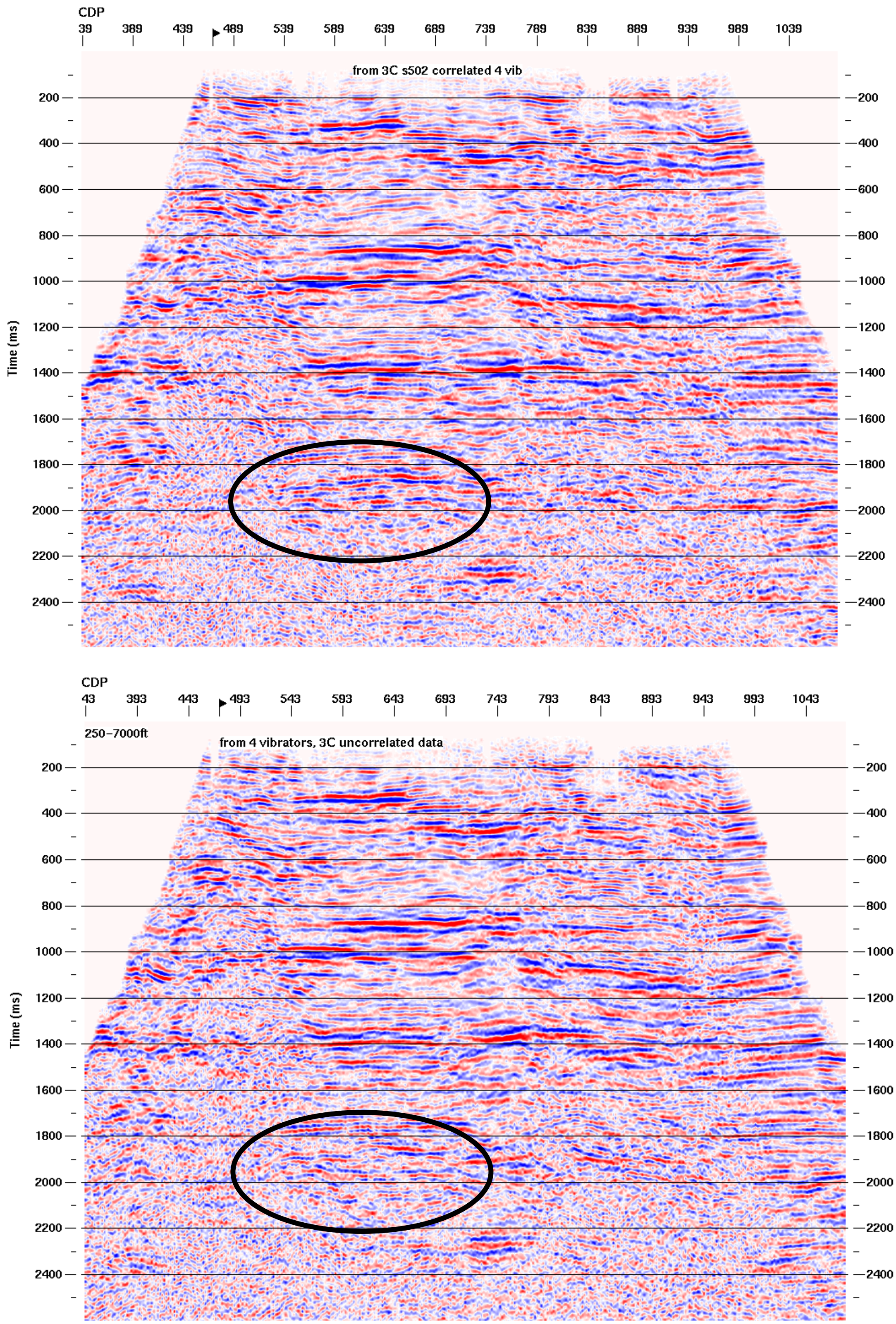



FIG. 6. Source line 502 (4 vibrators, 4 sweeps per VP) and vertical component of receiver line 201 (DSU, one per station), using shots vertically stacked and correlated in the field (conventional mean stack; top) and shots vertically stacked and correlated at CREWES (diversity power stack; bottom).

