Time-to-depth conversion using image waves

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ABSTRACT

Image rays have been used for time-to-depth conversion of seismic horizons. In this paper, an analogous wave approach is introduced. Each time slice from the time migrated section is used to propagate as an image wave. By applying the imaging condition, these time slices are mapped into depths.

INTRODUCTION

Structural imaging and drilling requires good techniques for time-to-depth conversion of the interpreted time section. Prestack depth migration provides a direct method for the conversion, however the time-consuming iterative velocity analysis make it less attractive for simple structural imaging. Alternatively, normal-ray migration or zero-offset depth migration, which based on the ray / wave propagating upwards, normal to the horizons, can be used for the conversion in simple structures with improved efficiency. The result for the zero-offset depth migration is equivalent to the prestack depth migration provided that DMO successfully converts the data from the common-mid-point gather into the common-reflection-point gather. This may be true for a V(z) velocity field. For smooth velocity structures, prestack time migration can be first used to collapse the diffraction patterns and improve the interpretation of the time horizons. Then the concept of an image ray, introduced by Hubral (1977), can be used to convert time-migrated horizons into depths. It is assumed that after time migration, the ray is described by image ray, which propagating downwards and perpendicularly to the surface. Unfortunately, it was shown (Black and Brzostowski, 1994) that image ray migration is corrected for small dips only. This paper extends the concept of the image ray into a wave approach for the possibility of the time-to-depth conversion.

IMAGE RAY MIGRATION

Figure 1 shows the concept of image ray for the time-to-depth conversion.The image ray originates from the surface and propagates vertically downwards. It obeys Snell's law as it hits various interfaces. From the time-migrated section, the trace at the same lateral position as the image ray at the surface is mapped into depths by tracing the rays and converting the two-way travel-times it takes to the corresponding depths. Hence the traces on the time-migrated section are converted into depths and corrected to their appropriate lateral position.

WAVE APPROACH

Figure 2 shows the image rays, with the same travel-times, but originating from different lateral position along the surface are mapped into depths. Since these rays have the same travel time, the surface perpendicular to these rays forms wavefront, therefore this wavefront can be modeled with the wave equation starting from the surface with uniform amplitudes. Once this initial condition is set up, image waves are generated and propagated downwards as time increases in the wave equation.

In Figure 3, a velocity model with three layers is shown. Figure 4 shows the image wavefront propagating through the velocity model at every 50 ms interval. If a spike is propagated from the surface instead of a uniform sources, circular wavefronts will be generated as shown in Figure 5. To propagate the wave in the image ray direction, the wavefronts in any other directions need to be filtered out. This can be done, in general, by propagating a selected time slice from a time migrated section, and at each time step, filtering the energy that does not match with the image wave modeled at that time step. Figure 6 shows the result of this process on propagating a selected spike in a velocity model shown in Figure 3. The waves are propagated along the image ray direction and refracted at the interface according to the Snell's law.

IMAGE WAVE MIGRATION

Once the waves are downward continued in the image ray directions, the imaging condition is required to complete the migration process. The imaging condition is simply to stop propagating the waves and output the samples at depths when the downward continued time is equal to the one-way time of the selected time-migrated slice.

EXAMPLES

Figure 7 is the synthetic time-migrated section resulting from the velocity model shown in Figure 3. The result of the image wave migration is shown in Figure 8. Figure 9 is another velocity model. The zero-offset stacked section is shown in Figure 10. The time-migrated section is shown in Figure 11. Figures 12 to 15 are examples of image waves modeled at different time intervals. The result of the image wave migration is shown in Figure 16. It is shown that, after image wave migration, a reasonably good depth image of a flat layer underneath the structures results, with small depth errors. These depth errors may represent the limitation of using image ray/wave for the conversion in an area with large dips, as suggested by Black and Brzostowski (1994).

CONCLUSIONS

In this paper, the concept of the image wave is introduced. It is demonstrated that, like an image ray, it can be used for the time-to-depth conversion from a time-migrated section, but without picking the time horizons. Since each time slice is preformed for the mapping independently, they can be selected accordingly, to image the target.

REFERENCES

Hubral, P., 1977, Time-migration -- Some ray-theoretical aspects: Geophys. Prosp. 25, 738-745.

Black, J. L., and Brzostowski, M. A., 1994, Systematic of time-migration errors: geophysics 59, 1419-1434.

