Multicomponent Processing: South Casper Creek, Wyoming

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ABSTRACT

The Casper Creek South Field in Natrona County, Wyoming, is formed by two doubly-plunging anticlines having dips of as much as 30 degrees. A multicomponent reflection survey was conducted across the field by Union Oil of California (UNOCAL) in 1988, in which data from a dynamite source were recorded in the vertical, radial, and transverse directions. These data have since been donated to the CREWES Project for analysis.

It was found in processing this data set that considerable energy exists on the crossline component. Geophone rotation tests indicate maximum energy on the radial component is achieved by a 22 degree counter-clockwise rotation of the horizontal components away from the direction of acquisition. This rotation positions the radial and transverse components closer to the direction of maximum dip and strike. The section obtained from the rotated radial component was found to have slightly greater reflection continuity, while the rotated transverse component had little recognizable signal.

The application of P-SV dip moveout to the rotated data was able to improve the continuity of deeper reflections over that produced by depth-variant binning. Migration of the DMO-corrected section gives a result which correlates structurally to the migrated vertical-component stack, but has much lower signal bandwidth and signal-to-noise level.

INTRODUCTION

Multicomponent seismic surveys have been recorded for a number of years, mostly as an aid to interpretation of stratigraphic traps with little structural component (Garotta et al., 1985; Boyd and Harrison, 1991). A successful processing flow for such areas has largely been established (e.g., Tessmer and Behle, 1988). For regions in which significant structure occurs, however, dip moveout and migration of converted-wave data can become important additional processing considerations (Harrison, 1991).

One such area is the Casper Creek South Field of Wyoming. This field is composed of a pair of dome-like structures, formed by two doubly-plunging anticlines. Major fracturing and dips as large as 30 degrees are known to occur in the structure. The southern part of the field has become a major area of study by the Colorado School of Mines Reservoir Characterization Project. A discussion of the geology of the field can be found in Kramer and Davis (1991).

In 1988, a multicomponent reflection survey was conducted by UNOCAL across the field. The orientation of the UNOCAL line relative to the Casper Creek South Field is shown in Figure 1. Structural contours of the producing Pennsylvanian Tensleep

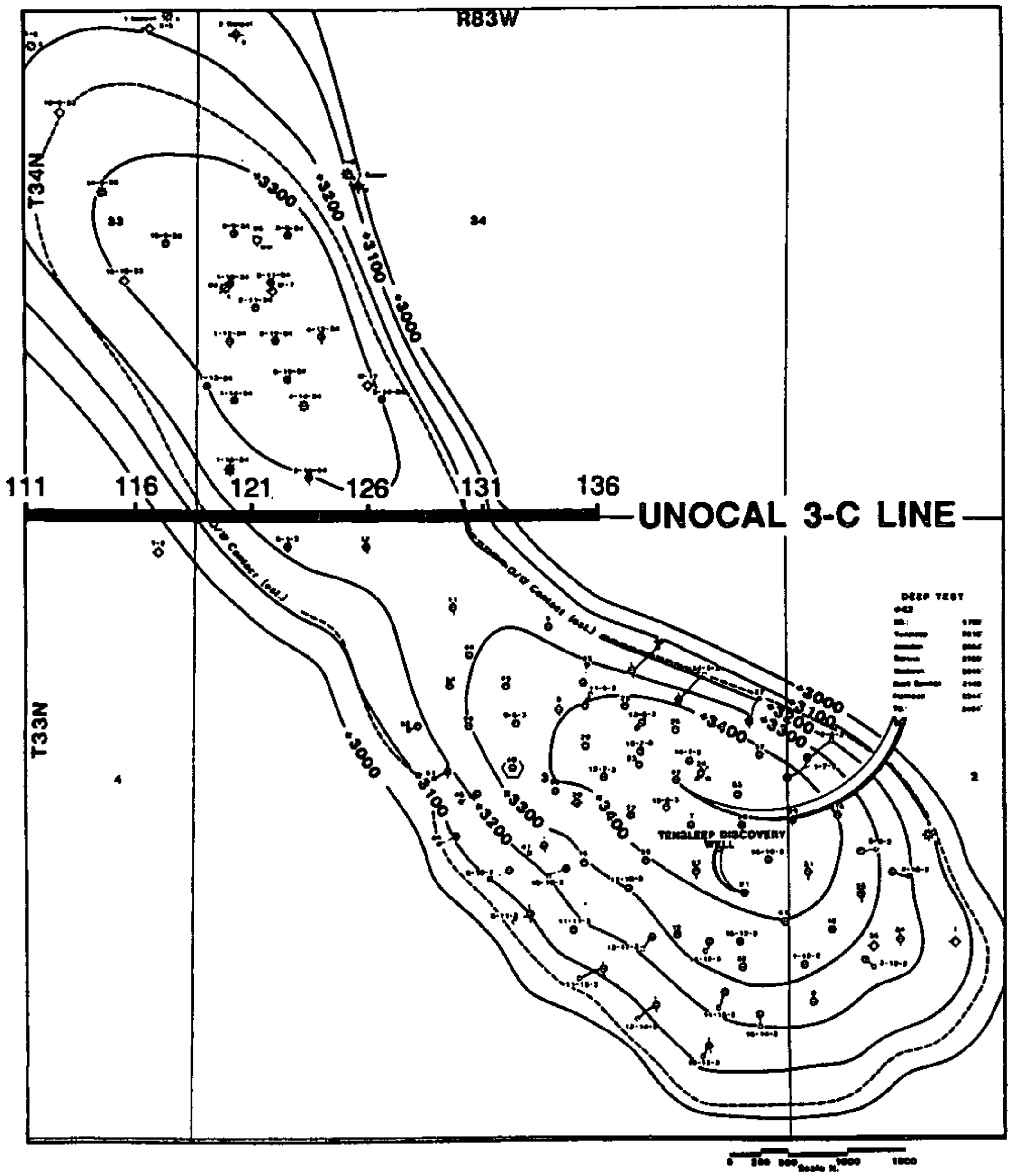

FIG. 1. Location map for Casper Creek South survey. Contours indicate structure in feet on the Tensleep Sandstone Formation (from Ruddiman, 1989).

Sandstone Formation are plotted in the figure, and the line is seen to cross an anticline at an angle of approximately 35 degrees from maximum dip.

The UNOCAL 3-C data set has been donated to the CREWES Project at the University of Calgary and was subjected to an extended converted-wave processing sequence. The results of this flow, which includes geophone rotation, P-SV dip moveout (DMO), and P-SV poststack migration, are presented in the following sections.

DATA ACQUISITION

The acquisition parameters used in the survey are summarized in table 1. The data were recorded using a 240-channel MDS-10 field system and a single 3-component geophone at each receiver station. The line consisted of a total of 80 receiver stations, from which data were recorded in the vertical, radial, and transverse directions for each sourcepoint. The receiver cable was held constant while the shot position was rolled through the line in an east-west direction. A typical record from shotpoint 131 of the survey is shown in Figure 2. The radial and horizontal components have been filtered with a 50 Hz highcut to remove high-frequency noise. The data are seen to have a very low signal-to-noise ratio, and reflections are difficult to distinguish on the horizontal components.

Table 1. Field acquisition and recording parameters for the Casper Creek South survey.

Energy source	Dynamite
Shot size	4.5 kg
Shot depth	46 m
Geophone array	single geophone
Type of geophones	3-component, 14 Hz
Group interval	15 m (50 ft)
Shot interval	60 m (200 ft)
Instruments	MDS-10
Channels	240
Recording filter	Out-128 Hz
Notch filter	Out
Sample interval	2 ms
Record length	4 s

DATA PROCESSING

The vertical-component data were processed using the flow outlined in Figure 3. The final stack section shown in Figure 4 is seen to have many coherent reflections. At SP 126 the Tensleep Formation is estimated to be at around 470 ms, and basement is at around 640 ms. A structure time difference of about 80 ms occurs between the west end of the line and the crest of the anticline. This stack section was migrated using a finite-difference algorithm, giving the result shown in Figure 5.

The radial and transverse component data were initially processed using the sequence summarized in Figure 6. Obtaining a receiver static solution is complicated by the presence of structure. To illustrate the problem, a common-receiver stack created using the final static and velocity solutions is shown in Figure 7. The large difference in structure across the line causes improper stacking of events within the receiver gathers, giving severe attenuation away from the crest of the anticline. To overcome this problem, differences in CCP structure time were measured from an initial CCP section. The NMO-corrected data were then shifted to a common time by removal of the differences on a CCP basis. This

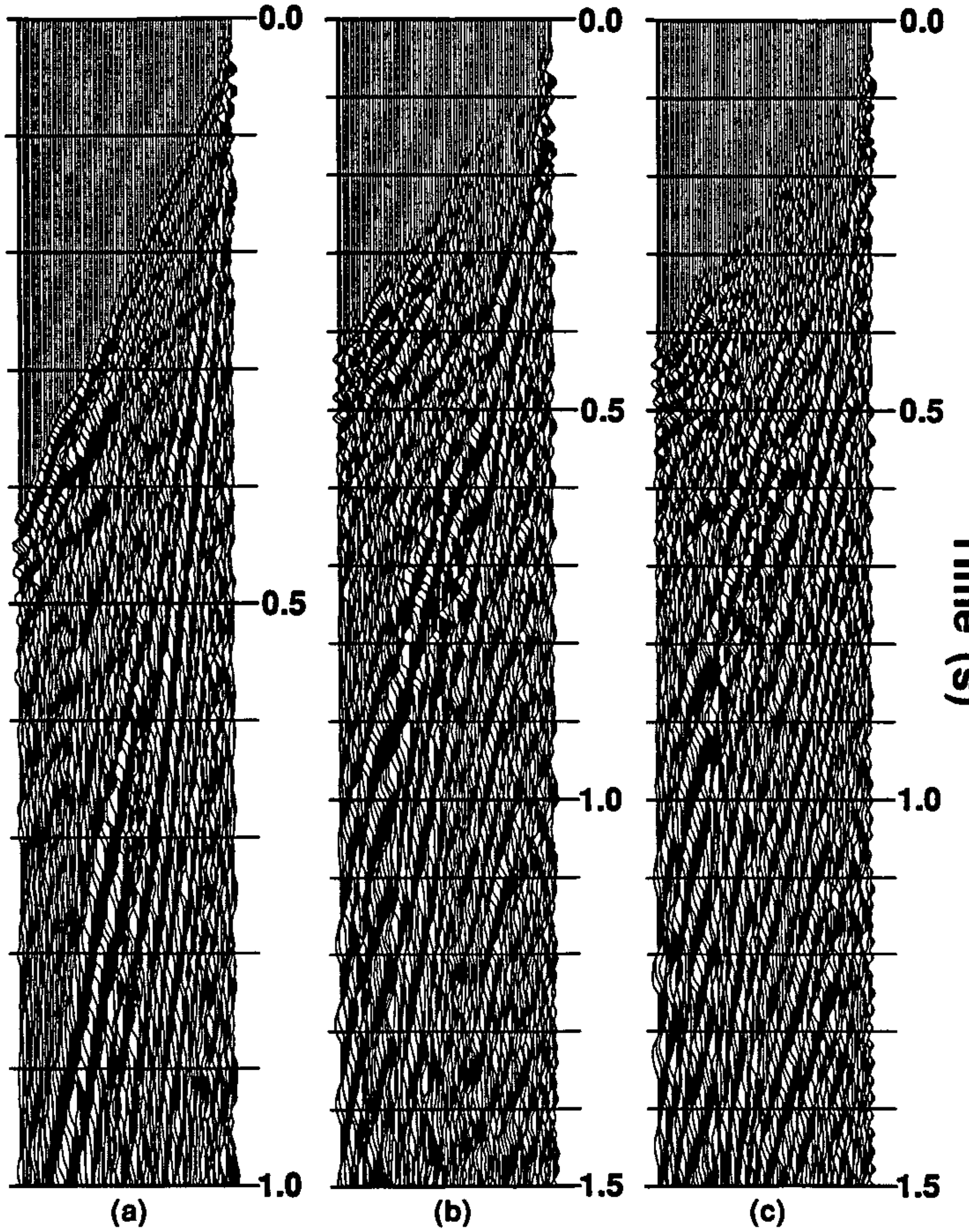

FIG. 2. Data from SP 131: a) vertical component; b) radial component; c) transverse component.