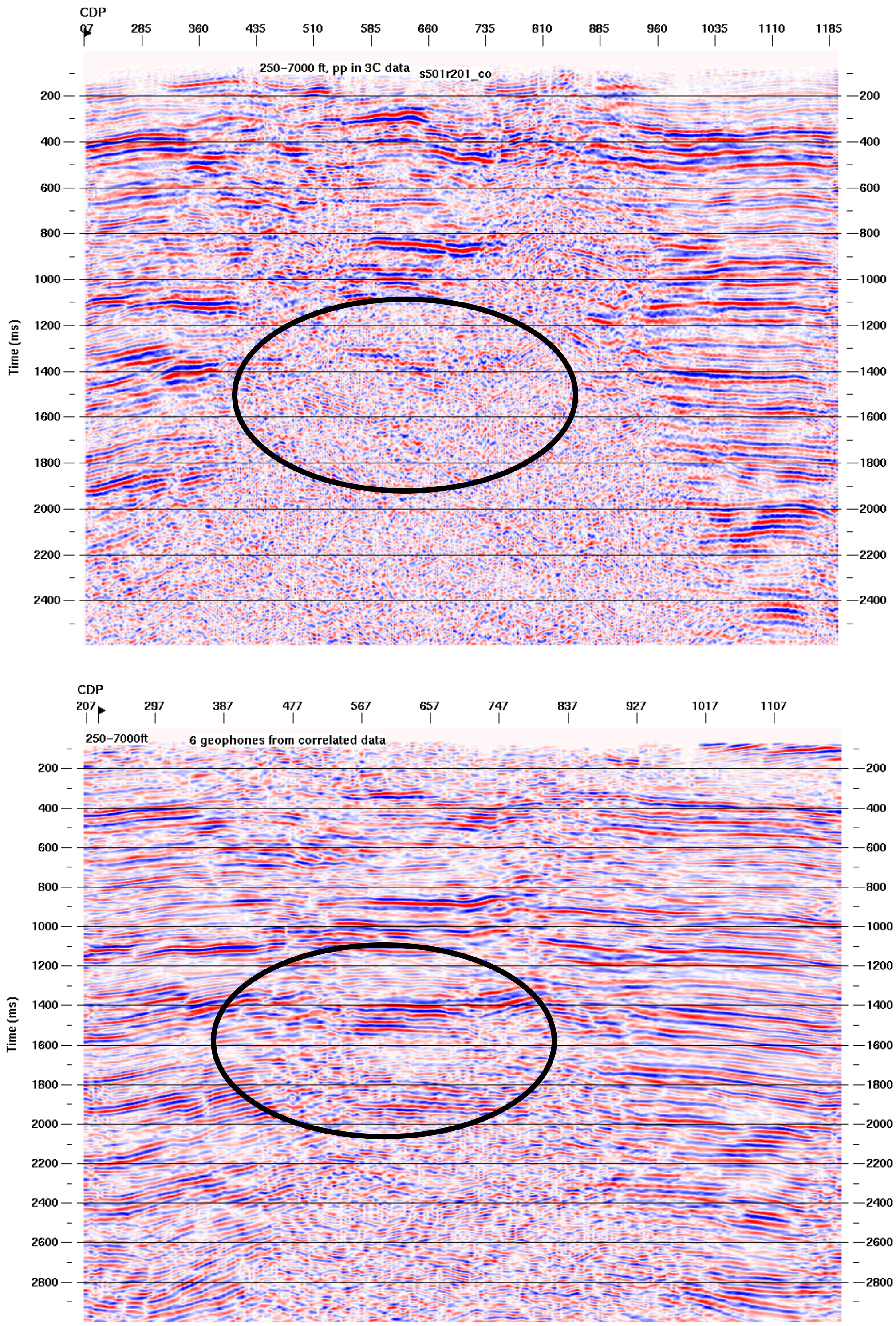



FIG. 7. Source line 501 (2 vibrators, 16 sweeps per VP) recorded by vertical component of receiver line 201 (DSU, one per station; top) and receiver line 101 (geophone array, six per station; bottom), using shots vertically stacked (conventional mean stack) in the field.

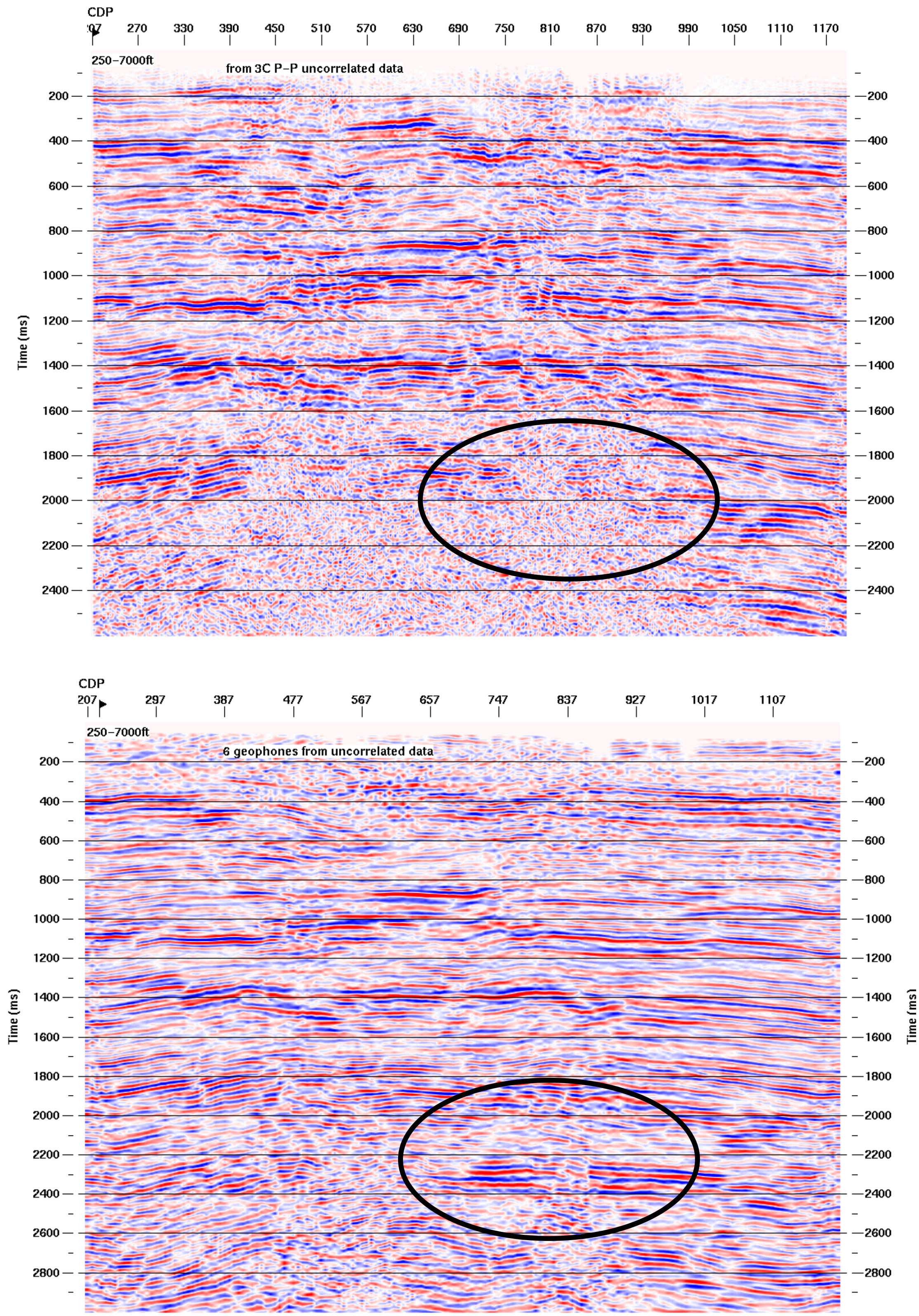



FIG. 8. Source line 501 (2 vibrators, 16 sweeps per VP) recorded by vertical component of receiver line 201 (DSU, one per station; top) and receiver line 101 (geophone array, six per station; bottom), using shots vertically stacked (diversity power stack) at CREWES.