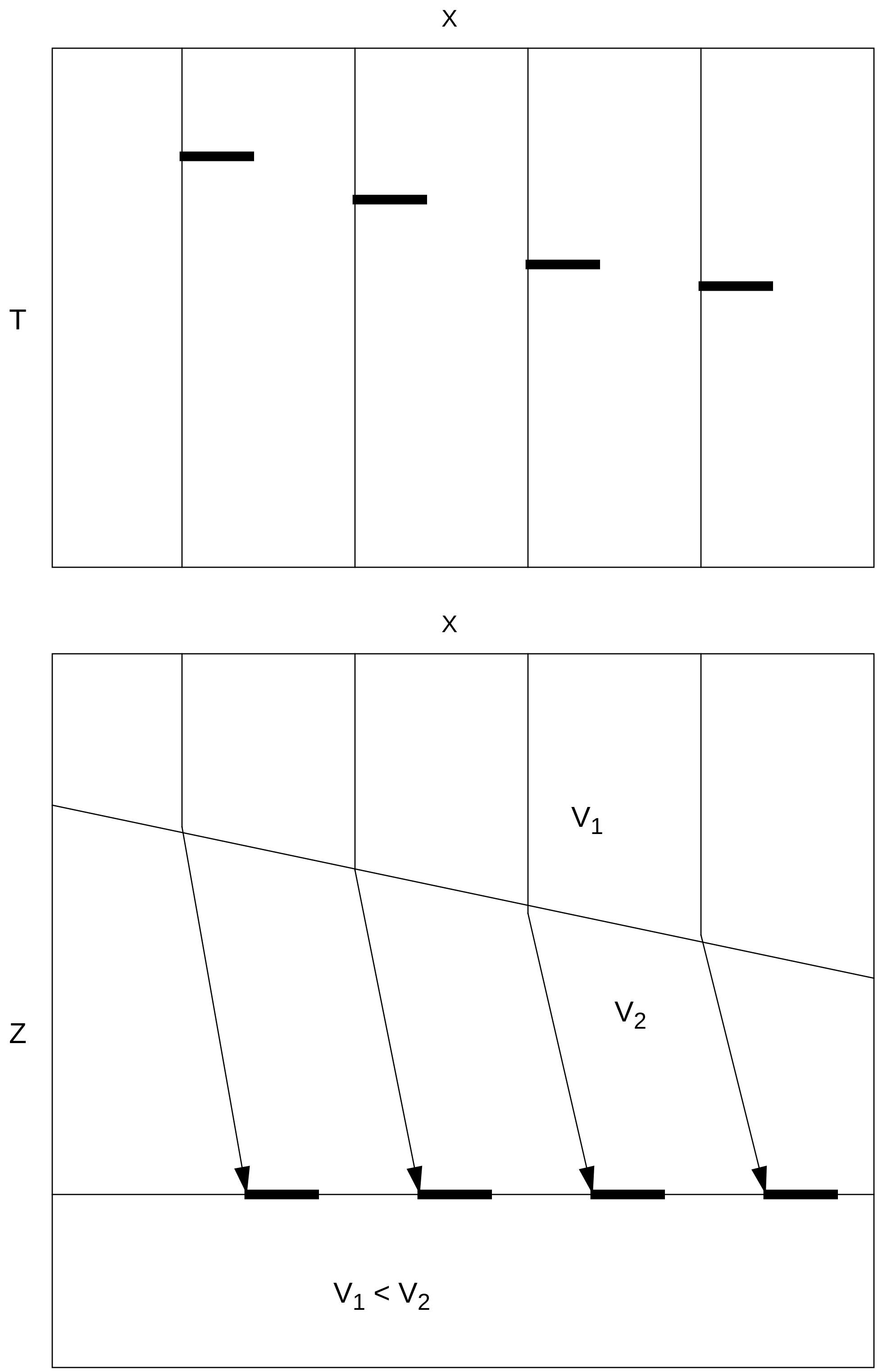

Fig. 1. Image ray migration. The events from the time migrated section (top) are mapped into depths (bottom) by tracing the image rays.

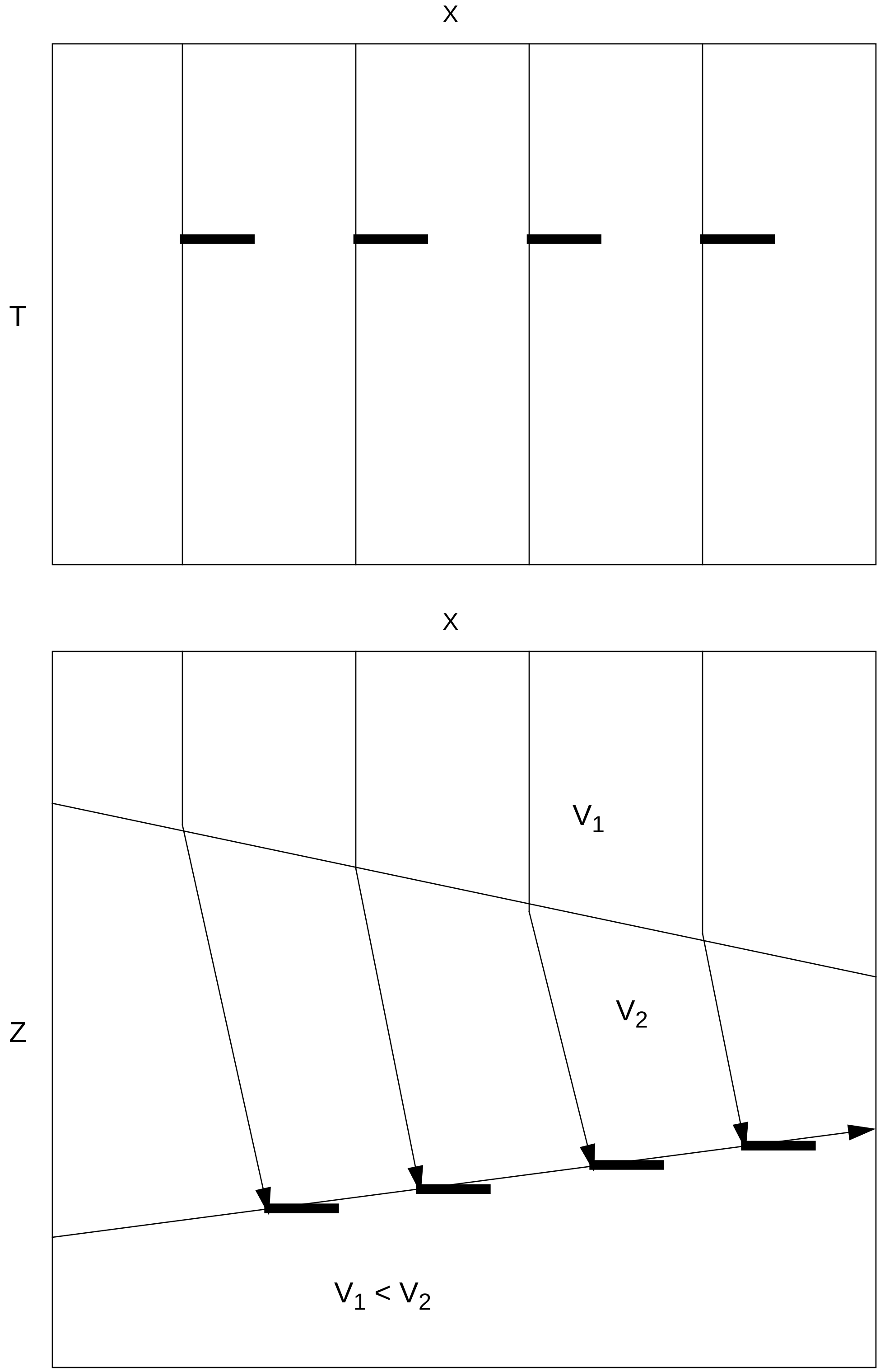

Fig. 2. Image ray migration. Result of mapping a time slice (top) into depths (bottom).

