

Title:

***Elastic-Wavefield Seismic Stratigraphy: A New Seismic  
Imaging Technology***

**TECHNICAL PROGRESS REPORT**

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## **Abstract**

The focus of elastic-wavefield seismic stratigraphy research shifted from onshore prospects to marine environments during this report period. Four-component ocean-bottom-cable (4-C OBC) seismic data acquired in water depths of 2400 to 2500 feet across Green Canyon Block 237 in the Gulf of Mexico were processed and analyzed. The P-P and P-SV images of strata immediately below the seafloor exhibit amazing differences in P-P and P-SV seismic facies. These data may be one of the classic examples of the basic concepts of elastic-wavefield seismic stratigraphy.

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## **Introduction**

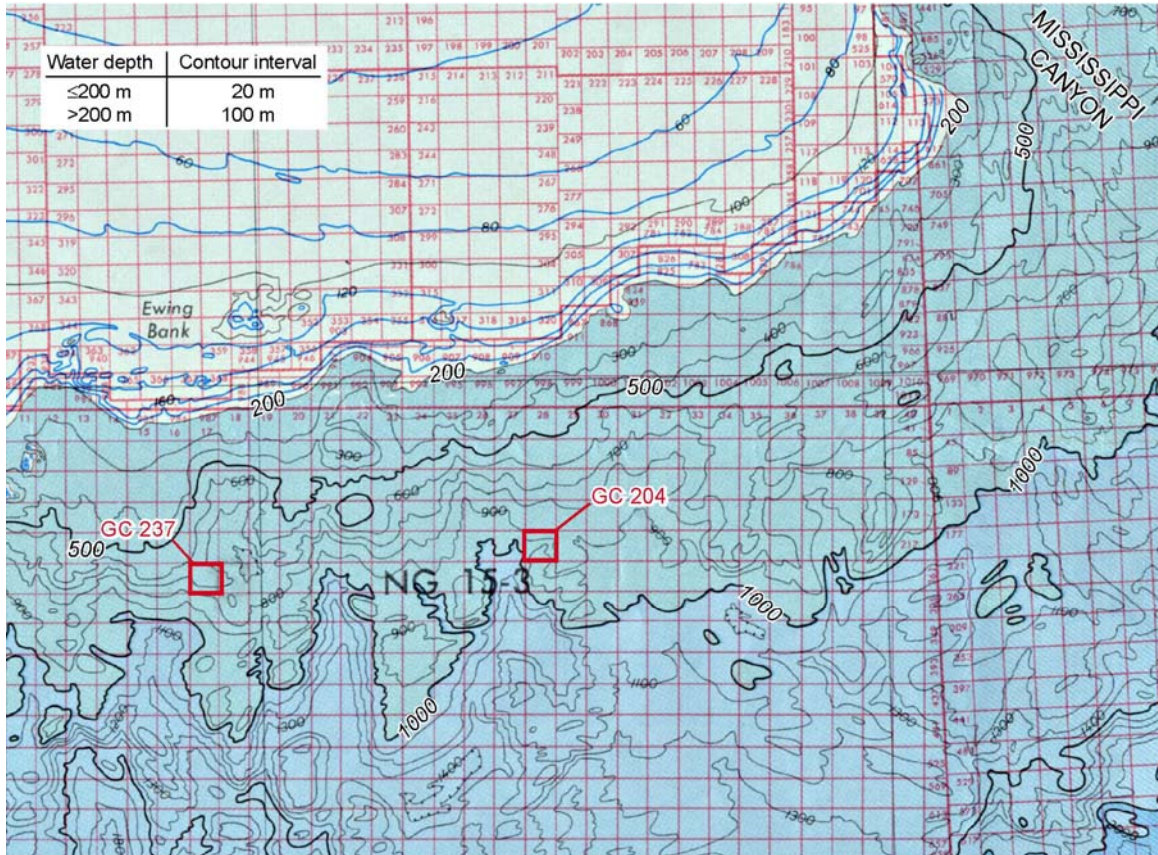
There is increasing industry interest in applying multicomponent seismic technology in marine environments, which requires that some of the elastic-wavefield research in this project focus on the interpretation of P-P and P-SV data acquired using four-component ocean-bottom-cable (4-C OBC) technology. We describe here our processing of 4-C OBC data acquired in the Gulf of Mexico and our interpretation of the seismic sequences and seismic facies observed in shallow seafloor strata in the P-P and P-SV images. The  $V_p/V_s$  velocity ratio in these strata is quite high, ranging from 5 to as much as 15. This velocity property causes dramatic differences in the P-P and P-SV responses. An objective of this research is to document these types of differences in P-P seismic sequences and facies and P-SV seismic sequences and facies.