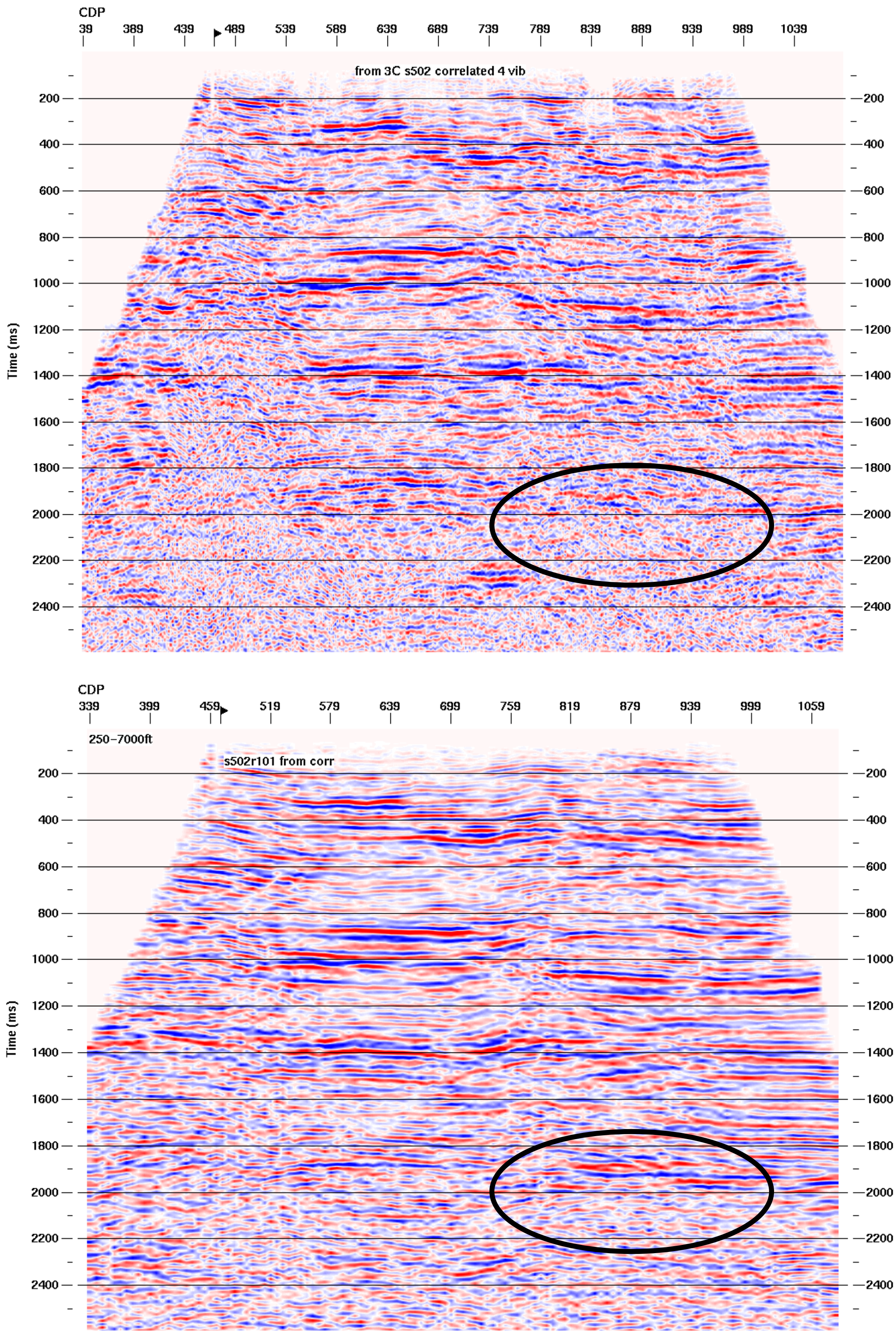



FIG. 9. Source line 502 (4 vibrators, 4 sweeps per VP) recorded by vertical component of receiver line 201 (DSU, one per station; top) and receiver line 101 (geophone array, six per station; bottom), using shots vertically stacked (conventional mean stack) and correlated in the field.

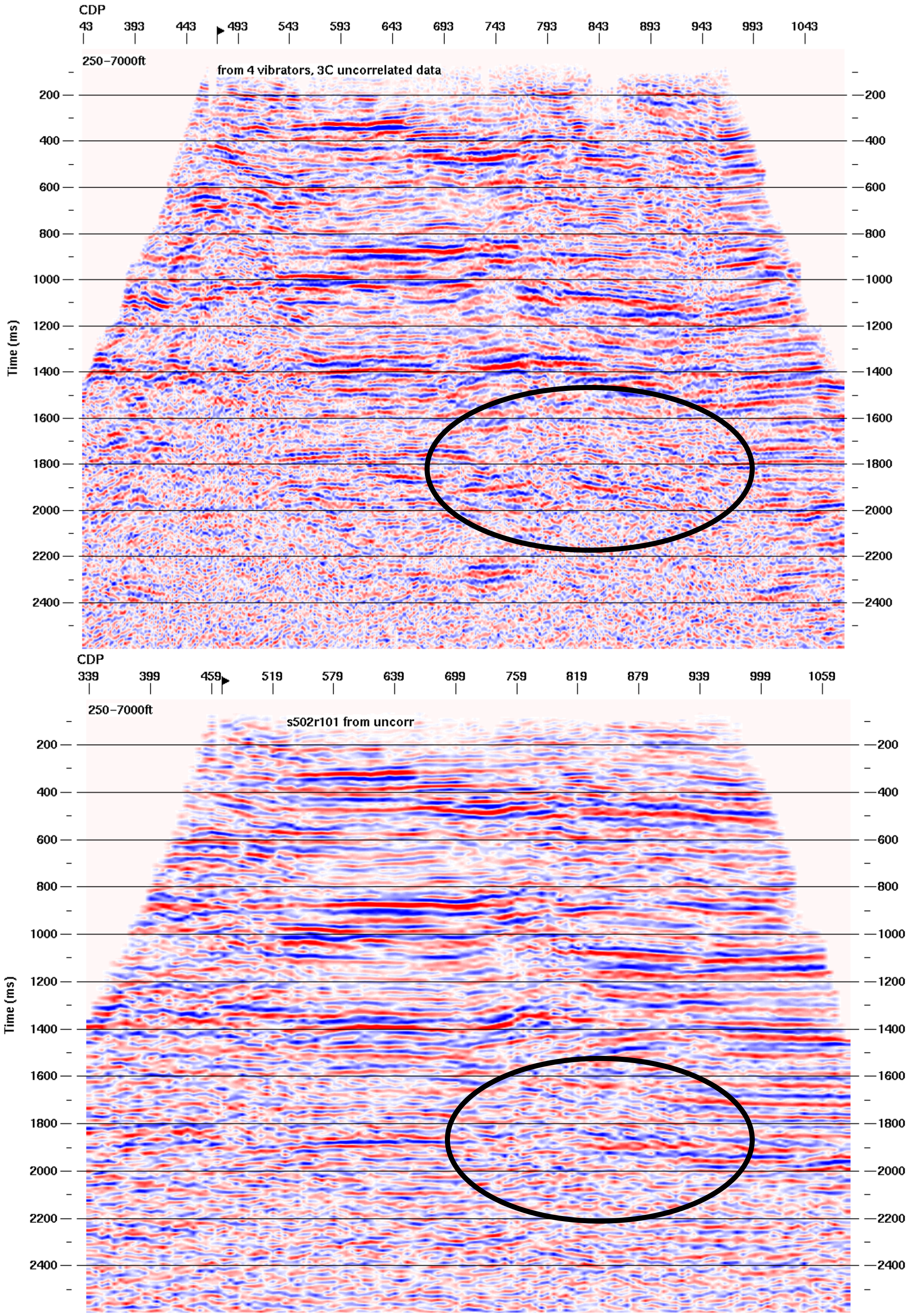



FIG. 10. Source line 502 (4 vibrators, 4 sweeps per VP) recorded by vertical component of receiver line 201 (DSU, one per station; top) and receiver line 101 (geophone array, six per station; bottom), using shots vertically stacked (diversity power stack) and correlated at CREWES.