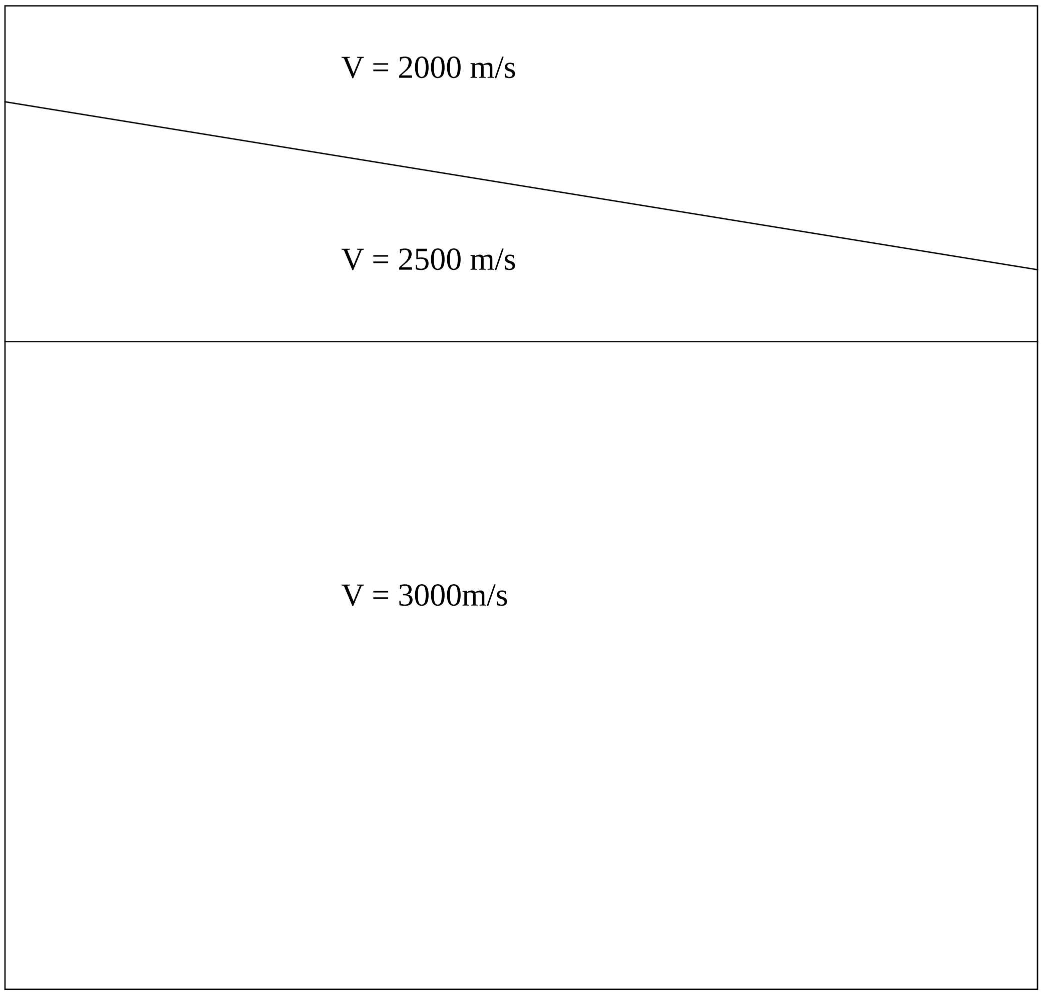

Fig. 3. A three-layer velocity model.

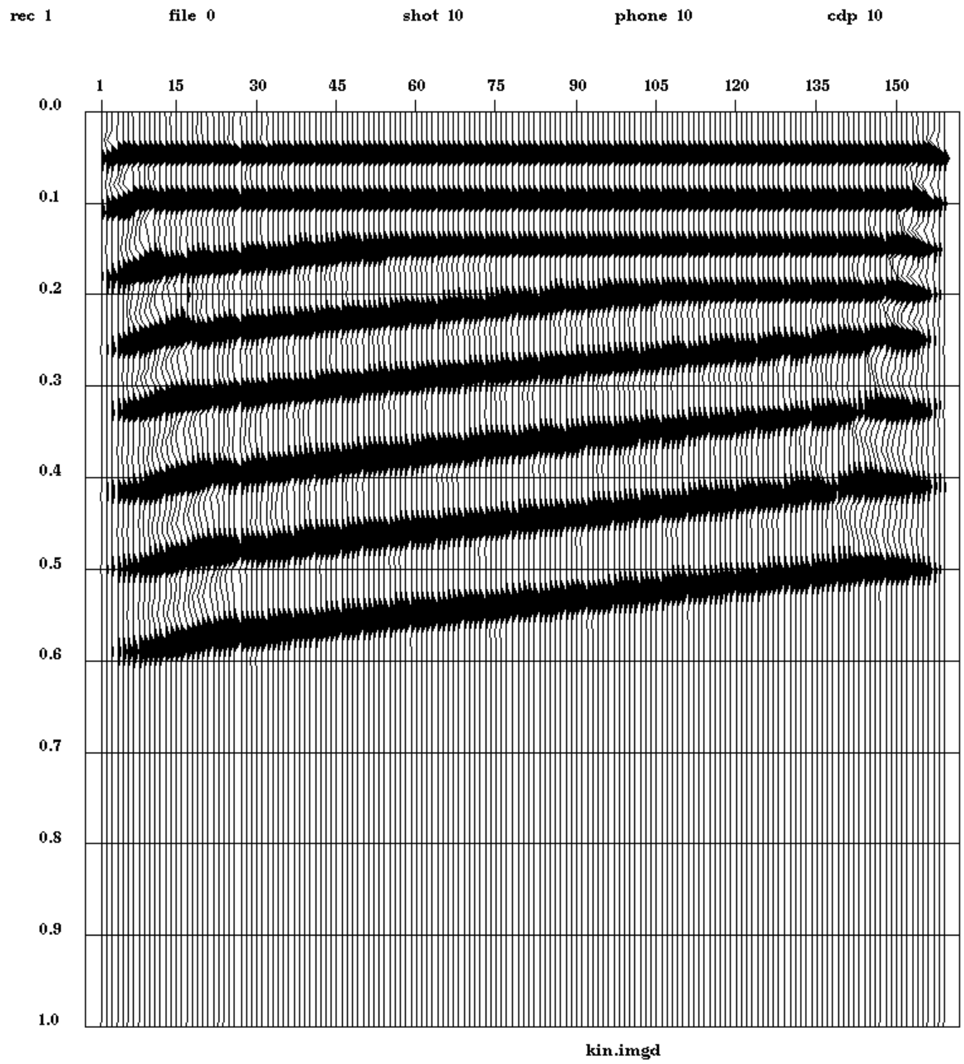

Fig. 4. Snap shots of image wave propagating through the velocity model shown in Figure 3. The trace spacing is 10 m and the depth interval is 10 m.