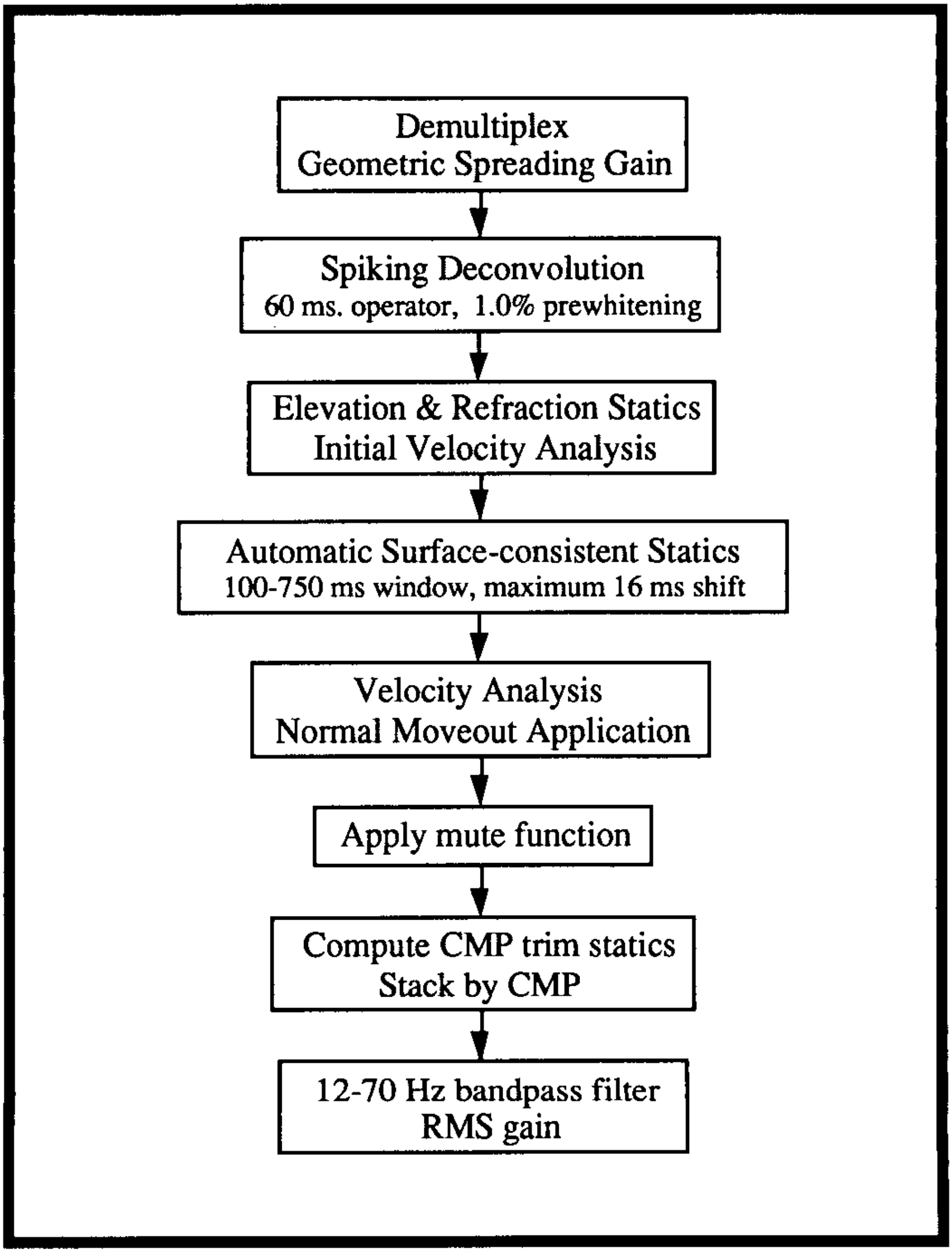

FIG. 3. Processing flowchart for the vertical-component data.

was found to greatly increase the coherency of events on subsequent surface stacks (Figure 8). It should be noted that the removal of structure was only done as an aid in determining statics; all other processing was carried out on the uncorrected data. Residual statics were found to be generally within ±16 ms, with a maximum value of -36 ms.

An average Vp/Vs ratio of 2.10 was determined by event correlation between the vertical and radial sections. The data from the radial and transverse directions were

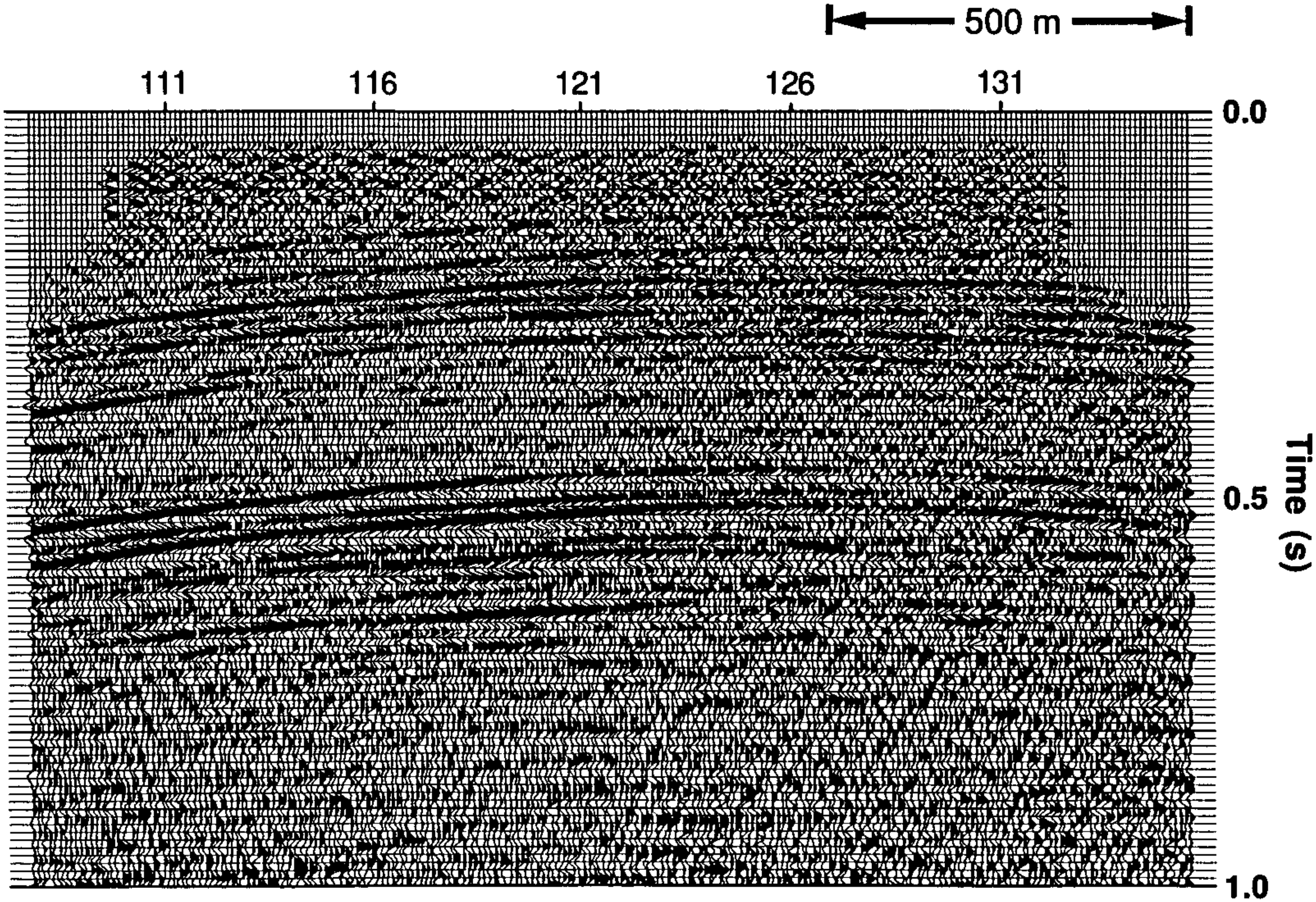

FIG. 4. Final stack section for the vertical-component data.