## **Executive Summary**

We focused our research on two 4-C OBC seismic lines acquired in water depths of about 2,400 feet in the Green Canyon area of the Gulf of Mexico. WesternGeco provided the seismic data along these two profiles. We processed the data to create P-P and P-SV images and then interpreted the sequences and facies patterns observed in these images. These data show the greatest contrast between P-P seismic sequences and seismic facies and P-SV seismic sequences and facies that we have seen in any multicomponent seismic data. There are gas production facilities in the block where we focused our analysis. We are negotiating with the operator of that block to obtain copies of any available subsurface measurements of petrophysical properties in the strata that we are studying. We believe we will gain access to information that will be important for documenting why such great differences occur between P-P and P-SV sequences and facies.

## **Experimental**

Our experimental activity consisted of the tasks required to create P-P and P-SV images from the 4C2D OBC data provided by WesternGeco. WesternGeco has acquired 4C2D OBC data across a large area of the Gulf of Mexico. We selected only two blocks (GC 237 and GC 204) from the Green Canyon area of this large survey area where we concentrated our study. The locations of these two blocks are shown in Figure 1. This report describes our analysis of 4-C OBC data across only Block GC 237. Our analysis of data across Block GC 204 will be reported later. A detailed view of the positions of the two OBC profiles that traverse Block GC 237 is presented as Figure 2. In our processing of the P-SV data, we created images of only the radial component of the P-SV wavefield. We will determine later if there is sufficient signal on the transverse component of the P-SV wavefield that warrants the effort to make transverse-component P-SV images.



U. S. Department of Commerce (1986)

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Figure 1. Seafloor topography and water depth across Green Canyon Blocks 204 and 237.

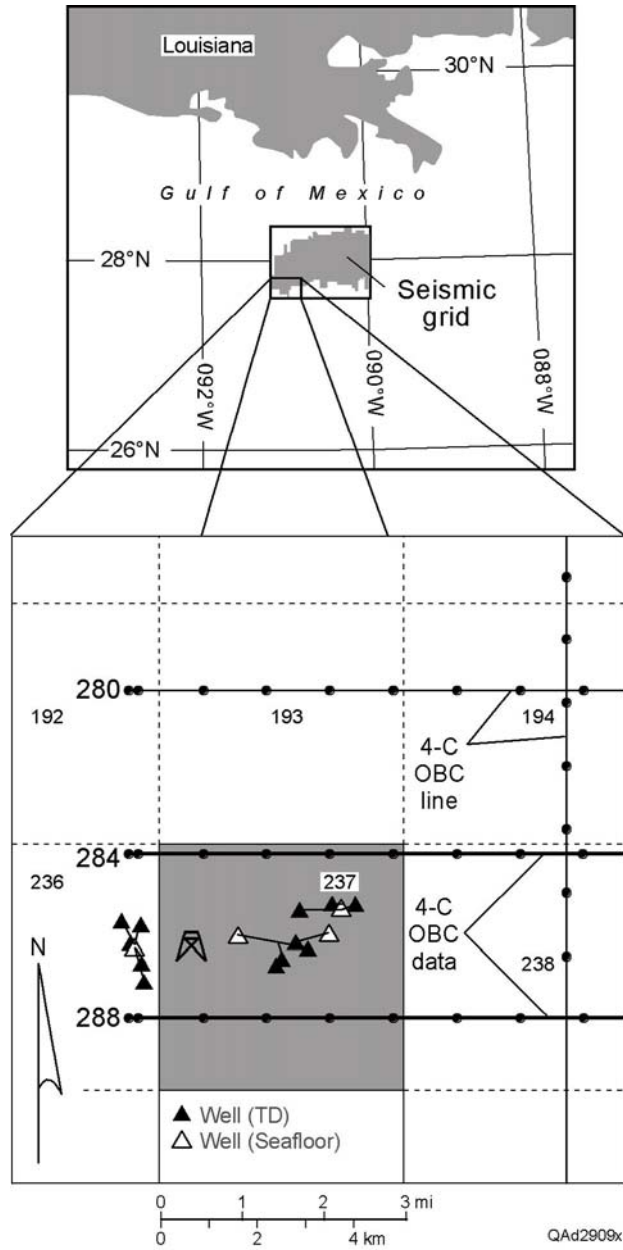


Figure 2. 4-C OBC lines across Block 237.