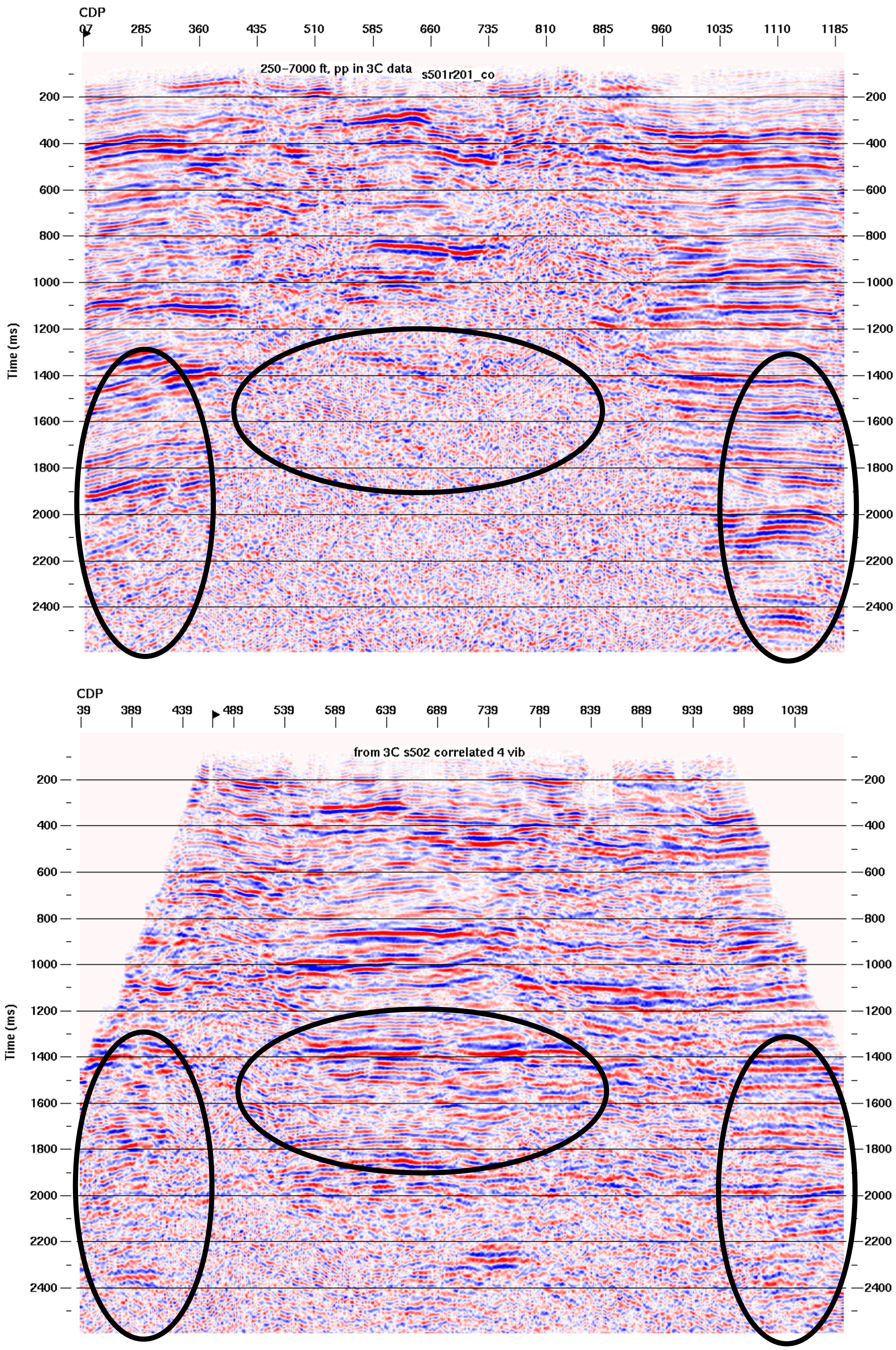



FIG. 11. Source lines 501 (2 vibrators, 16 sweeps per VP; top) and 502 (4 vibrators, 4 sweeps per VP; bottom) and vertical component of receiver line 201 (DSU, one per station), using shots vertically stacked (conventional mean stack) and correlated in the field.