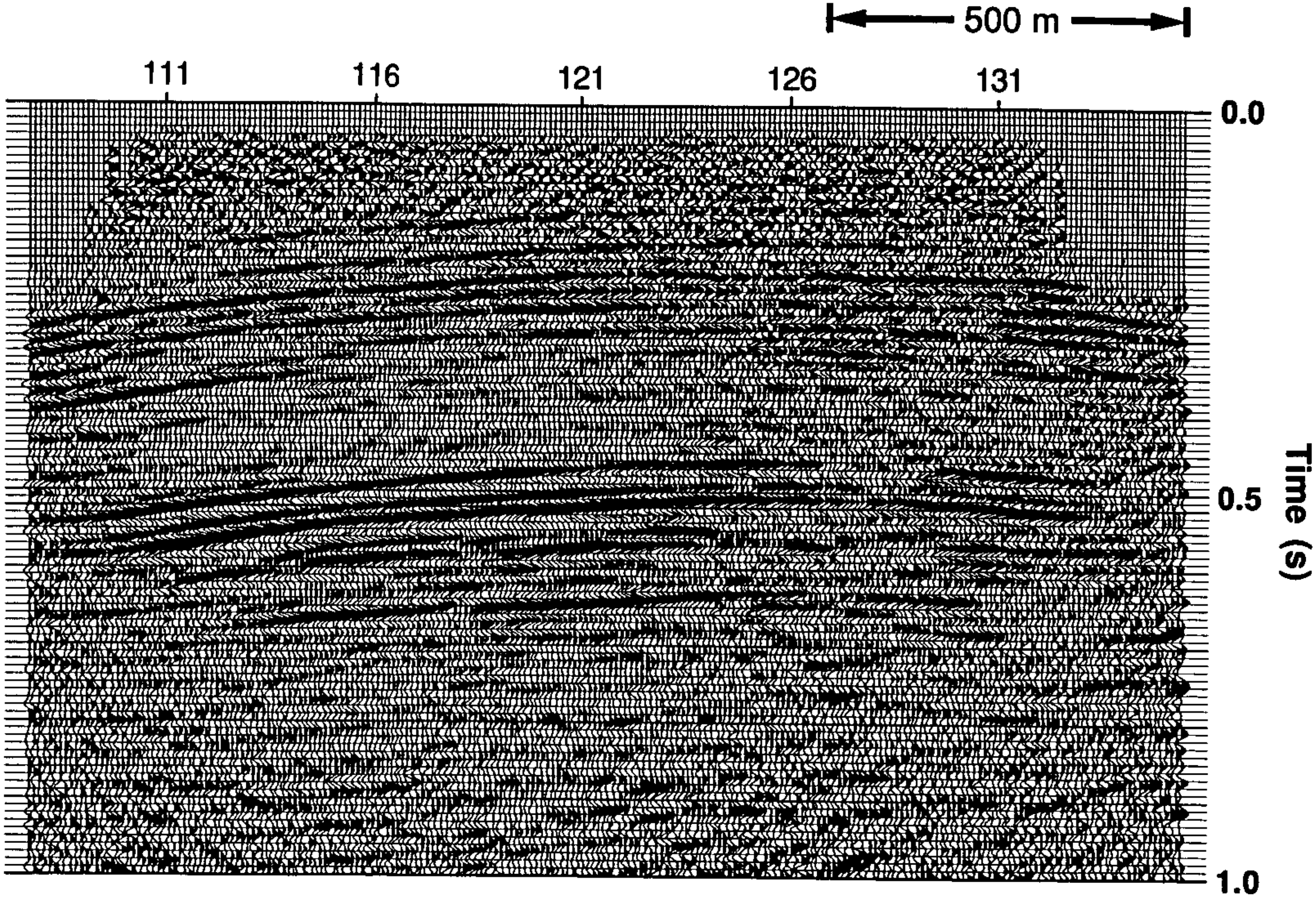

FIG. 5. Migrated stack section for the vertical-component data.

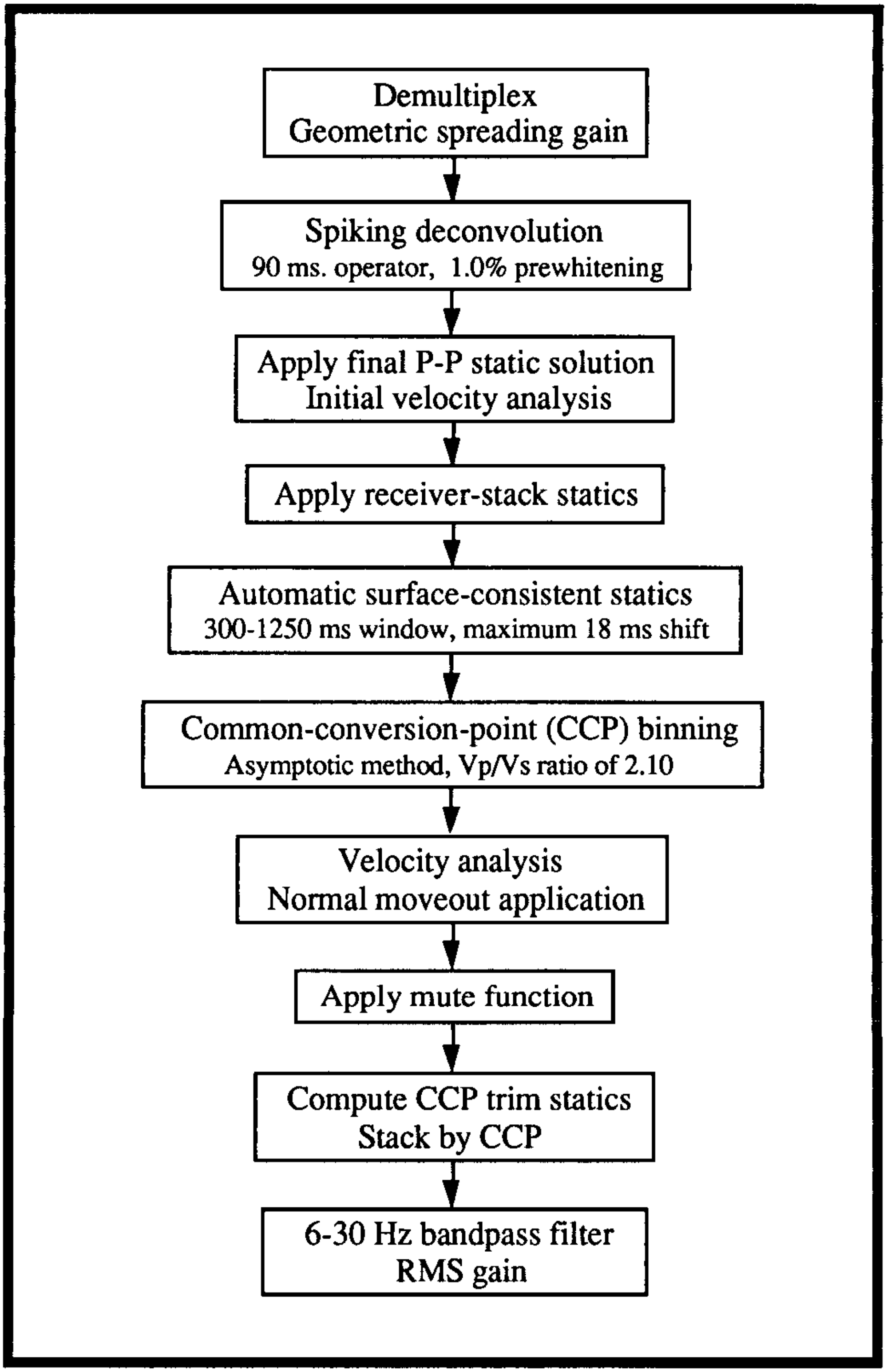

FIG. 6. Processing flowchart for the radial and transverse component data sets.

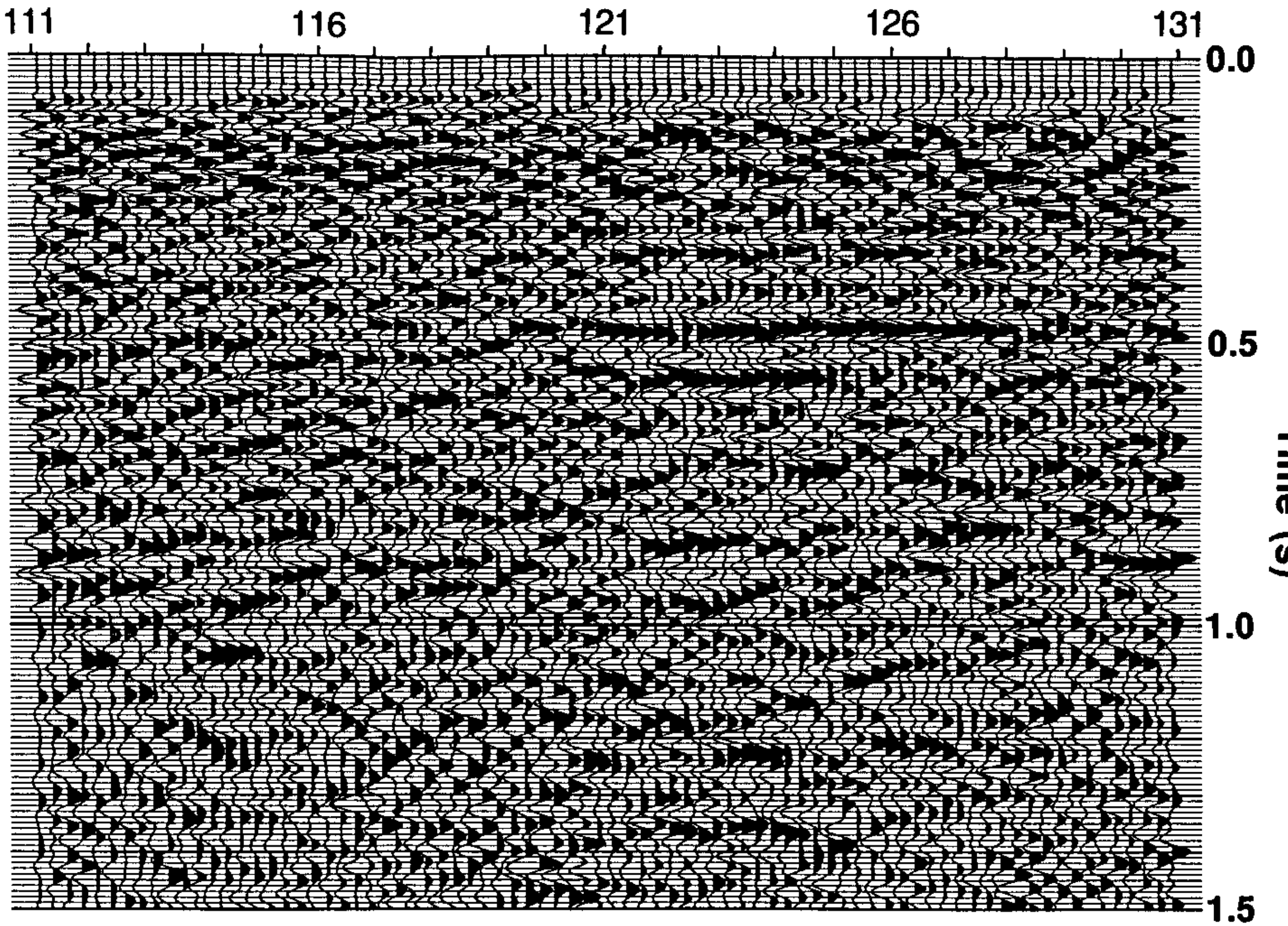

FIG. 7. Radial-component common-receiver stack created using the final static and velocity solutions.