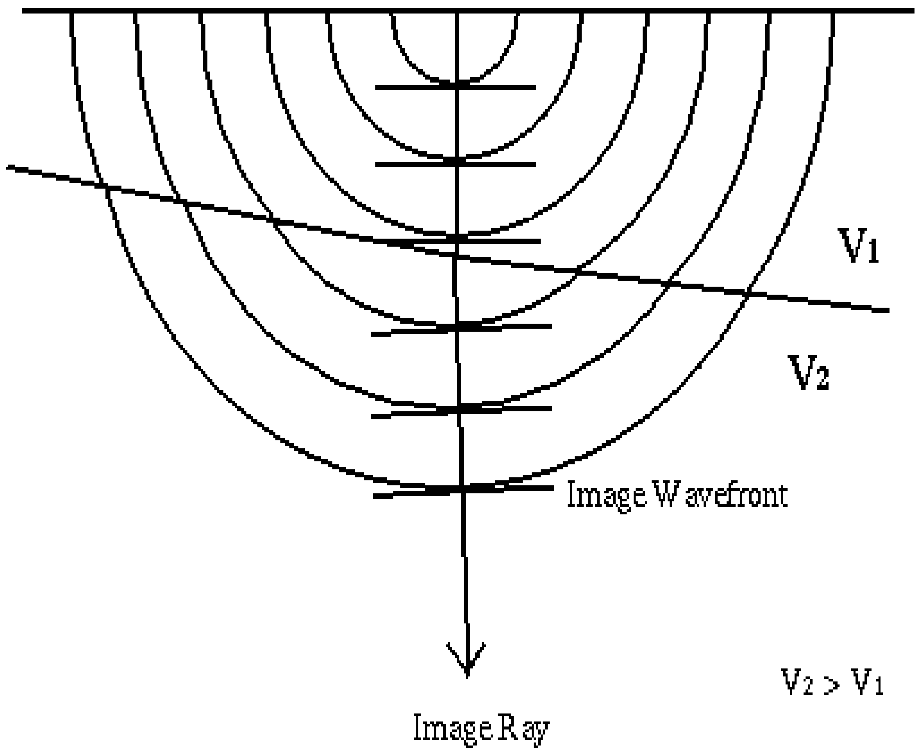

Fig. 5. Schematic diagram of generated image wave generated from a spike.

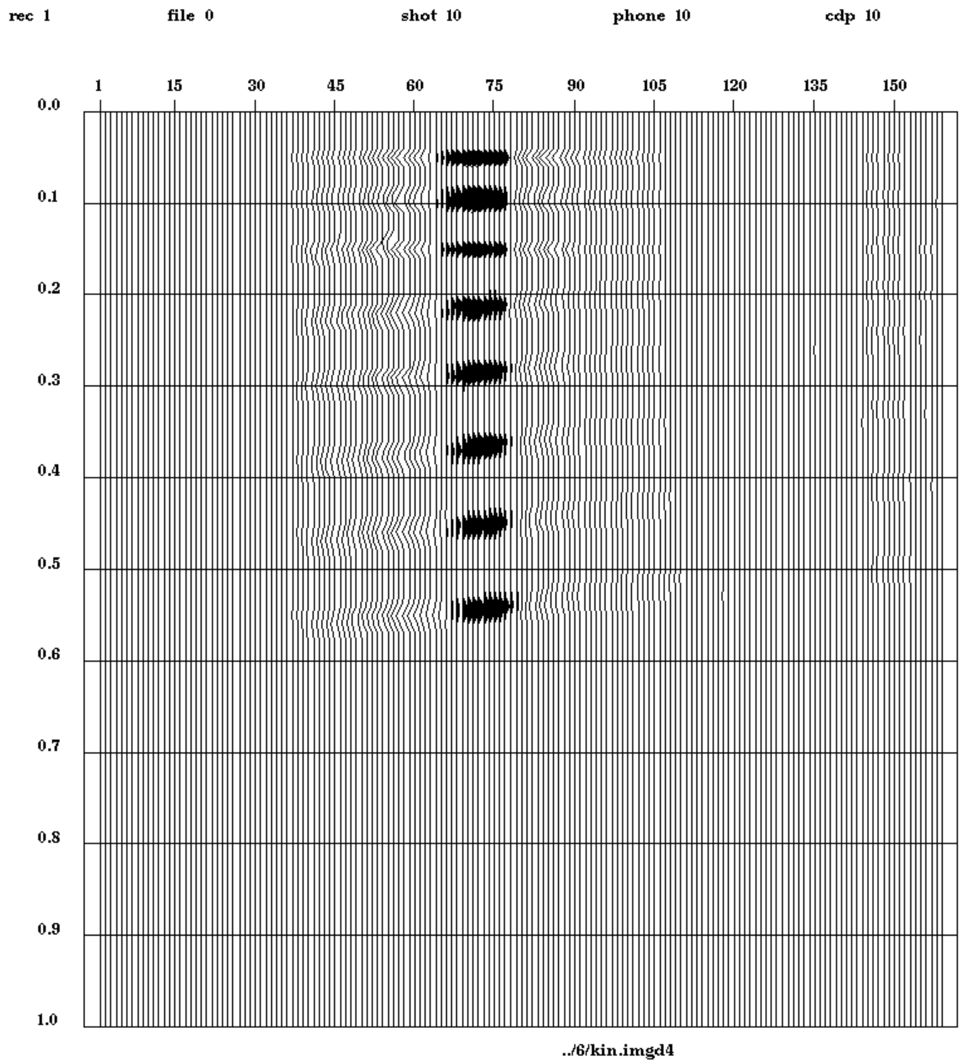

Fig. 6. Snap shots of image wave generated from a spike propagating through the velocity model shown in Figure 3.