## Results and Discussion

The P-P image along Line 288 is displayed as Figure 3. Several interpreted horizons are shown that define the seismic sequences immediately below the seafloor. Horizon WB is the water bottom. Horizons 1 through 4 are successively deeper sequence boundaries. The seismic sequences defined by these boundaries are labeled A, B, C, D.

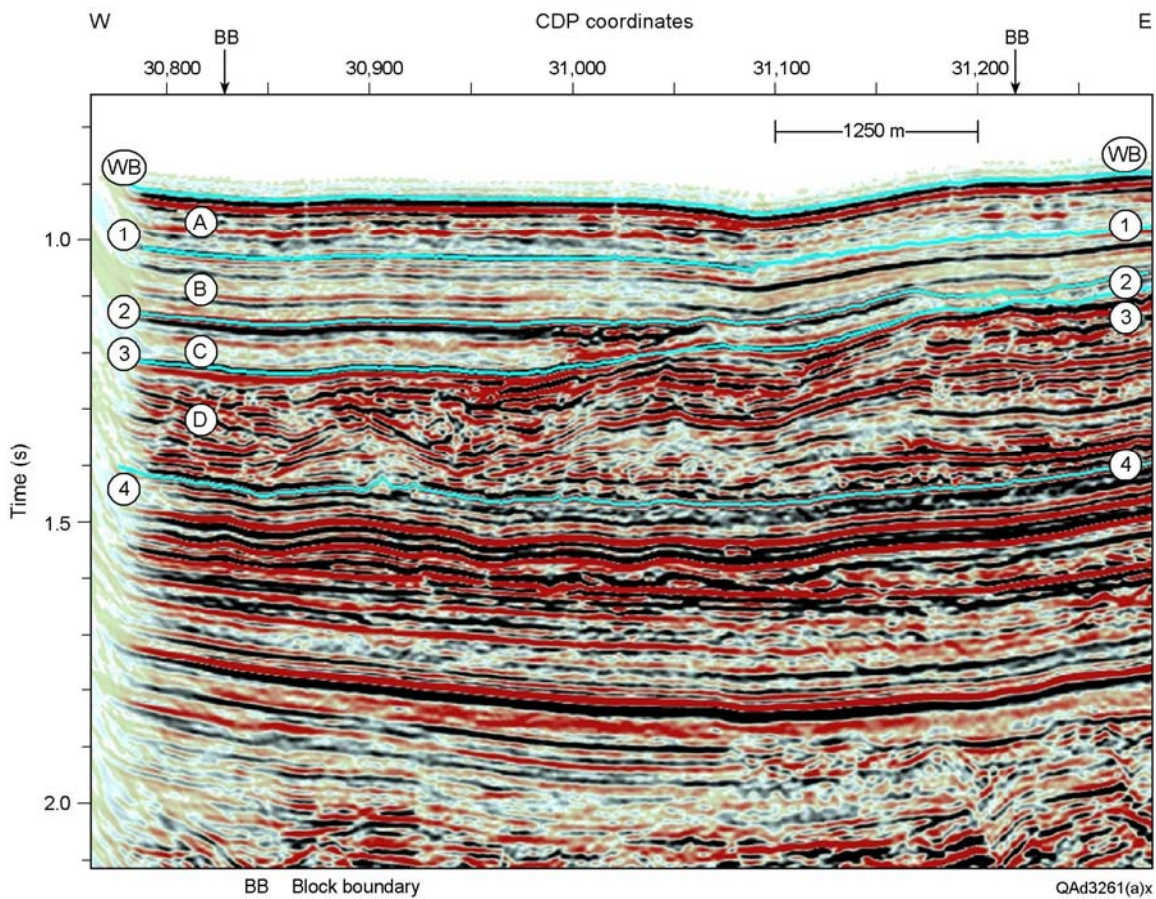


Figure 3. P-P profile along line 288. WB is the water bottom. Surfaces 1 through 4 are interpreted sequence boundaries.