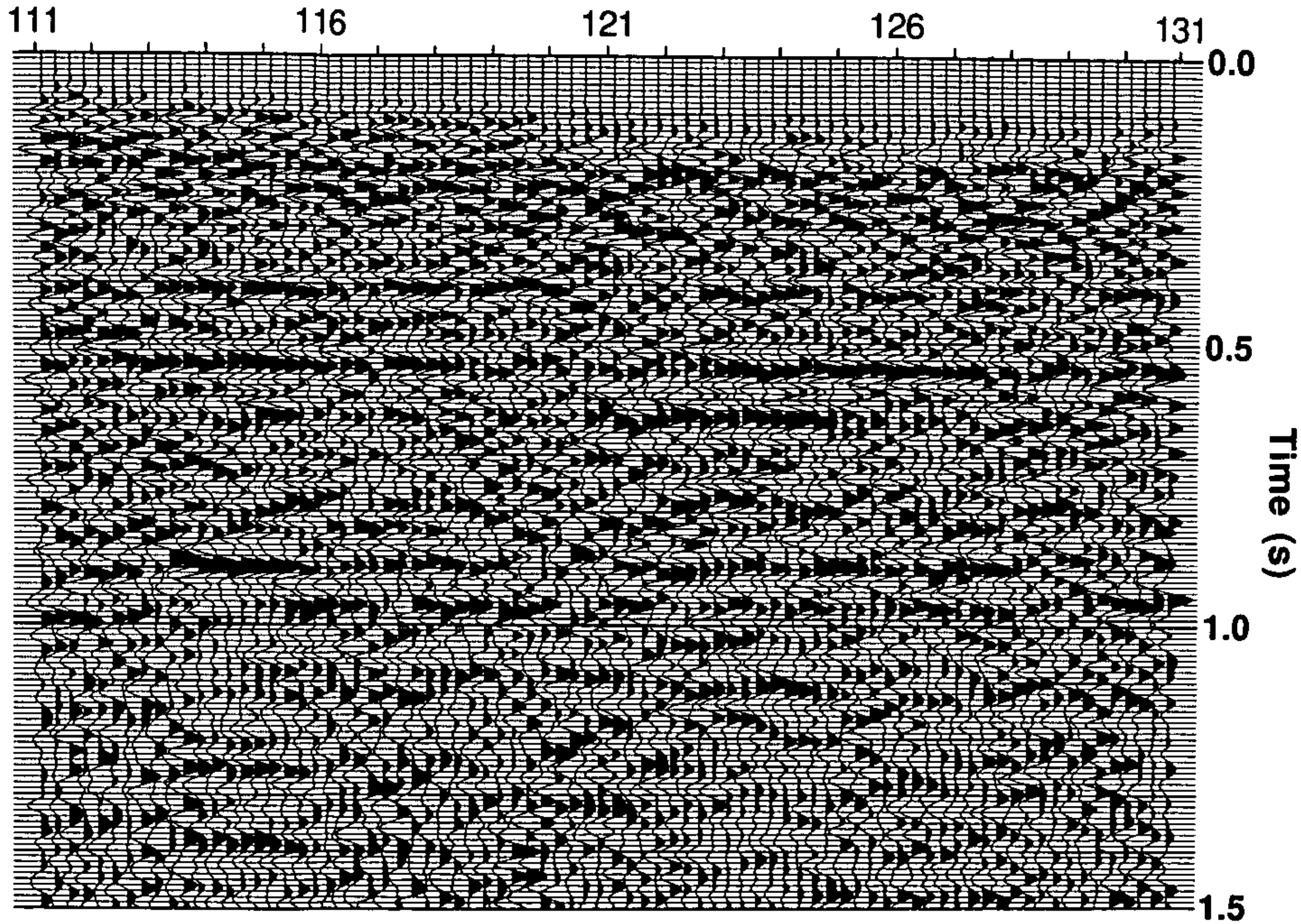

FIG. 8. Radial-component common-receiver stack after correction for differences in CCP structure time.

gathered and stacked using this ratio and the asymptotic approximation (Fromm et al, 1985), giving the sections shown in Figures 9 and 10.

There was found to be significant energy on the transverse-component section, and a geophone rotation test was performed in order to determine the orientation that minimizes the transverse component data. This was done in the hope of improving the quality of the radial-component section at the expense of the transverse section. The test was done by rotating and stacking the two horizontal data components using clockwise angles ranging from -60 degrees to +30 degrees in 15 degree increments. Portions of the resulting stack sections are shown in Figures 11 and 12. From this test, a rotation angle of -22 degrees was estimated, and the rotated data were again processed and stacked (Figures 13 and 14). The resulting radial component section shows better overall signal strength and reflection continuity than does the unrotated radial component section, while the opposite is true for the transverse component.

The rotated radial-component data were restacked using the depth-variant binning method (Eaton et al, 1989) to give the section shown in Figure 15. The process gives improved reflection continuity, but deeper events around the time of basement are generally absent.

Depth-variant P-SV DMO (Harrison, 1990) was also applied to the rotated radial-component data set (Figure 16). The process gives better overall reflection continuity than does the depth-variant-stacked section (Figure 15). Also, the basement reflection has been enhanced, and can be followed across most of the section. Operator noise from the far-offset data is, however, a problem at the ends of the line where fold is insufficient to give proper cancellation. The application of an *f-k* filter with a passband of ±4 ms/trace and a 6 db reject reduces some of this noise and enhances the continuity of the deeper events (Figure 17).

Poststack migration using the migration velocity equation of Harrison (1991) was applied to the *f-k* filtered DMO section, producing the result shown in Figure 18.

A side-by-side comparison of the vertical-component section and the DMO-corrected radial component is presented in Figure 19. Sample NMO-corrected common-offset records for the vertical- and radial-component data are shown in Figure 20.

DISCUSSION

The data quality of the radial component is seen from the common-offset stacks of Figure 20 to be very poor, with no optimum window for shear reflections. This general absence of good reflection signal, coupled with the presence of substantial amounts of structure, make both static and velocity estimation difficult.

Although the rotation of the horizontal components did give some overall improvement in the rotated radial-component section, it can be seen in Figures 11 and 12 that the reflection at about 1100 ms is not maximized by a -22 degree rotation. The best rotation angle appears to fall in the range of 0-15 degrees. In support of this, it was found that P-SV dip moveout applied to the unrotated data gave a more continuous reflection at 1100 ms than is seen in Figure 16. This change in rotation angle with depth might indicate

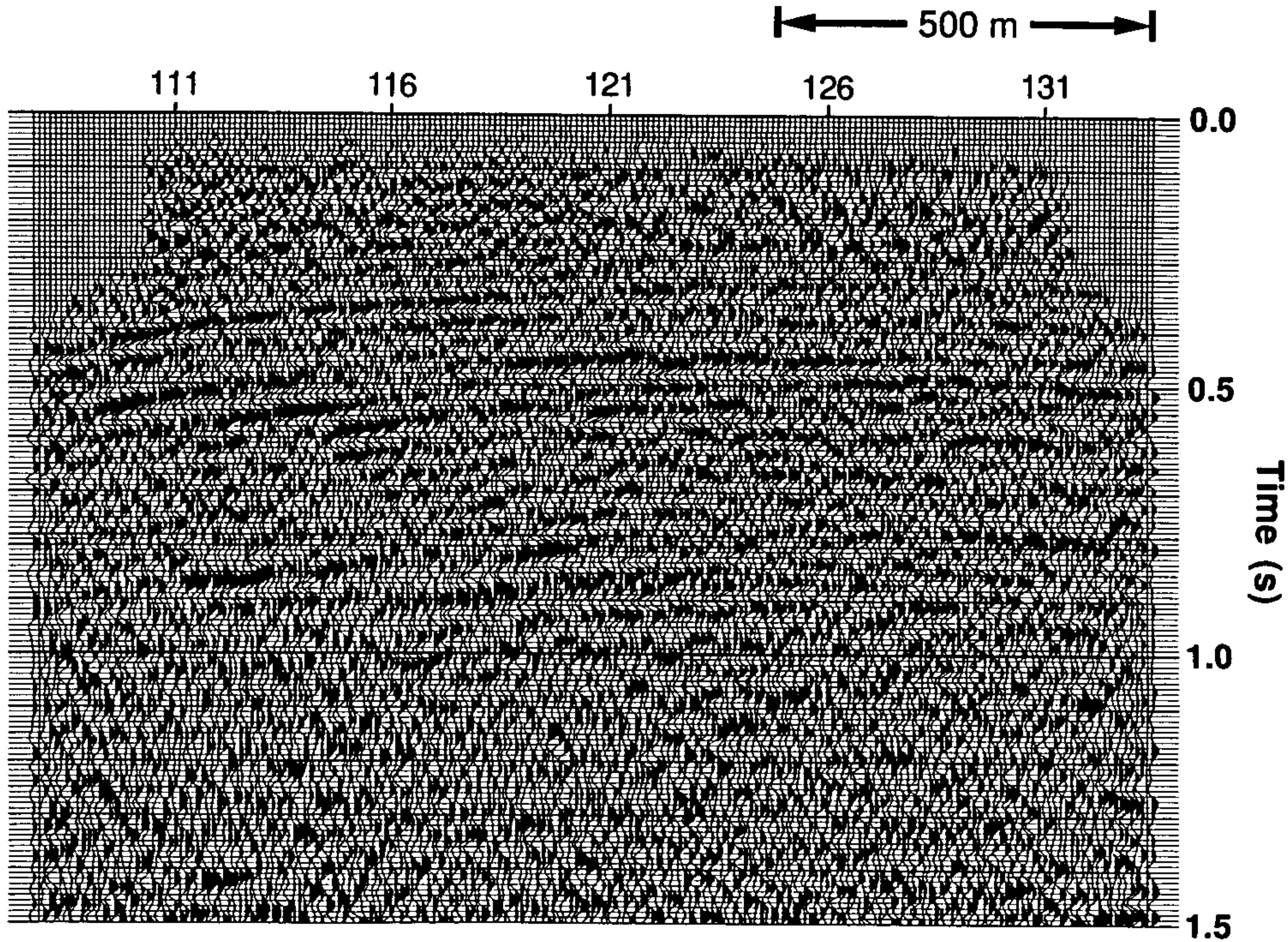

FIG. 9. Radial-component data stacked using the asymptotic method.