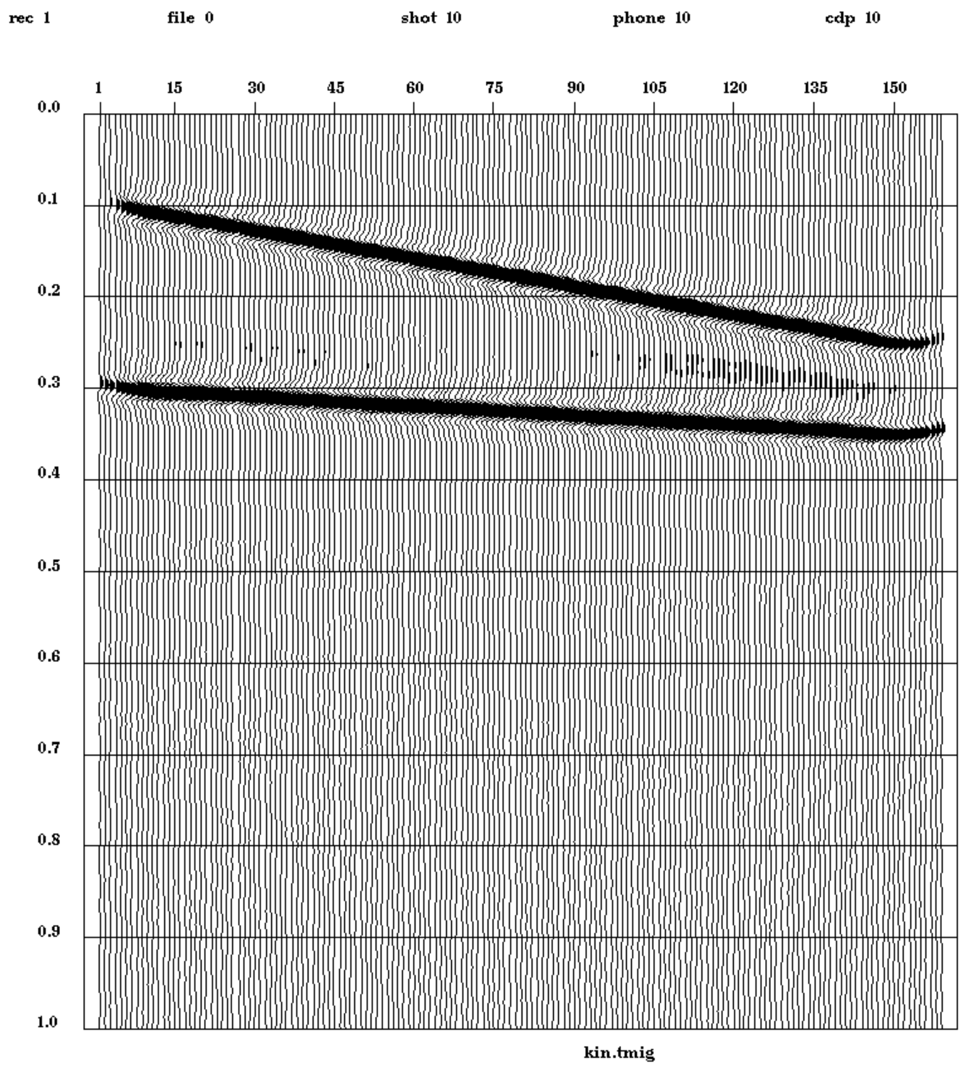

Fig. 7. Synthetic time migrated section generated from the velocity model shown in Figure 3.