The radial P-SV image along this same profile is shown in Figure 4. The labeled horizons are interpreted to be depth equivalent to the horizons shown in the P-P image (Fig. 3). The horizons occur at different image times than do the P-P horizons because of the difference in P and SV propagation velocities through the strata. The water bottom cannot be imaged with P-SV data because shear waves do not propagate in water. Consequently, horizon WB from the P-P image is transferred onto the P-SV image. Sequences A, B, C, D are interpreted to be depth equivalent to P-P sequences A, B, C, D.



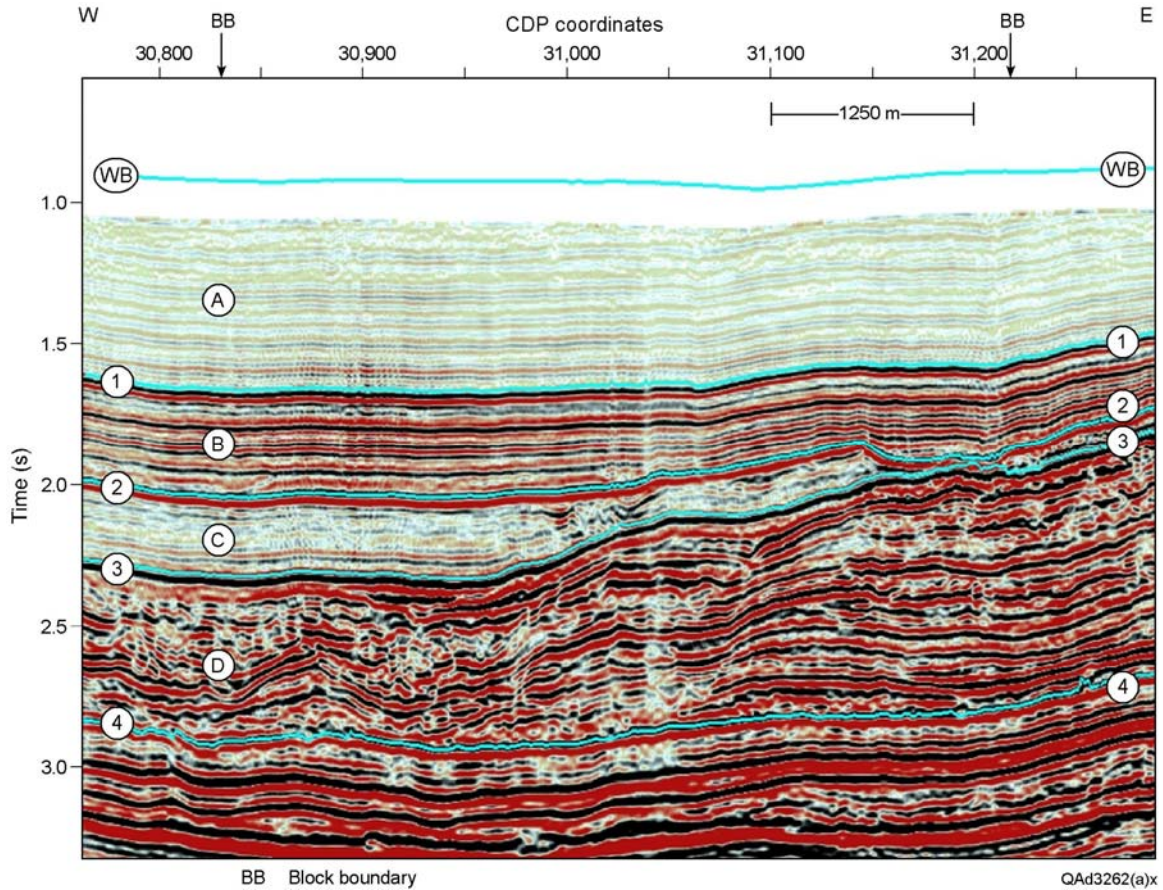


Figure 4. P-SV profile along line 288. WB is the water bottom. Surfaces 1 through 4 are depth equivalent to the surfaces in the P-P image.