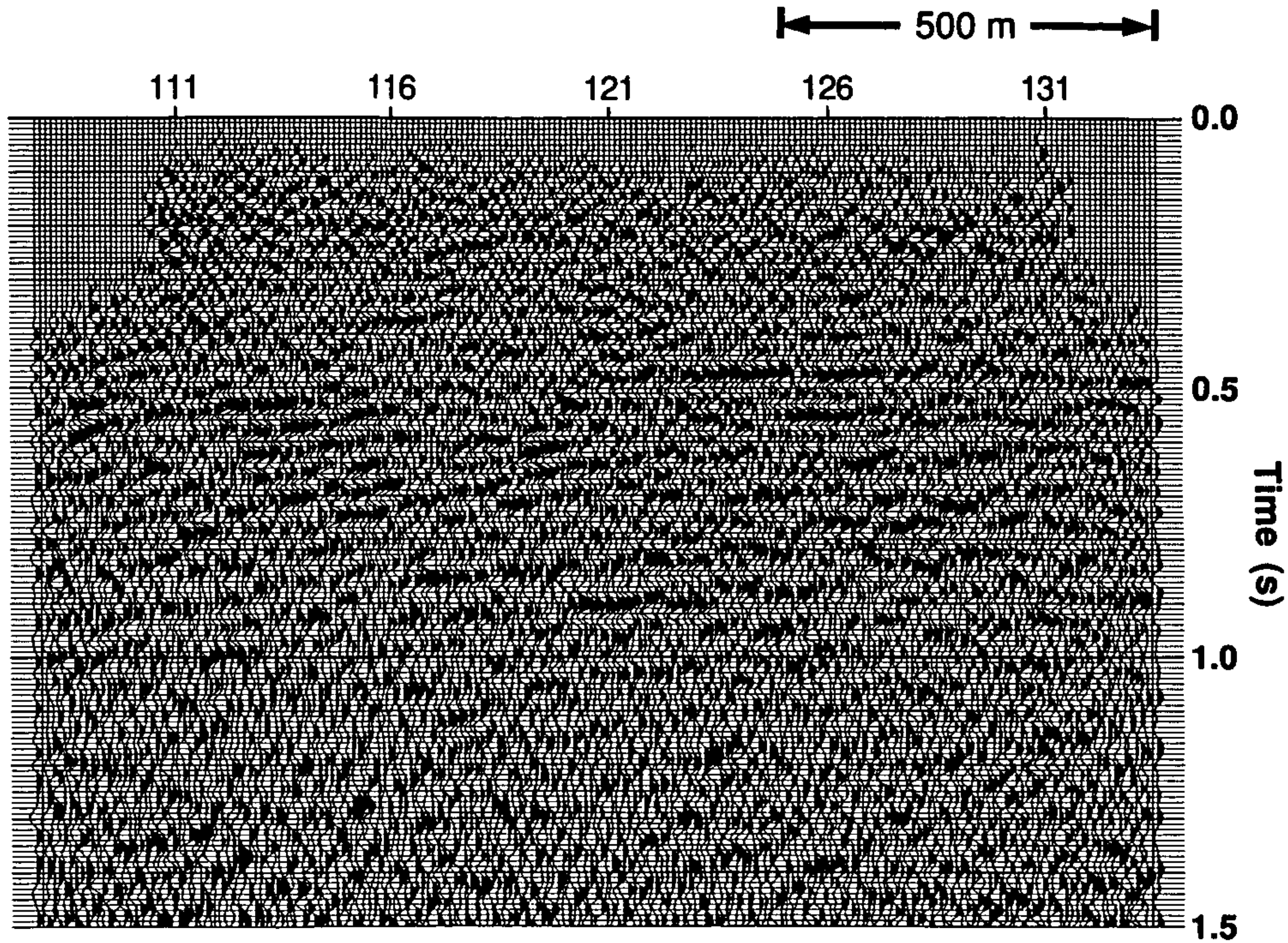

FIG. 10. Transverse-component data stacked using the asymptotic method.

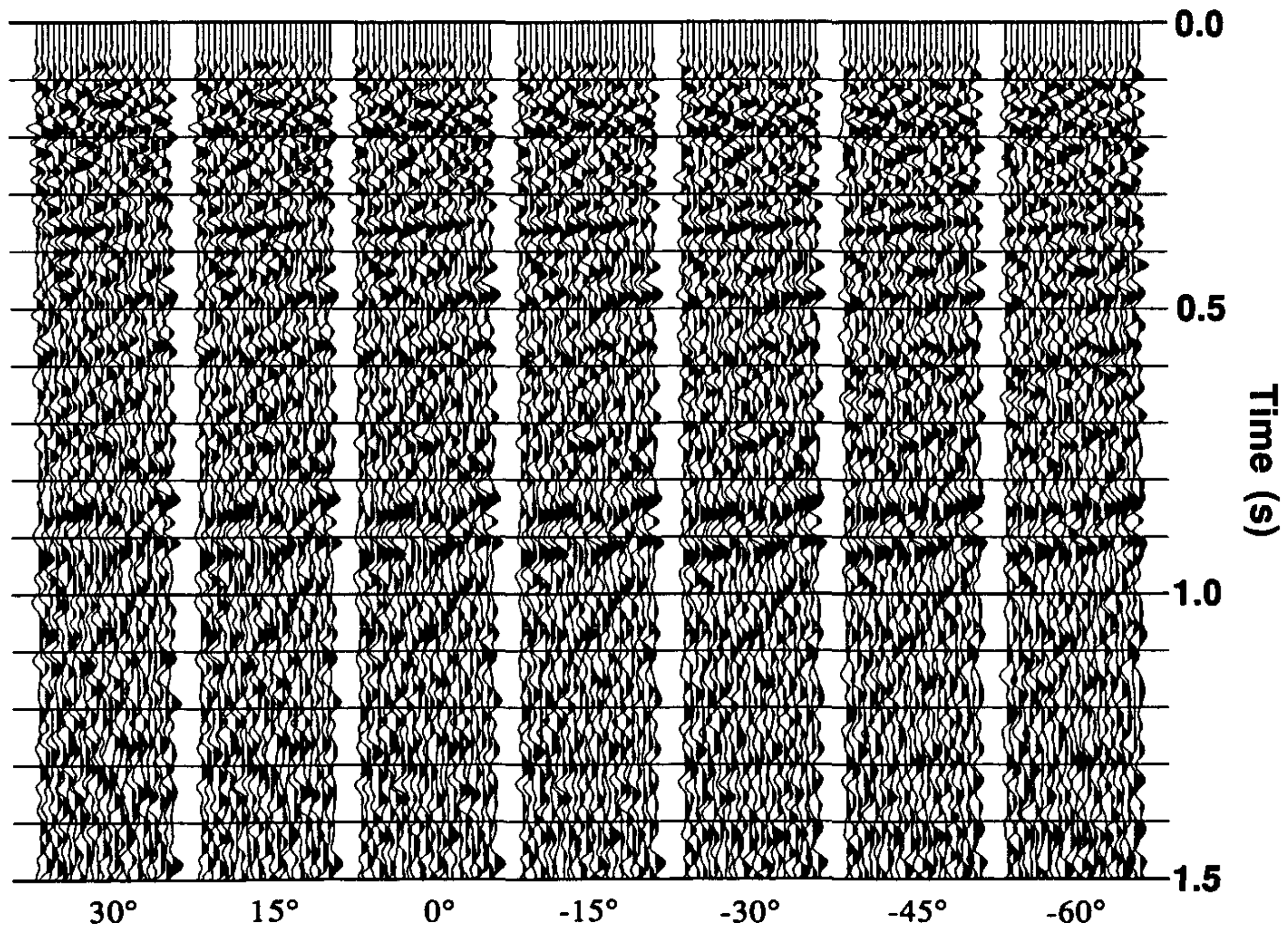

FIG. 11. Geophone rotation analysis for radial-component data.

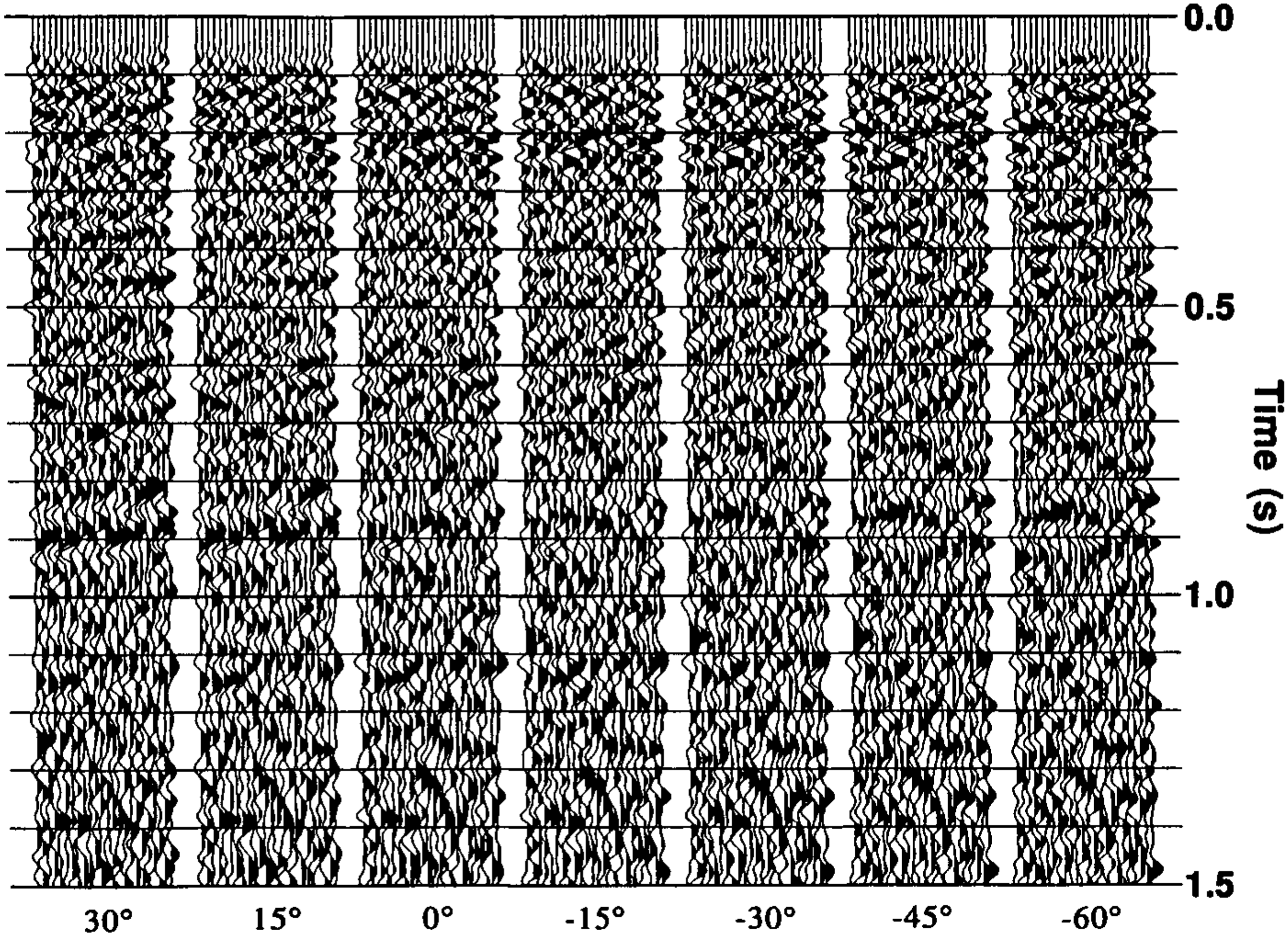

FIG. 12. Geophone rotation analysis for transverse-component data.