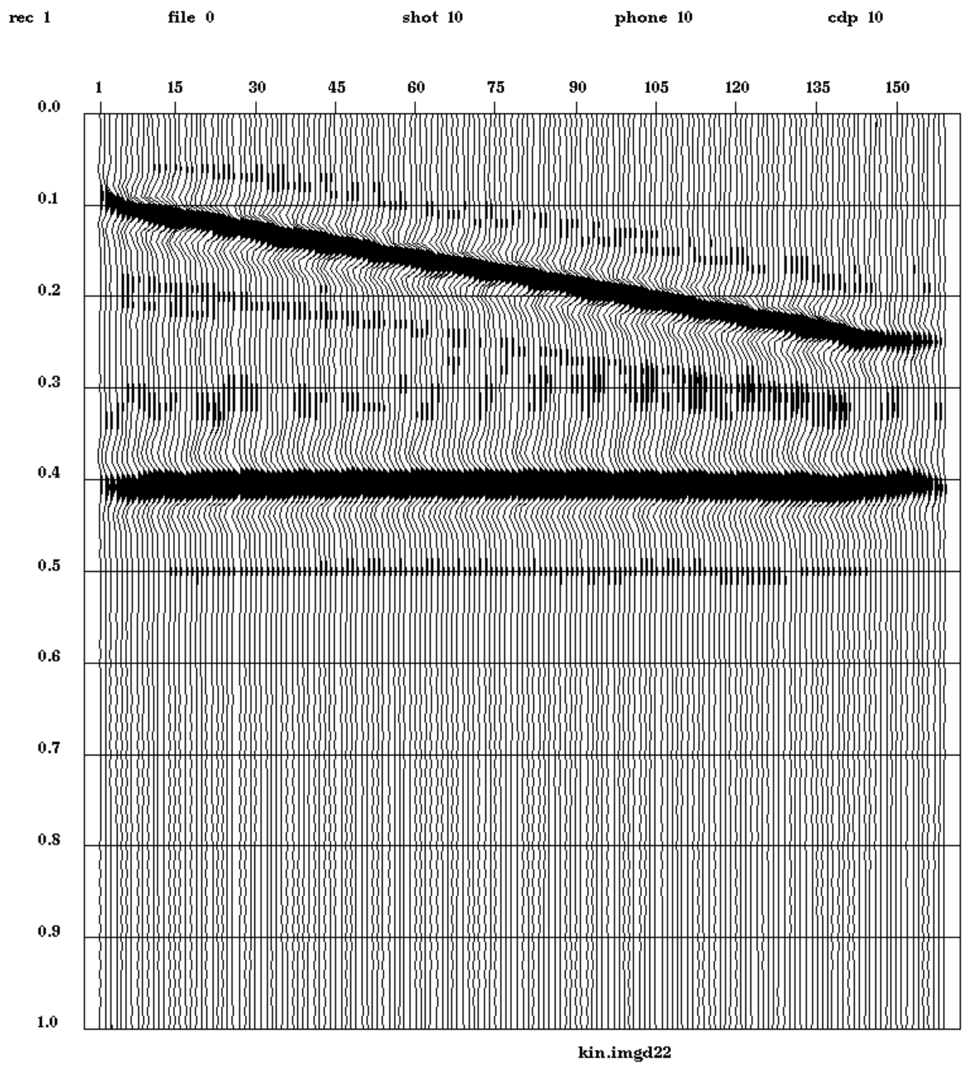

Fig. 8. Result of image wave migration of Figure 7.

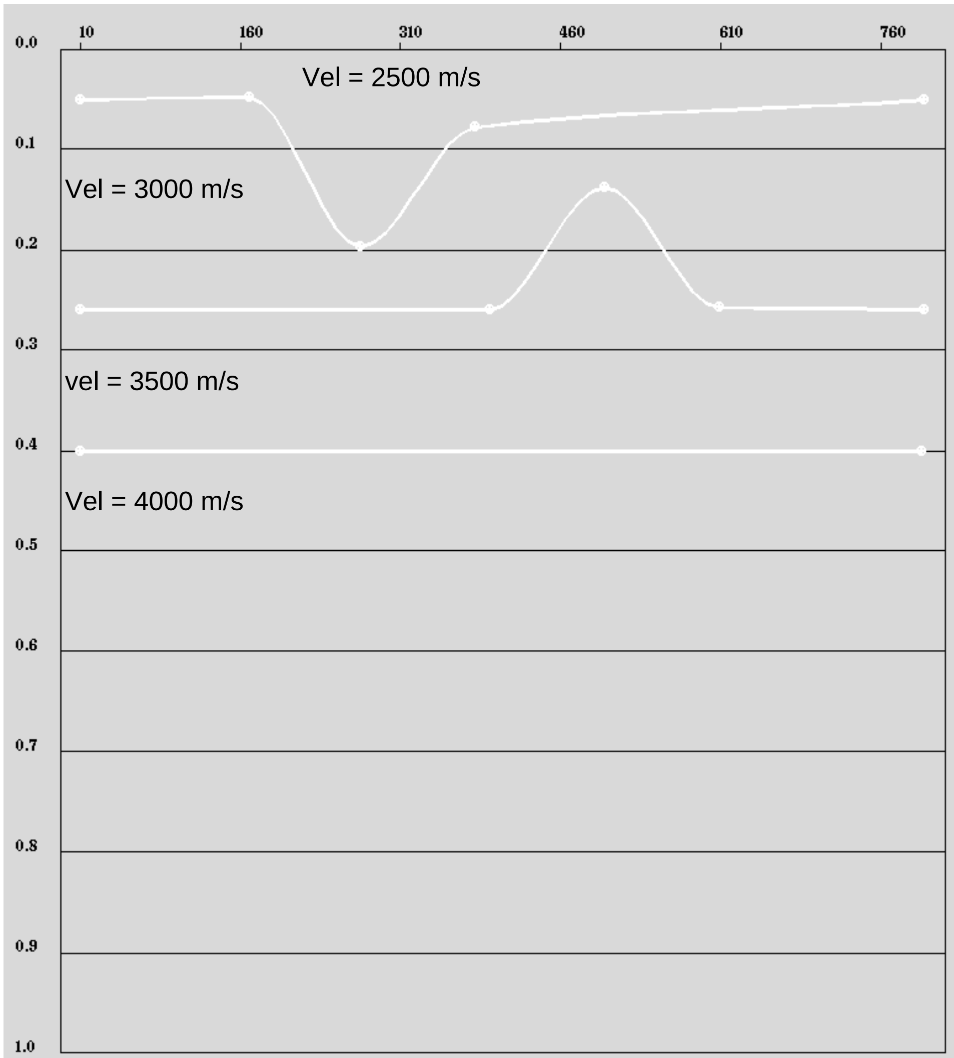

Fig. 9. A four-layer velocity model.