One obvious difference between the P-P and P-SV images is that the P-SV data show a more detailed picture of the internal fabric of the shallowest strata. The difference between the P-P and P-SV images is most pronounced for sequences A and B. The primary reason for the difference in vertical resolution is that the  $V_p/V_s$  velocity ratio is unusually high for these near-seafloor, deep-water sediments. Our measurements of  $V_p/V_s$  within sequence A ranged from 10 to 15 across Block GC 237, with a value of 12 being a reasonable average value for that part of Line 288 displayed in Figures 3 and 4. For each frequency component of the downgoing illuminating P wavefield, this  $V_p/V_s$  velocity condition means that the wavelength in the reflected SV wavefield is 12 times shorter than the corresponding wavelength in the reflected P wavefield. Shorter wavelengths result in better spatial resolution. The end result is that P-SV sequence A has a spatial resolution approximately an order of magnitude better than the spatial resolution of P-P sequence A.

The  $V_p/V_s$  velocity ratio decreases to about 8 in sequence B, to about 6 in sequence C, and then to about 4 in sequence D. The contrast between P-P and P-SV resolution diminishes as  $V_p/V_s$  decreases with depth below the seafloor.

There is a large difference between P-P and P-SV seismic amplitude facies, particularly for sequences A and B. There is almost no contrast between the P-P amplitude facies in sequence A and the P-P amplitude facies in sequence B (Fig. 3). In fact there is no obvious reason to introduce sequence boundary 1 into the P-P image if the data interpretation is restricted to only the P-P response. In contrast, there is a significant difference between the P-SV amplitude facies in sequence A and the P-SV amplitude facies in sequence B (Fig. 4). An interpreter is compelled to introduce a sequence boundary (horizon 1) into the P-SV image to segregate P-SV facies A from P-SV facies B. Once this sequence boundary was defined in P-SV image space, we then interpreted its depth-equivalent horizon in P-P image space.

The major support for interpreting these strata using an elastic-wavefield seismic stratigraphy approach rather than a conventional P-P seismic stratigraphy approach is the contribution made to geologic understanding by the stark difference between the P-P and P-SV seismic facies. Once sequence boundary 1 is introduced into the P-P image, the geometrical configurations of P-P sequences A, B, C, D are similar to the geometrical configurations of P-SV sequences A, B, C, D. Either suite of sequences suggests the same depositional architecture. In contrast, the P-SV amplitude facies in sequences A and B imply a lithofacies distribution that is significantly different from what is suggested by the P-P seismic facies within sequences A and B.

The P-P and P-SV images along profile 284 are displayed in Figures 5 and 6, respectively. Horizons WB through 6 drawn across each image are interpreted to be depth-equivalent sequence boundaries that create depth-equivalent sequences A, B, C, D, E. As was the case along profile 288, the P-SV data display a spatial resolution within sequence A that is an order of magnitude better than the spatial resolution of the P-P data within that sequence. The values of the  $V_p/V_s$  velocity ratio along profile 284 are similar to what exist and have been explained for profile 288.

P-P sequences A through E (Fig. 5) have individual geometries and a spatial pattern that are almost identical to the geometrical shapes and spatial patterns of P-SV sequence A through E (Fig. 6), just as was observed for profile 288. However, new geologic information about the strata is provided by comparing the P-P and P-SV seismic amplitude facies. The P-SV amplitude facies suggest a different spatial distribution of lithofacies within sequences A and C, in particular, than do the P-P amplitude facies.