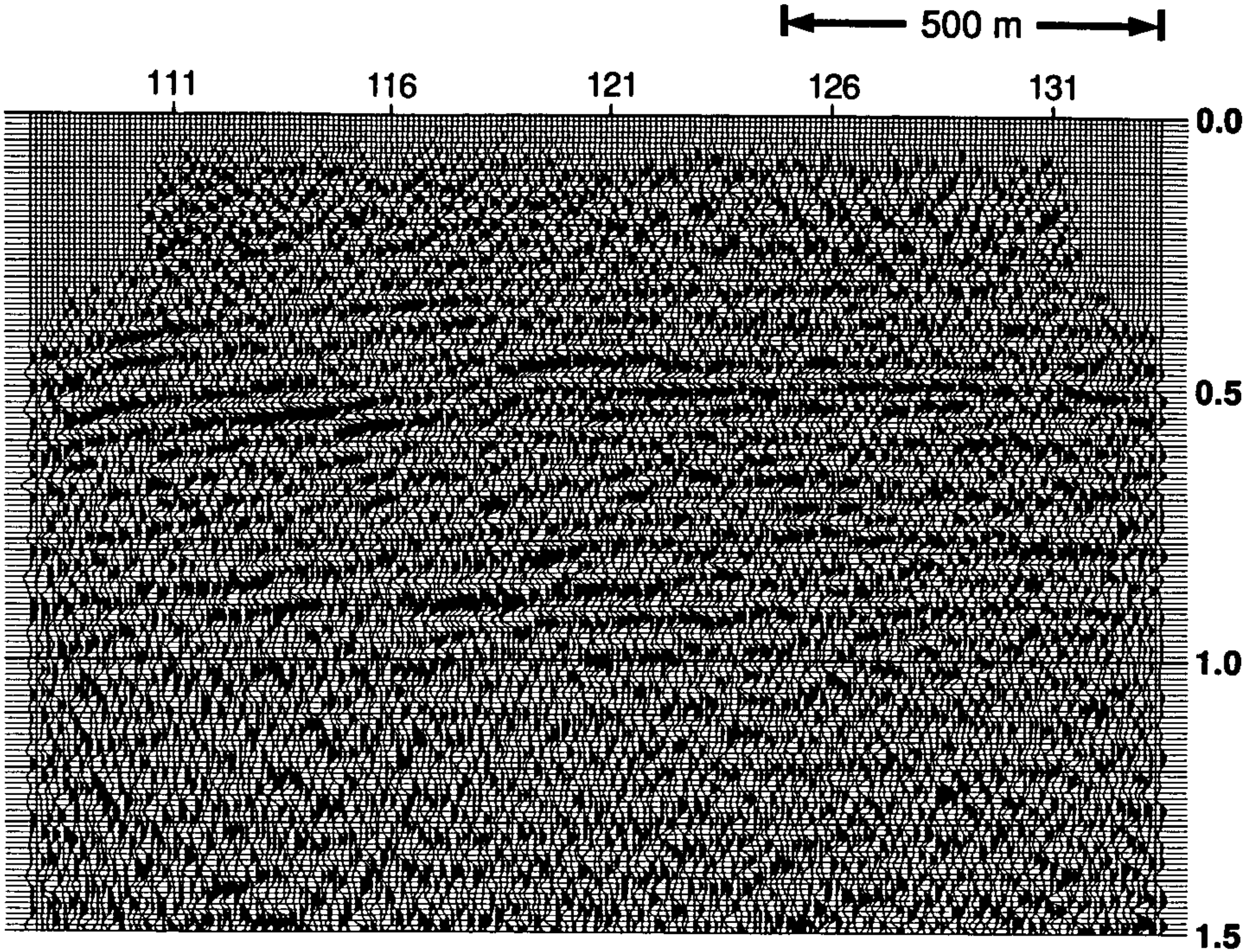

FIG. 13. Rotated radial-component data stacked using the asymptotic method.

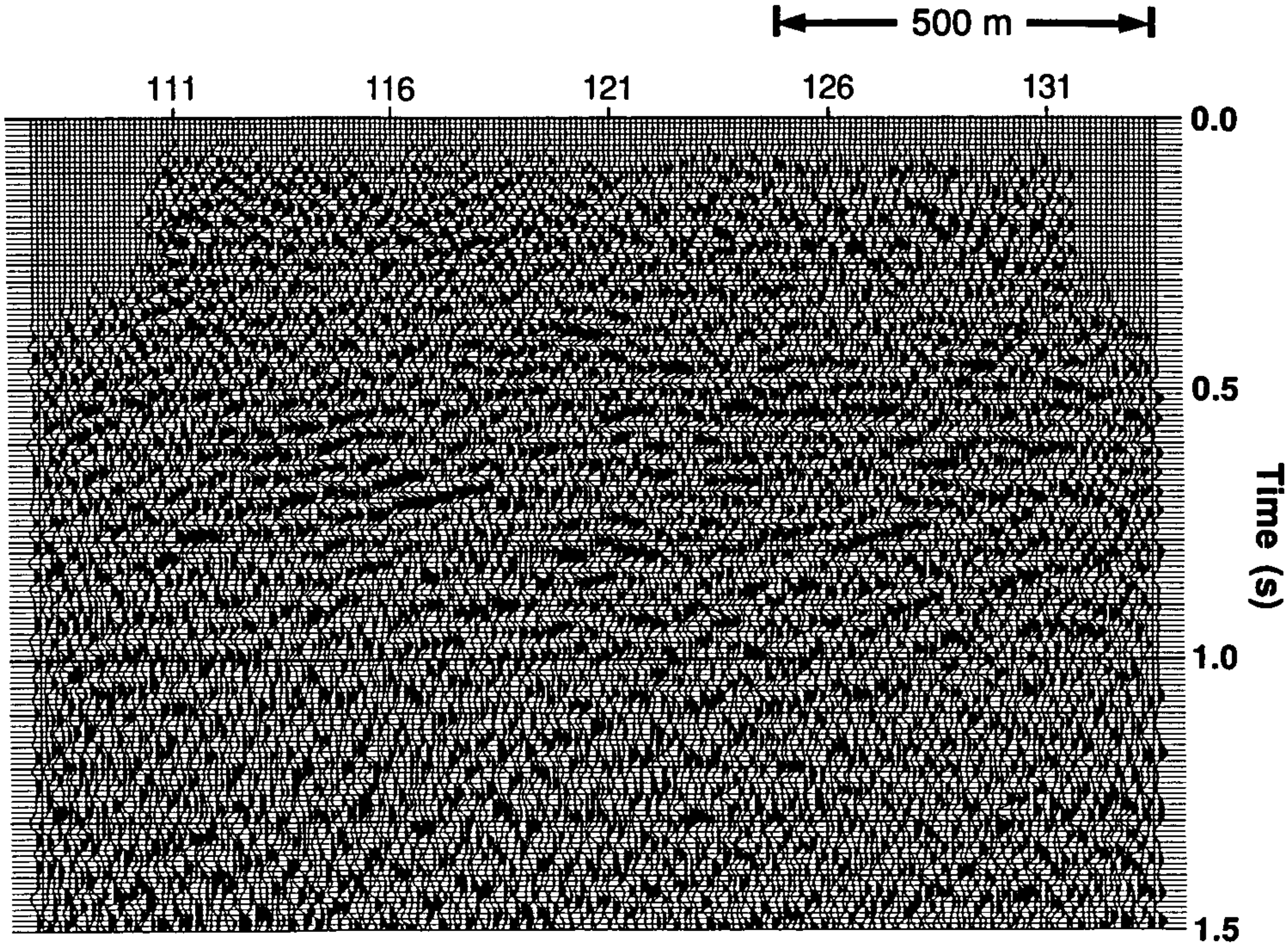

FIG. 14. Rotated transverse-component data stacked using the asymptotic method.

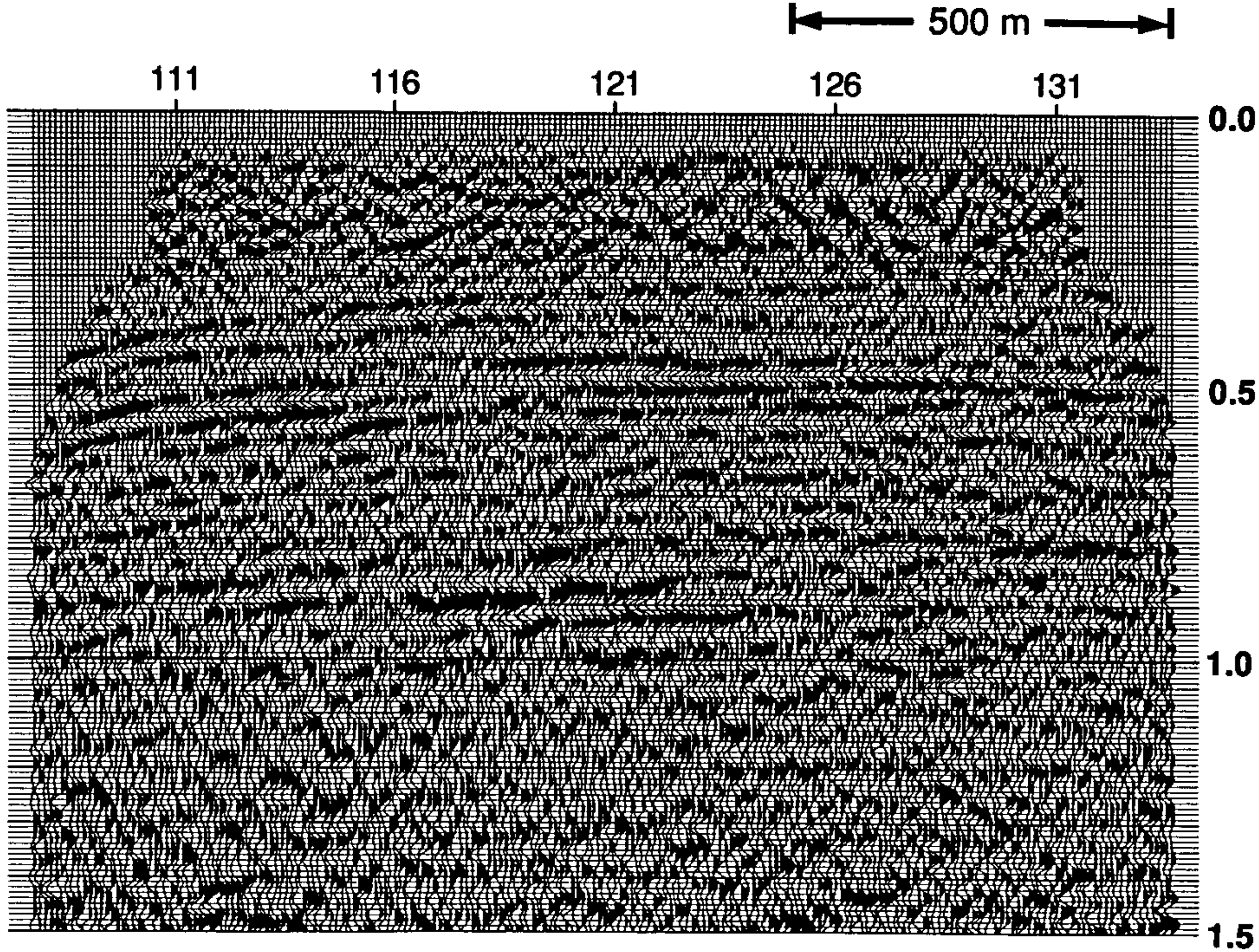

FIG. 15. Rotated radial-component data stacked using the depth-variant binning method.