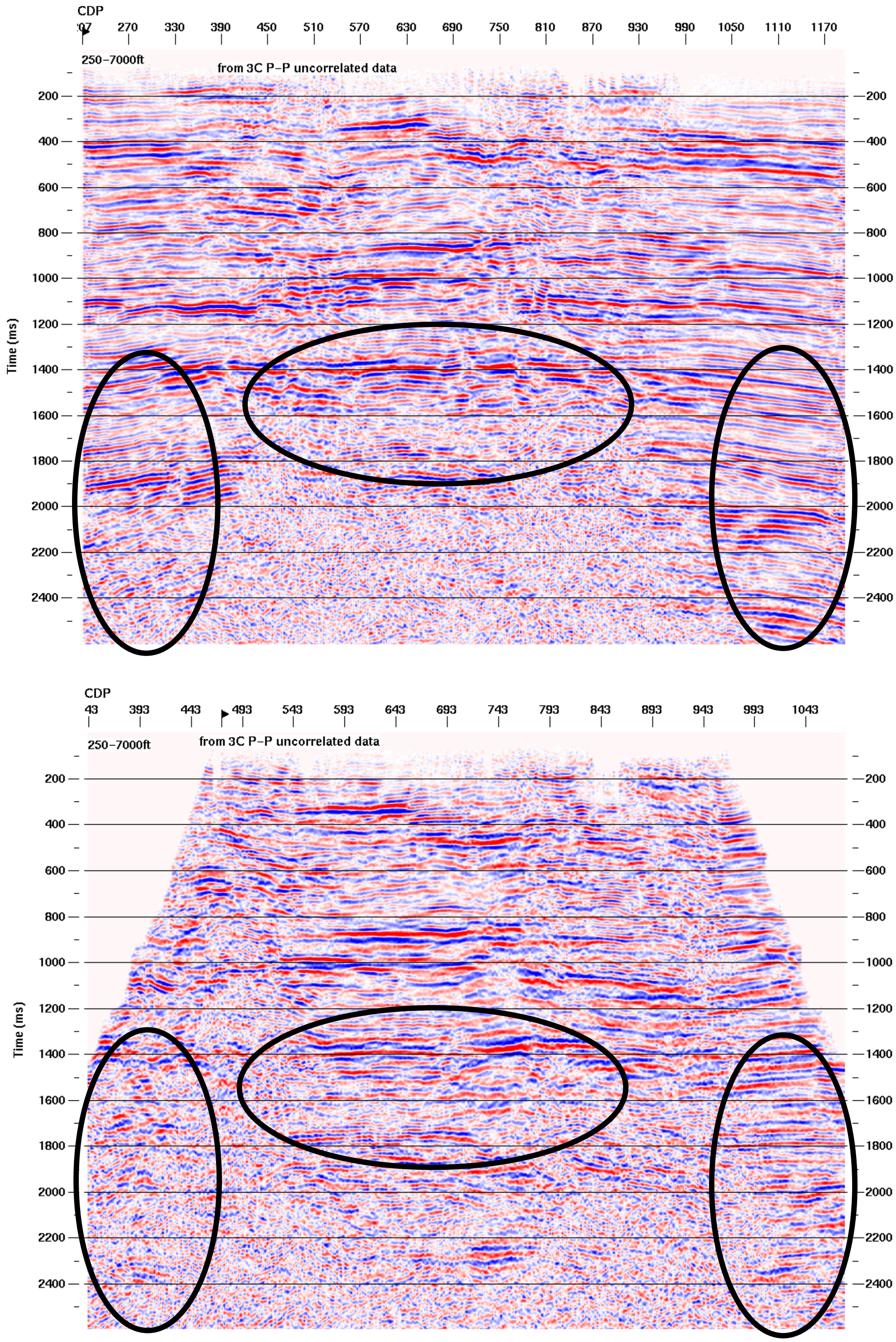



FIG. 12. Source lines 501 (2 vibrators, 16 sweeps per VP; top) and 502 (4 vibrators, 4 sweeps per VP; bottom) for vertical component of receiver line 201 (DSU, one per station), using shots vertically stacked (diversity power stack) and correlated at CREWES.

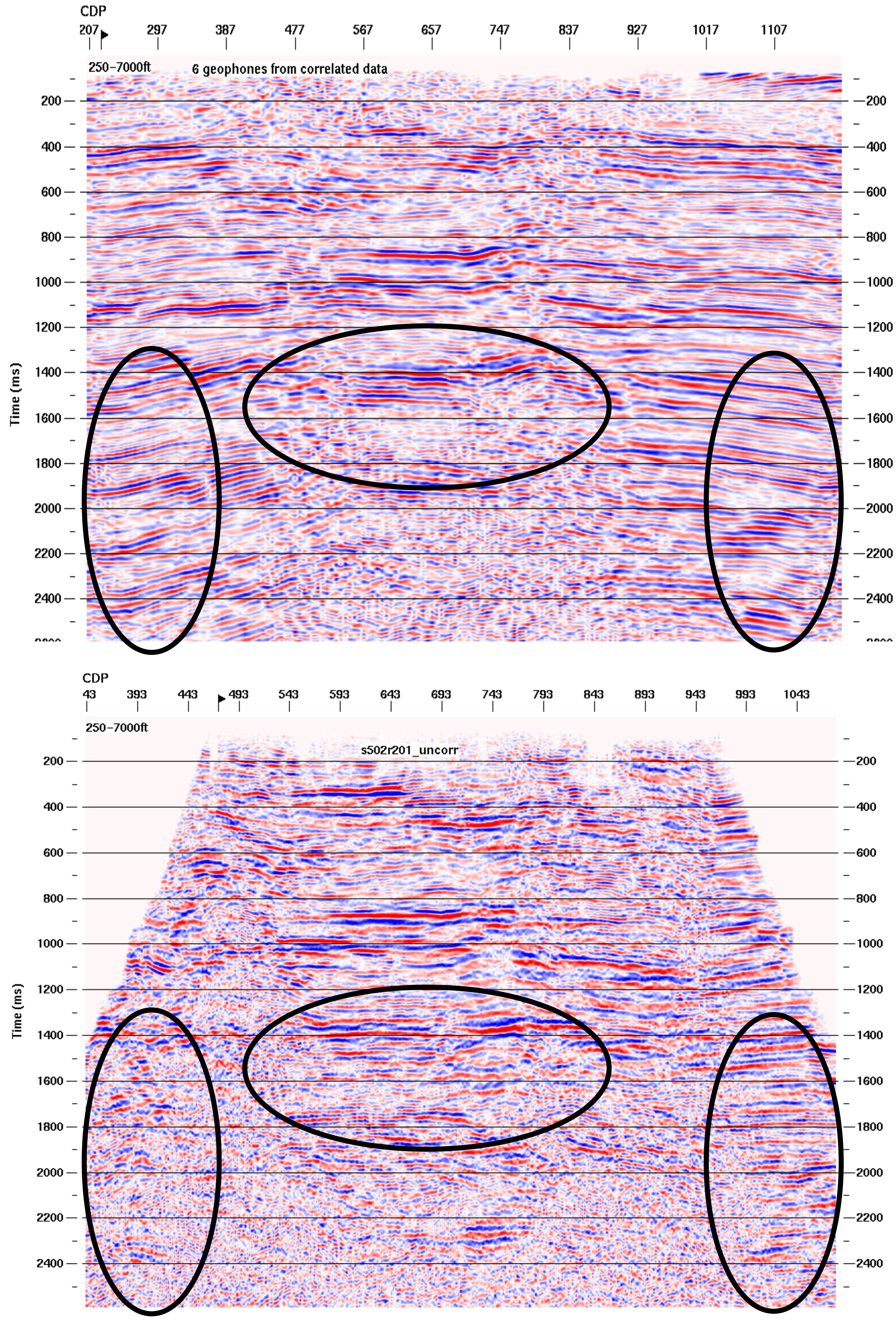
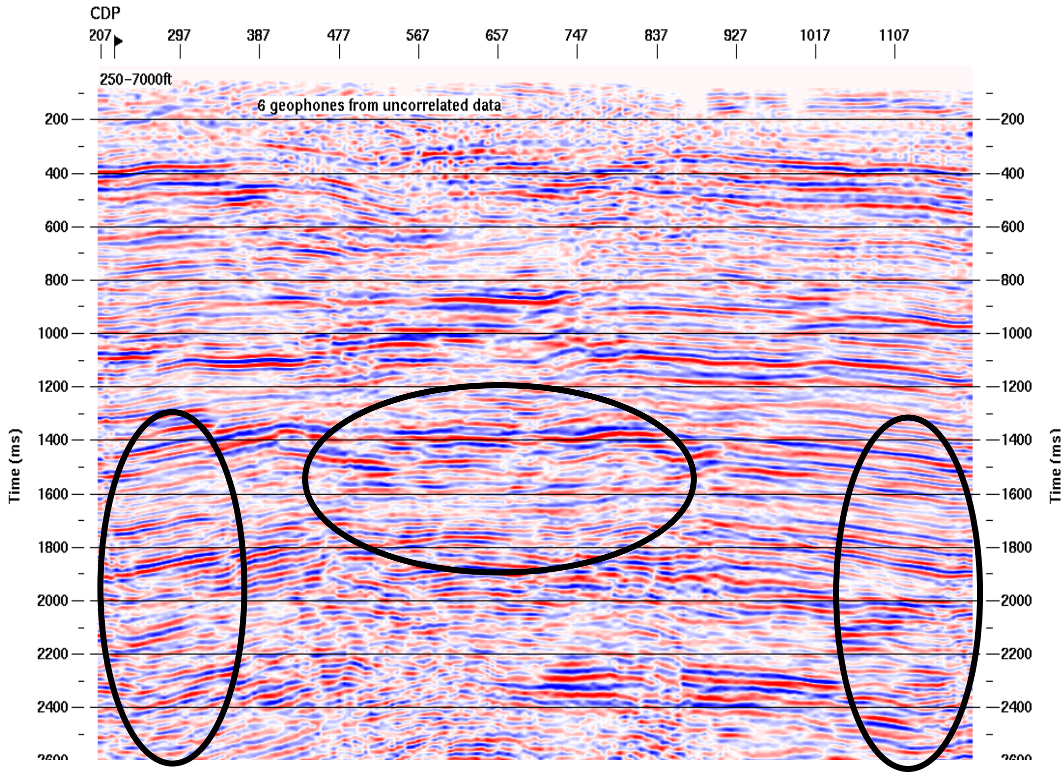