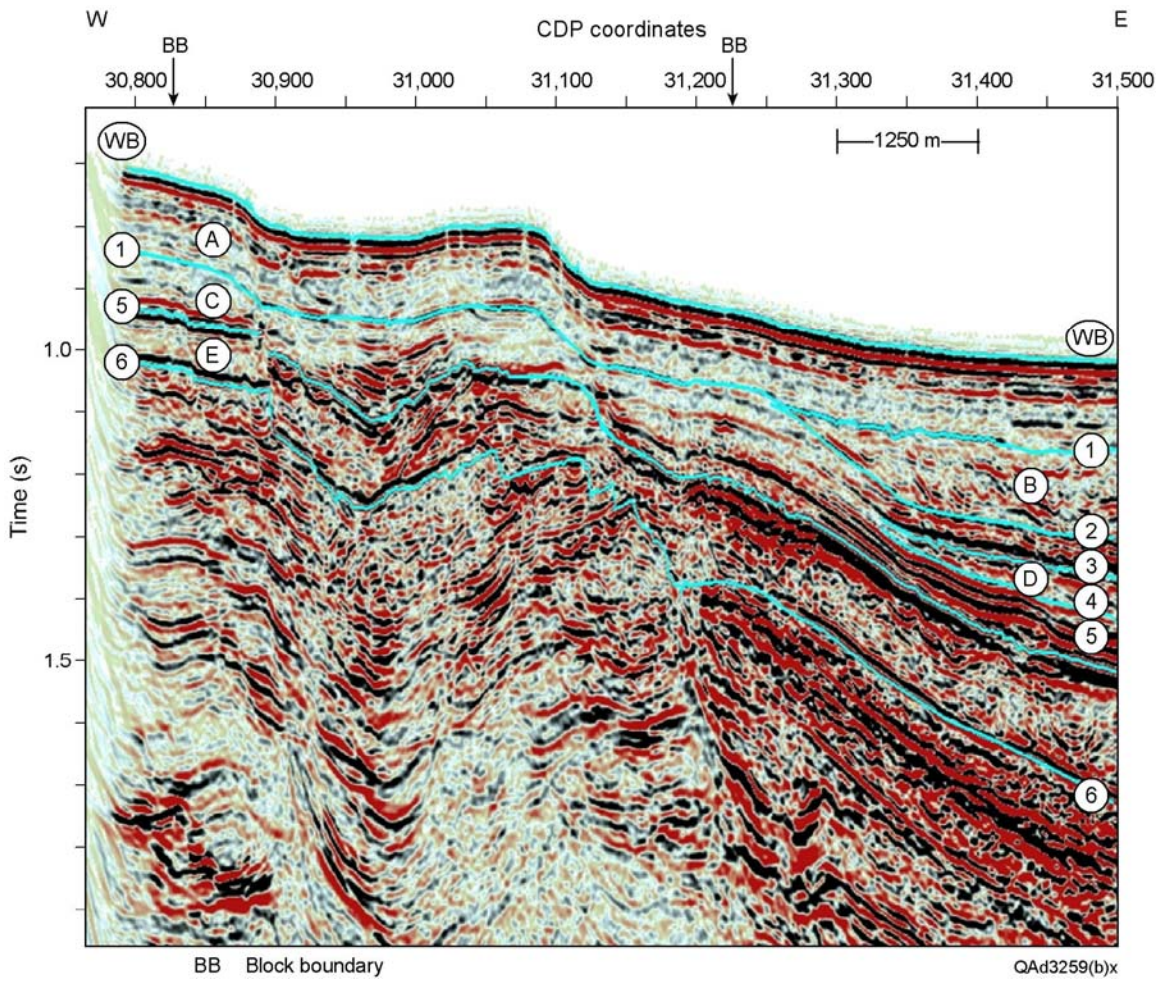


Figure 5. P-P profile along line 284. WB is the water bottom. Surfaces 1 through 6 are interpreted sequence boundaries.