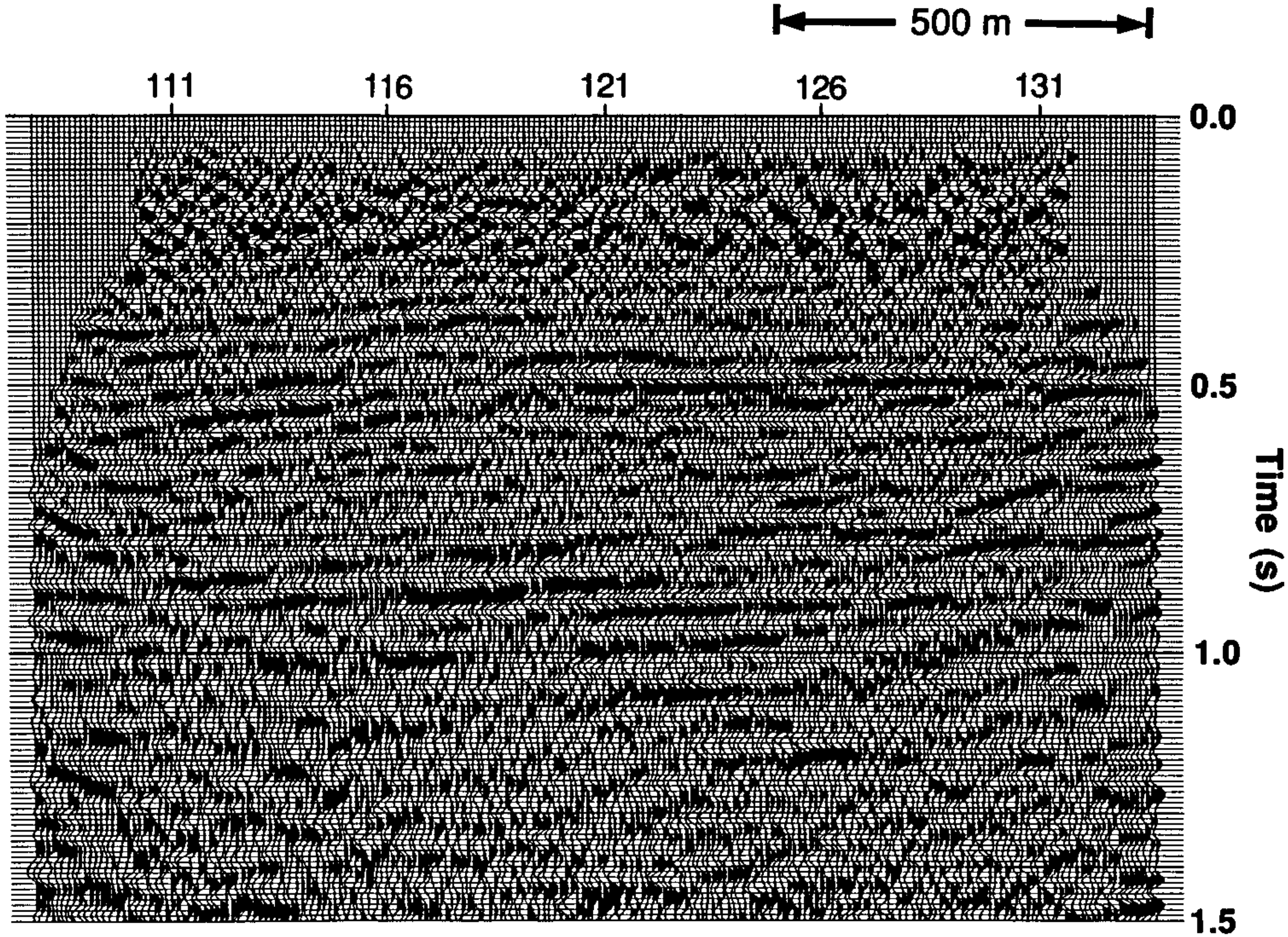

FIG. 16. Rotated radial-component data stacked using P-SV DMO.

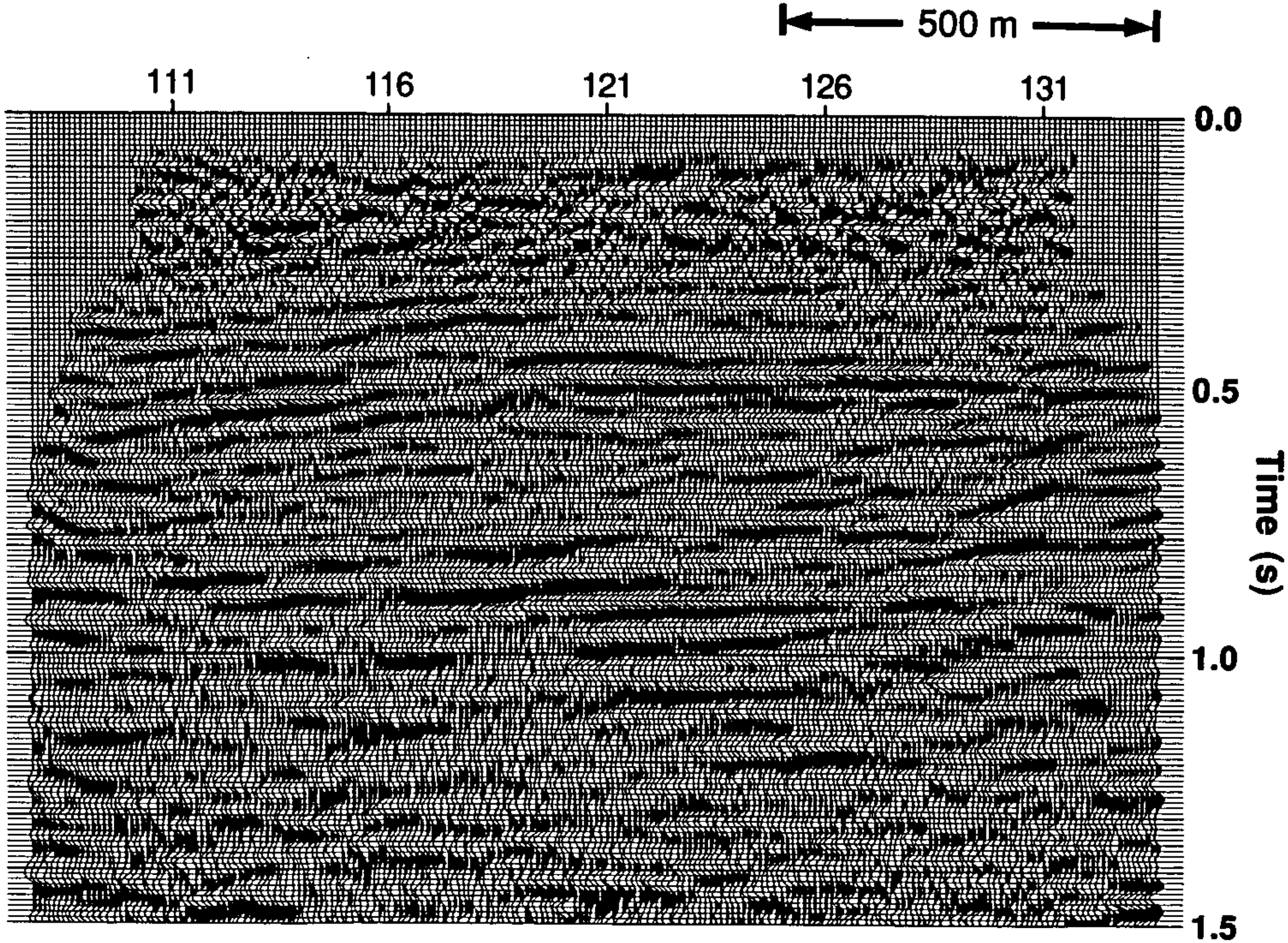

FIG. 17. *f-k* filter applied to the rotated radial-component data stacked using P-SV DMO.