FIG. 13. Source lines 501 (2 vibrators, 16 sweeps per VP; top) and 502 (4 vibrators, 4 sweeps per VP; bottom) recorded by receiver line 101 (geophone array, six per station), using shots vertically stacked (conventional mean stack) and correlated in the field.



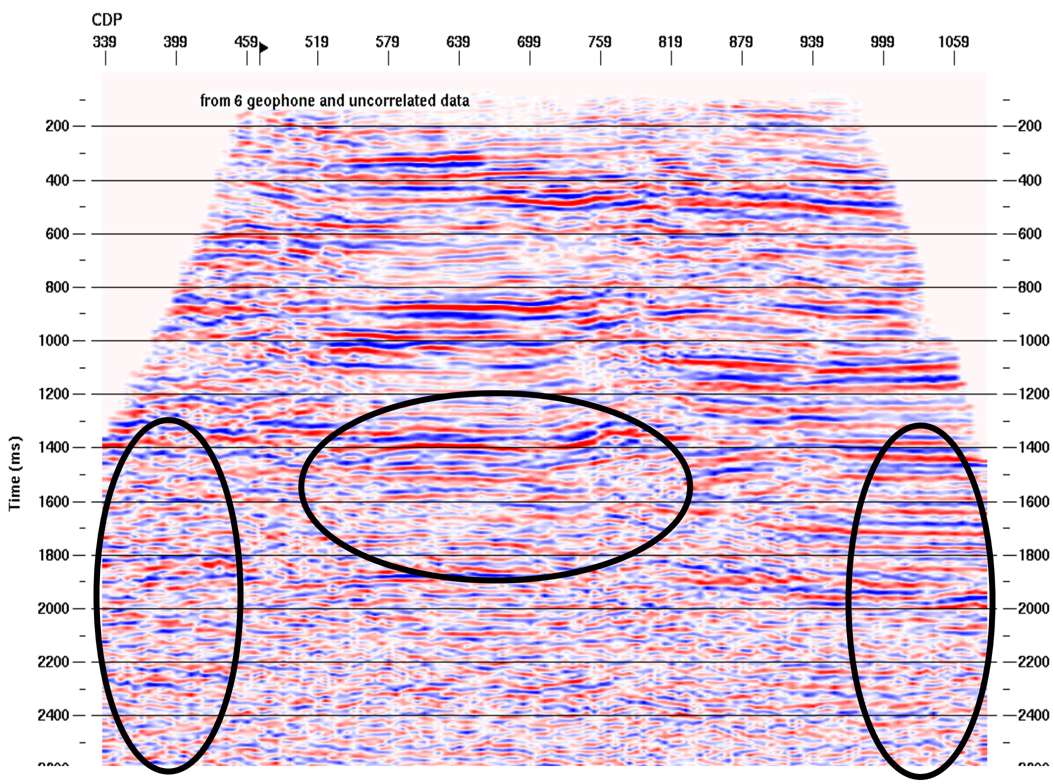




FIG. 14. Source lines 501 (2 vibrators, 16 sweeps per VP; top) and 502 (4 vibrators, 4 sweeps per VP; bottom) and receiver line 101 (geophone array, six per station), using shots vertically stacked (diversity power stack) and correlated at CREWES.