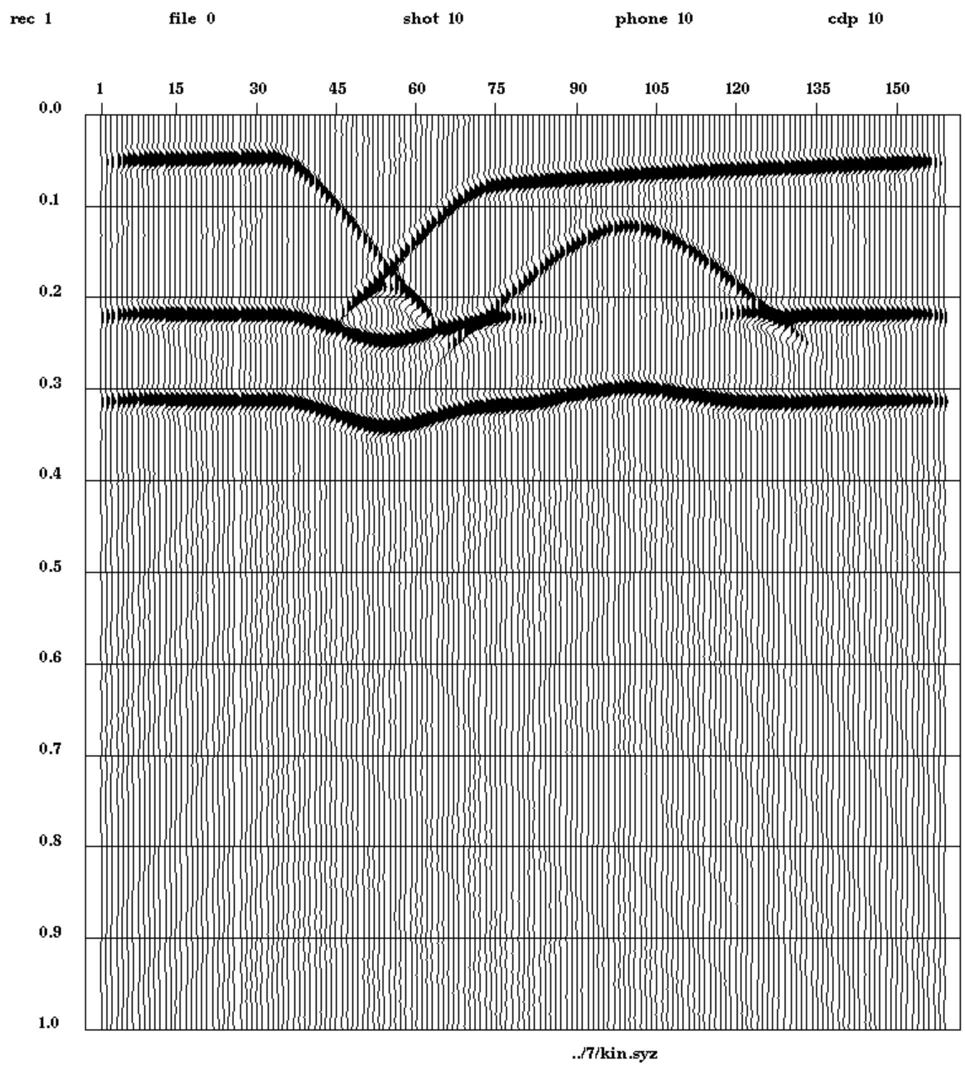

Fig. 10. Synthetic zero-offset section generated from the velocity model shown in Figure 9. The trace spacing is 10 m and the depth interval is 10 m.

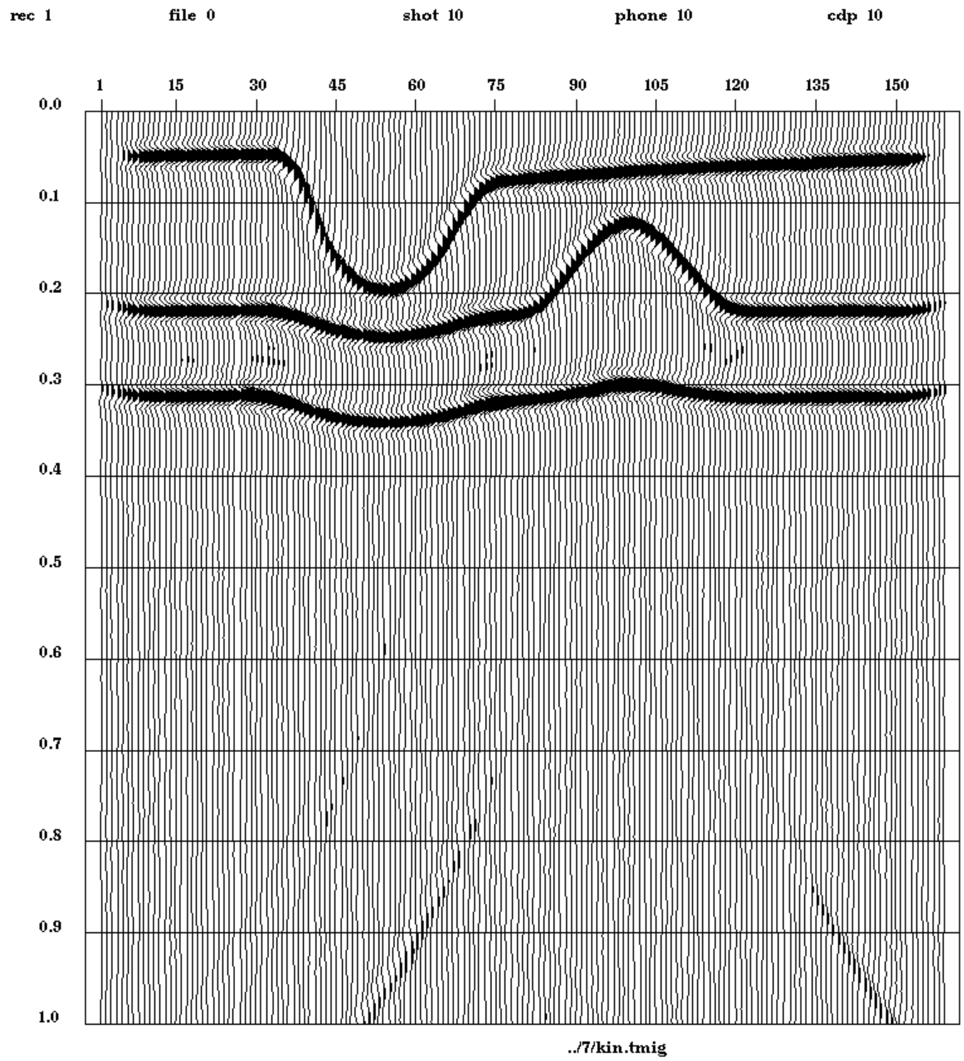

Fig. 11. Time migrated section of Figure 10.