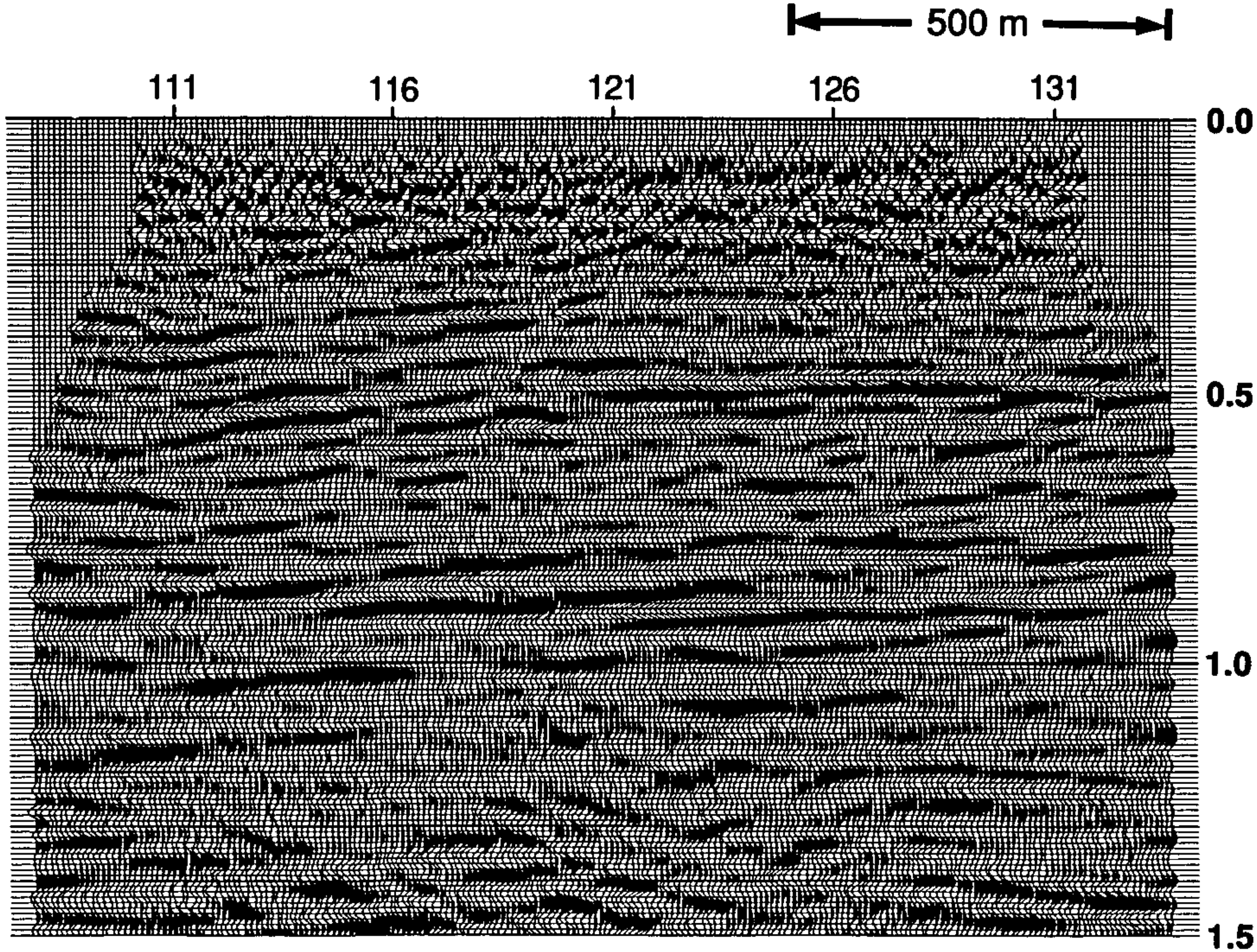

FIG. 18. Migration applied to the rotated radial-component data stacked with P-SV DMO and *f-k* filter.

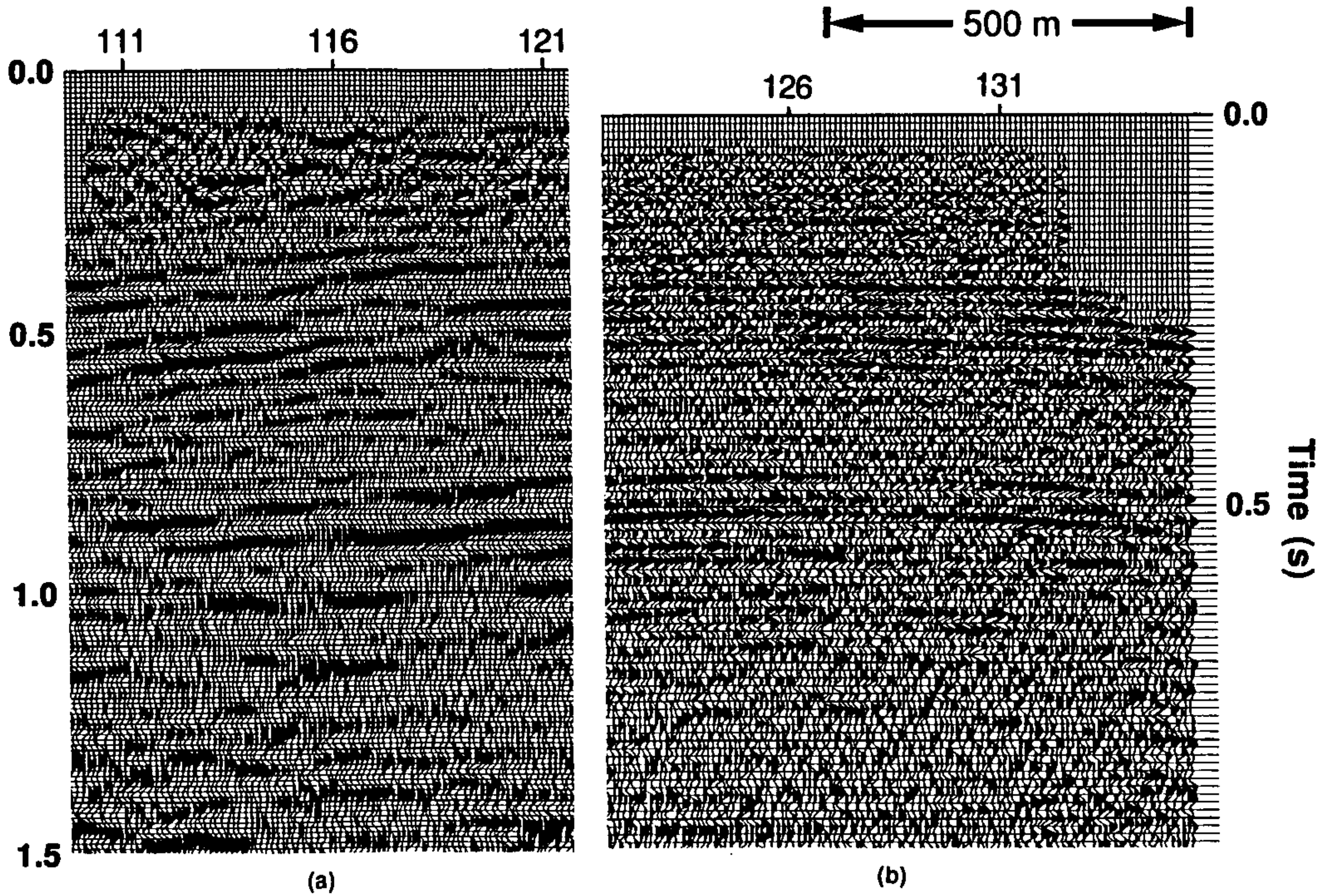

FIG. 19. Side-by-side comparison of a) the f-k filtered DMO section for the rotated radial-component, and b) the vertical-component stack section.

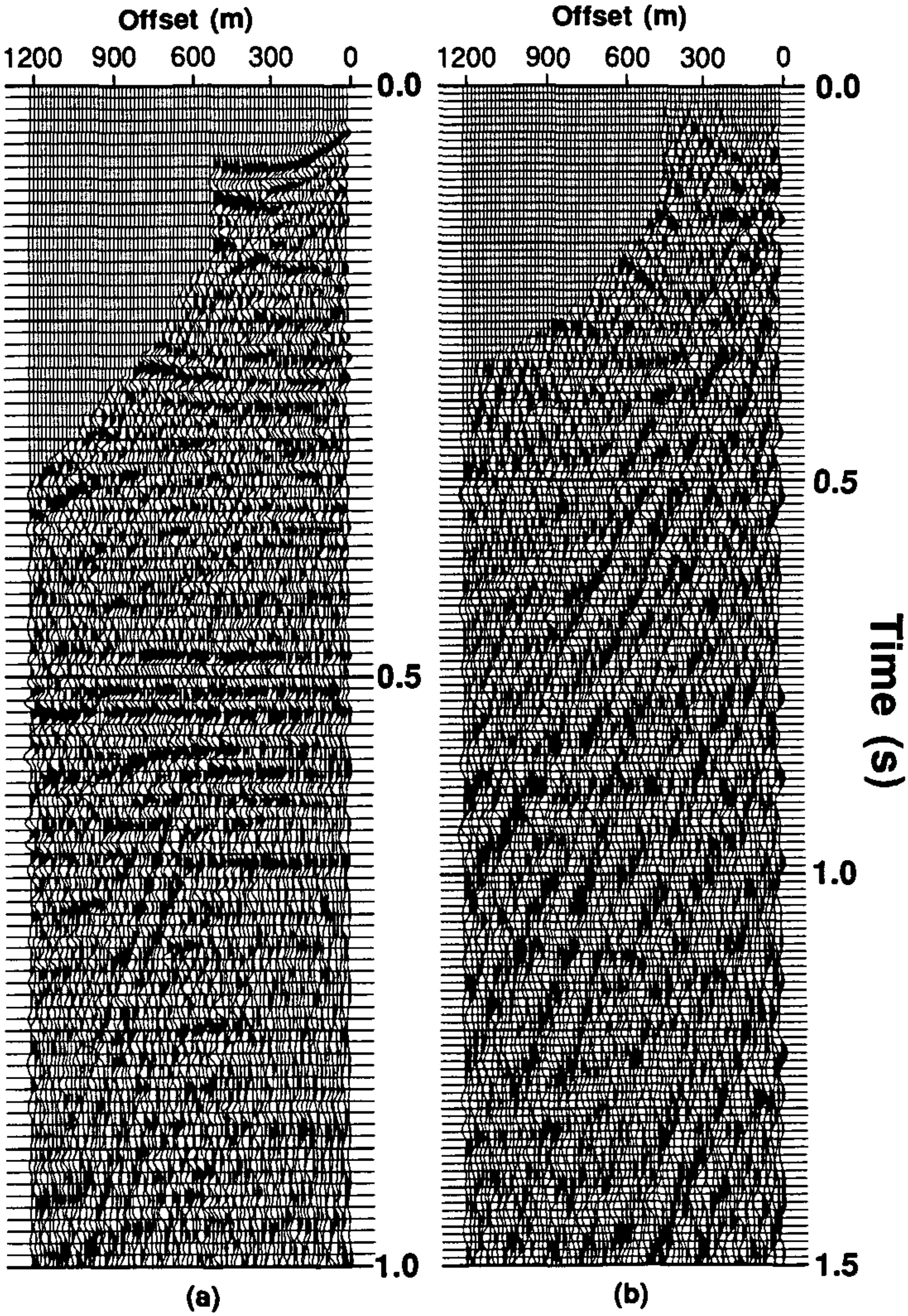

FIG. 20. NMO-corrected common-offset stack records: a) vertical component; b) radial component.

the presence of anisotropy in the 850-1100 ms interval. Through the analysis of multicomponent VSP data from a well south of this line, Kramer and Davis (1991) found that the zone encompassing the Tensleep formation does exhibit velocity anisotropy in the range of 4 to 11 percent.

From Figure 19, there does appear to be general correspondence between reflections on the vertical and radial sections. The large difference in data bandwidth and quality make the correlation of specific events difficult, especially in the absence of well information.

CONCLUSIONS

In areas of structure, the common-receiver stack method of resolving residual statics fails. The method must be modified to compensate for changes in structure time across the section, or some other, more robust, method must be found.

For the data set described here, it was found that geophone rotation was useful, although not all events were optimized by the same rotation angle. A more sophisticated method of polarization analysis and/or correction would be helpful.

The application of P-SV dip moveout to the rotated data was able to improve the continuity of deeper reflections over that produced by depth-variant binning. Migration of the DMO-corrected section gives a result which correlates structurally to the migrated vertical-component stack, but has much lower signal bandwidth and signal-to-noise level.

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