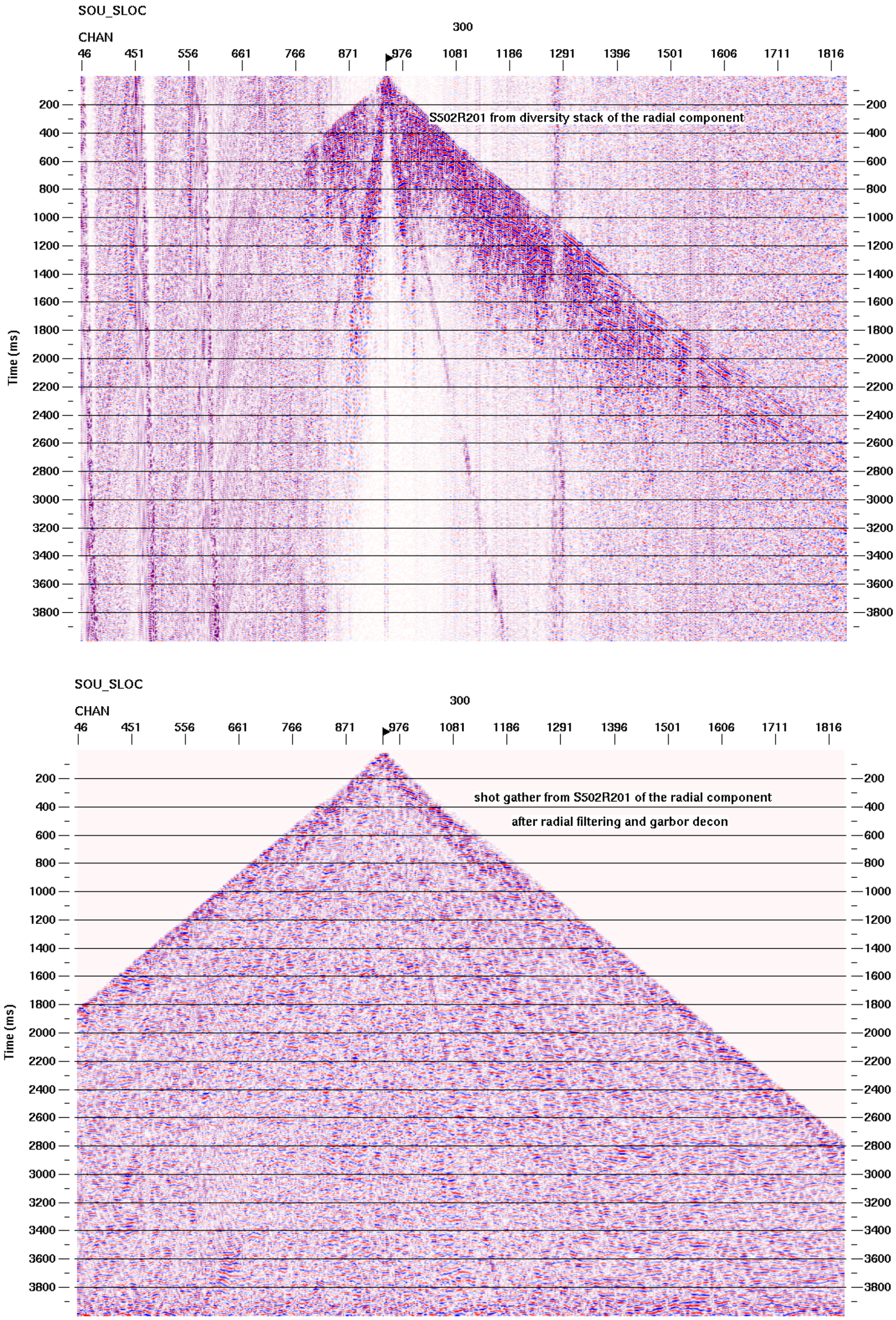



FIG. 15. Radial component shot gather from source line 502 (4 vibrators, 4 sweeps per VP) and receiver line 201 (DSU). Vertically stacked shot gather (diversity power stack; top), and the same gather after radial filtering and Gabor deconvolution (bottom).