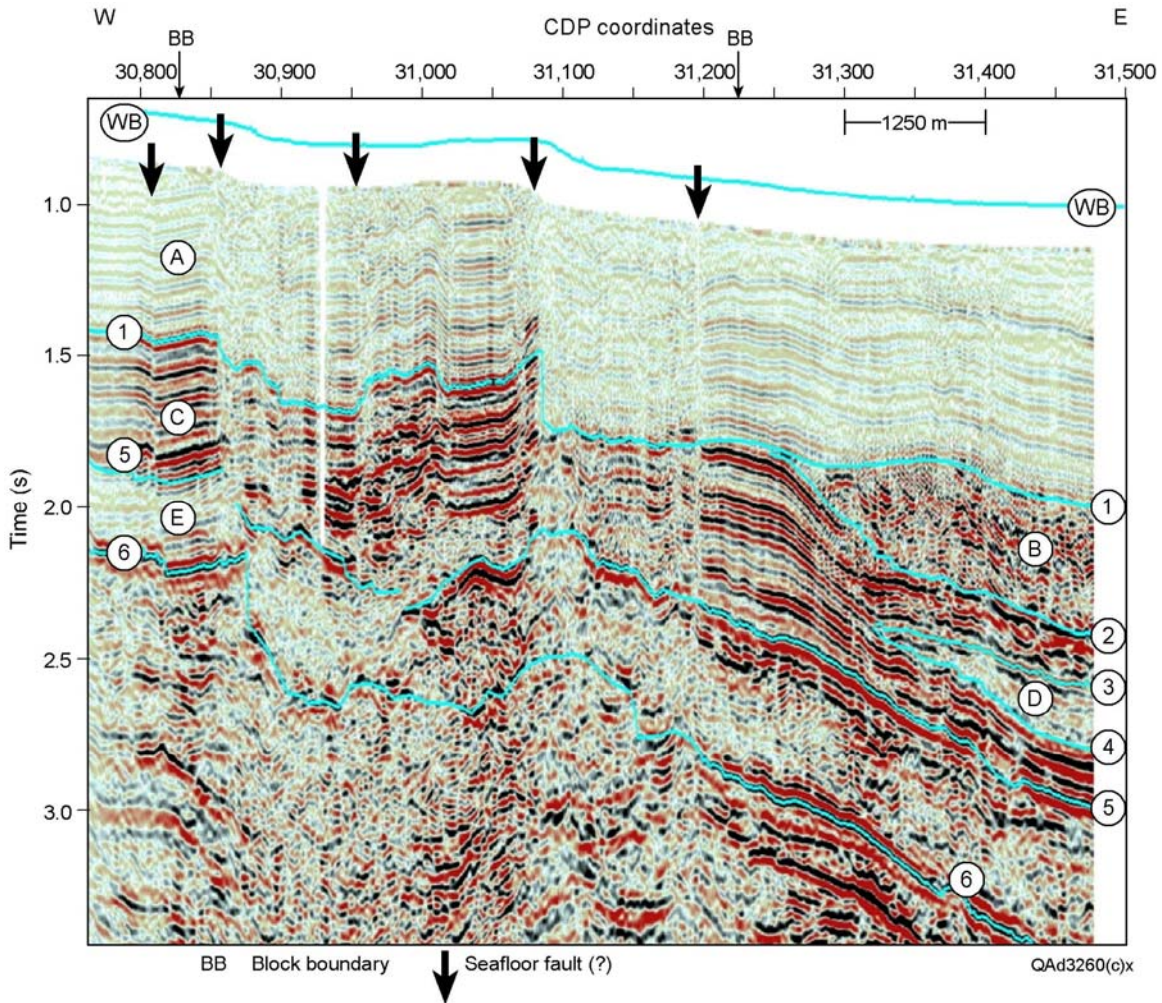


Figure 6. P-SV profile along line 284. WB is the water bottom. Surfaces 1 through 6 are depth equivalent to the surfaces in the P-P image.

One principal difference in these P-P and P-SV images is their different depictions of the minor faults that reach the seafloor. It is difficult to find faults in the P-P image that reach the seafloor. Several faults with minor throws appear to be present in the high-resolution P-SV data and are labeled with bold arrows.

## Conclusions

We applied elastic-wavefield concepts to the interpretation of 4-C OBC seismic data. Our interpretation focused on comparisons of P-P and P-SV images of strata immediately below the seafloor where there was a large difference in  $V_p$  and  $V_s$  velocities. We found at one study location that P-P and P-SV seismic sequences were similar. We think equivalent depositional architecture would be constructed along the short seismic profiles

we analyzed using either P-P or P-SV data for the stratigraphic construction. In contrast, we found that P-P and P-SV seismic facies differed significantly. P-SV amplitude facies imply more lateral and vertical variation in lithofacies than do P-P amplitude facies. We are attempting to amass geologic and engineering data from ChevronTexaco, who operates wells abutting the OBC profiles we analyzed. We are seeking data that will aid in understanding which seismic facies, P-P or P-SV, is the more accurate description of the lithofacies patterns in the shallow seafloor strata along the seismic profiles.

## References

None

## Abbreviations and Acronyms

**4-C:** Four-component

**4C2D:** Four-component, two-dimensional

**OBC:** Ocean-bottom cable

**$V_p/V_s$ :** Ratio of P-wave velocity  $V_p$  to S-wave velocity  $V_s$