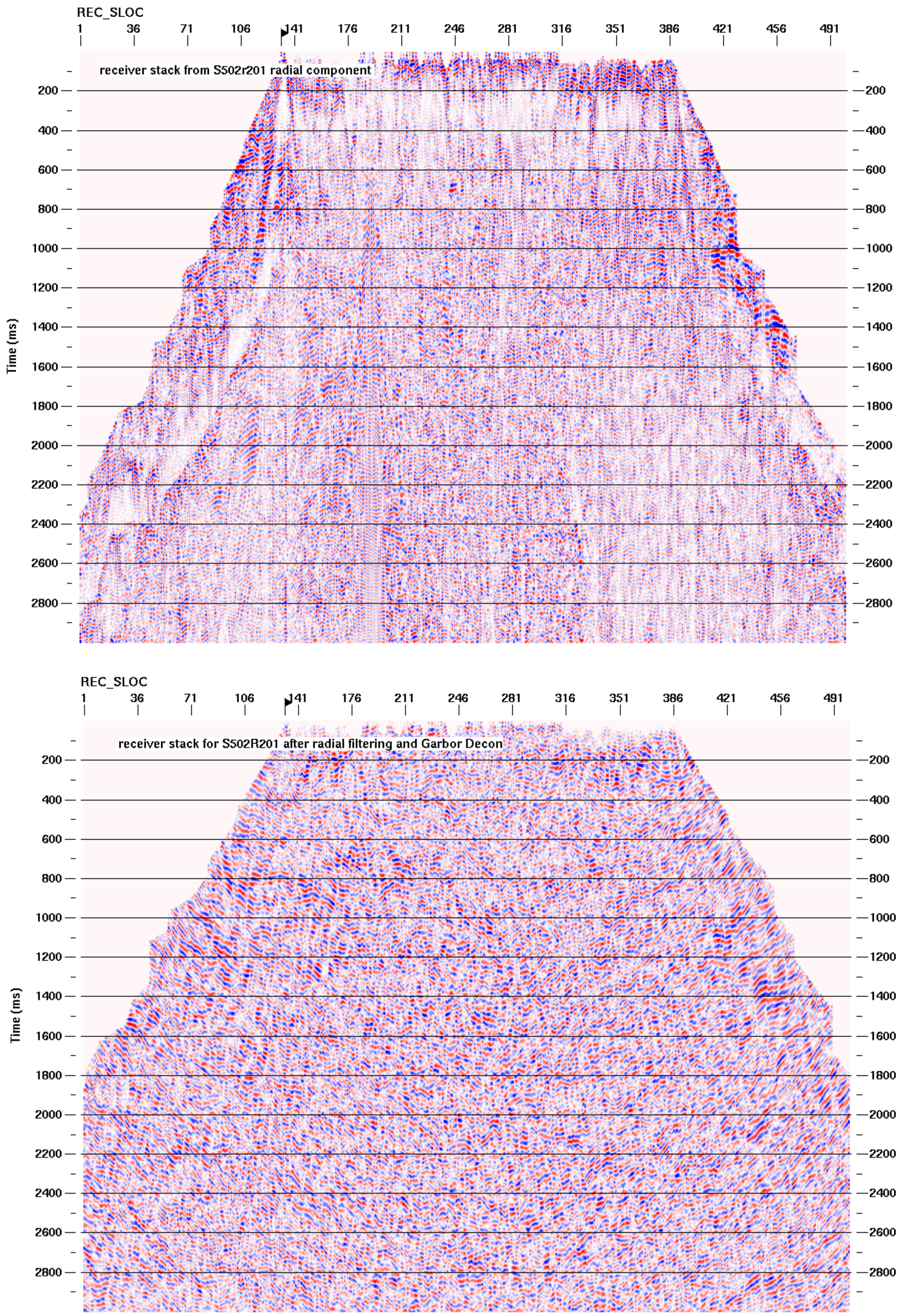



FIG. 16. Radial component receiver stack for source line 502 and receiver line 201 from diversity stacked shots with P-wave shot statics and scaled P-wave receiver statics (first guess at S-wave receiver statics).Top: unfiltered, Bottom: after radial filter and Gabor deconvolution.

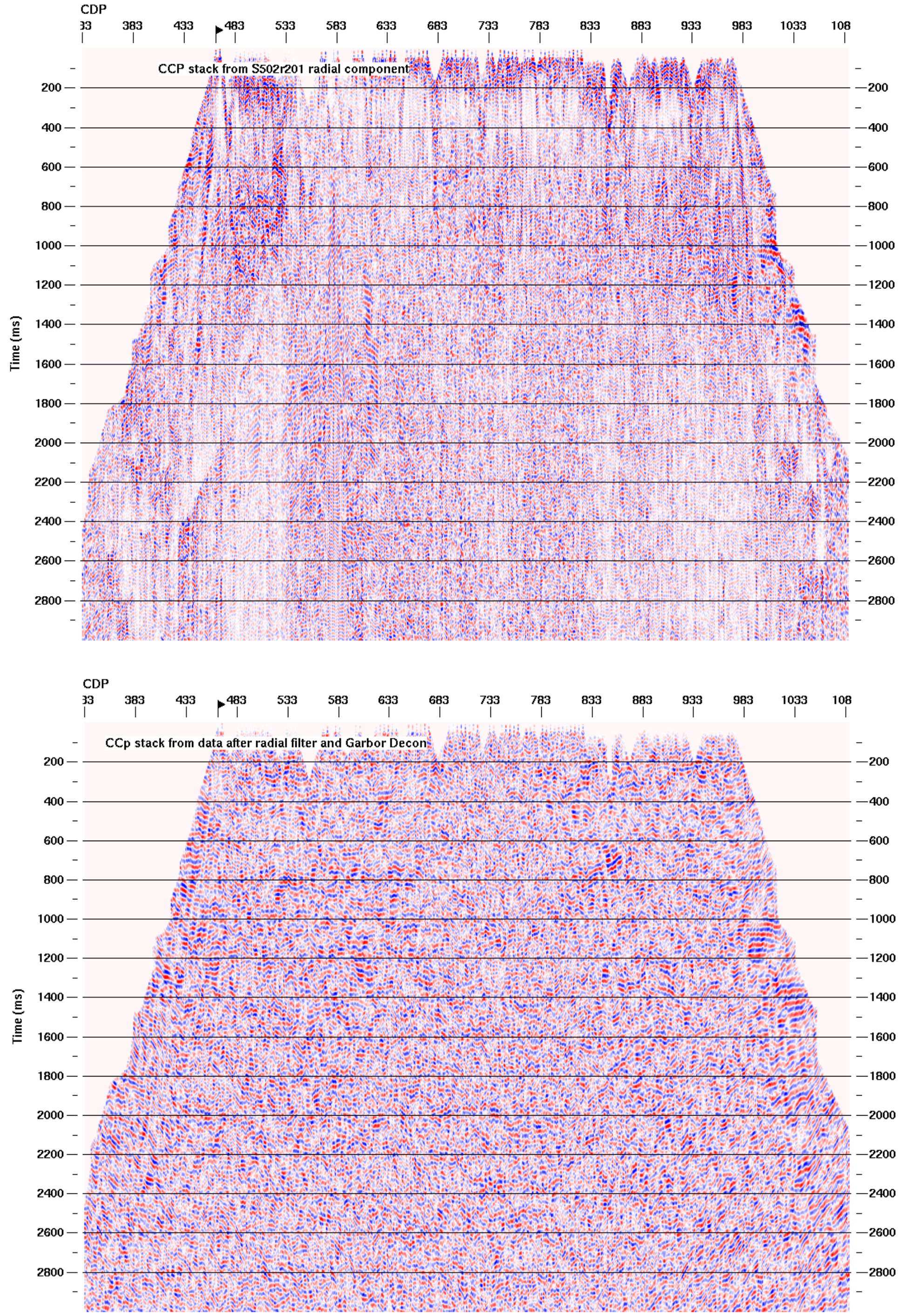



FIG. 17. Radial component brute CCP stack for source line 502 and receiver line 201 from diversity stacked shots with P-wave shot and scaled P-wave receiver statics (first guess at S-wave receiver statics). Top: unfiltered, Bottom: after radial filter and Gabor deconvolution.

## DISCUSSION

From comparisons of three field acquisition parameters, we have shown that each parameter has an influence on the quality of the final stacked sections.

### Effect of vertical stacking methods

Much improved images were obtained using diversity stacking for the case of two vibrators and sixteen sweeps per VP. Less improvement (if any) was observed when diversity stacking data from four vibrators and four sweeps per VP.

### Effect of receiver arrays

Images obtained from unfiltered six geophone arrays result in better image quality at depth than those from single or podded geophones, especially for the two vibrator case. Image quality for single geophone per station datasets should be improved by better filtering of surface noise (see Future Work).

### Effect of source arrays

It is difficult to directly compare 2 vibrators and 16 sweeps per VP (line 501; 205 VPs during the day) to 4 vibrators and 4 sweeps per VP (line 502; 130 VPs at night) due to differences in CDP fold and amount of noise from vehicular traffic. However, the best images obtained (based on reflection continuity) are from line 501 after diversity power stacking the raw shot gathers.

## FUTURE WORK

In future, we will examine the noise spread results, the effects of burying receivers to varying depths, and effect of using explosive sources at various depths and offsets. Future processing should include more filter testing for removal of surface noise from single geophone per station records, as well as processing the *PP* stacks shown in this report to final migrated stacks. More effort on the radial component of the DSUs is also warranted. Finally, it should be possible to conduct an interpretation project based on these data.

## ACKNOWLEDGEMENTS

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