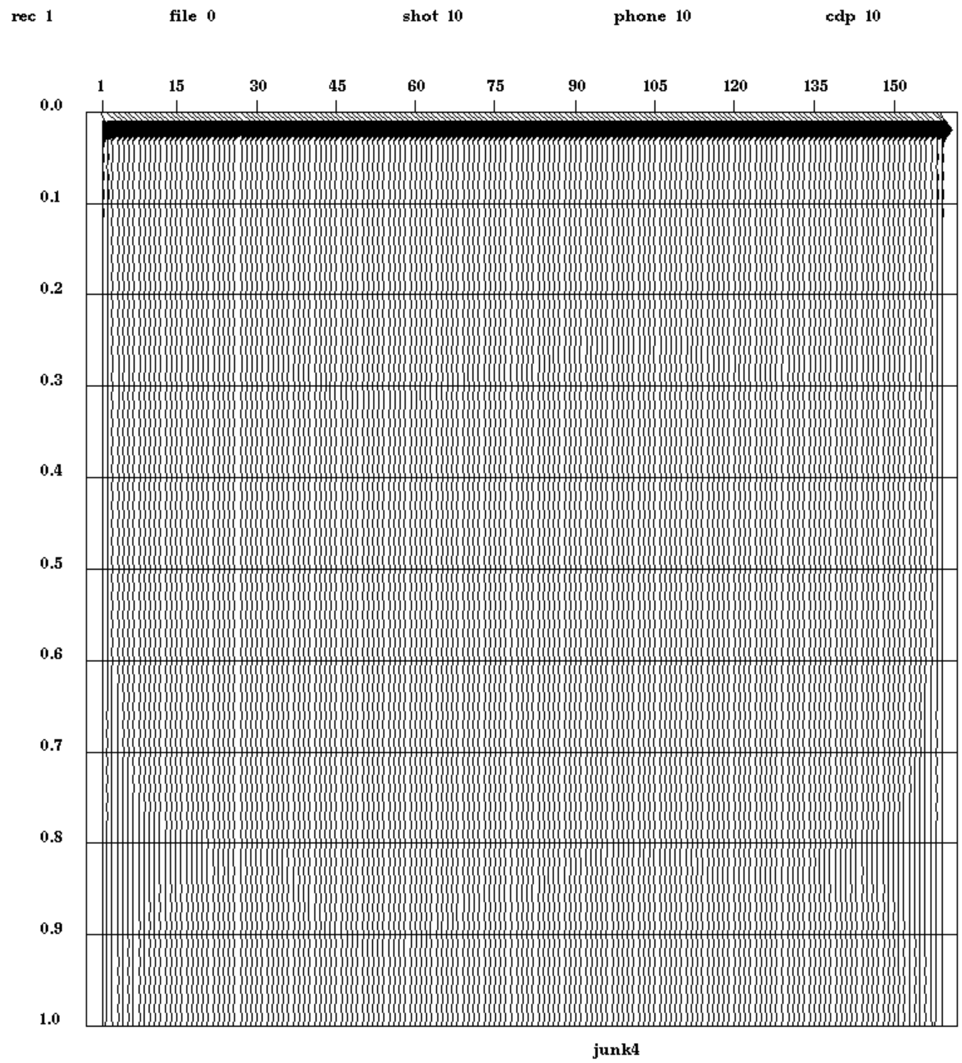

Fig. 12. Image wave modeled at 20 ms from the velocity model shown in Figure 9.

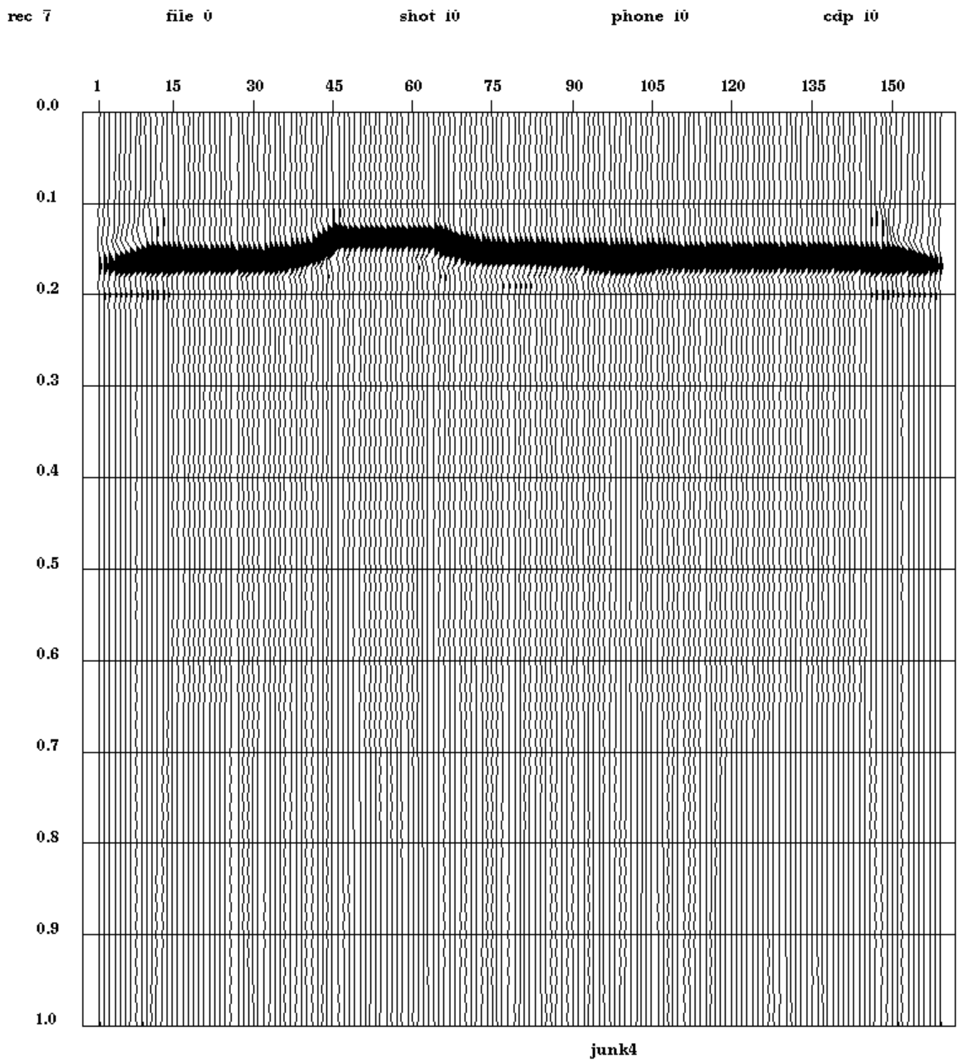

Fig. 13. Image wave modeled at 140 ms from the velocity model shown in Figure 9.

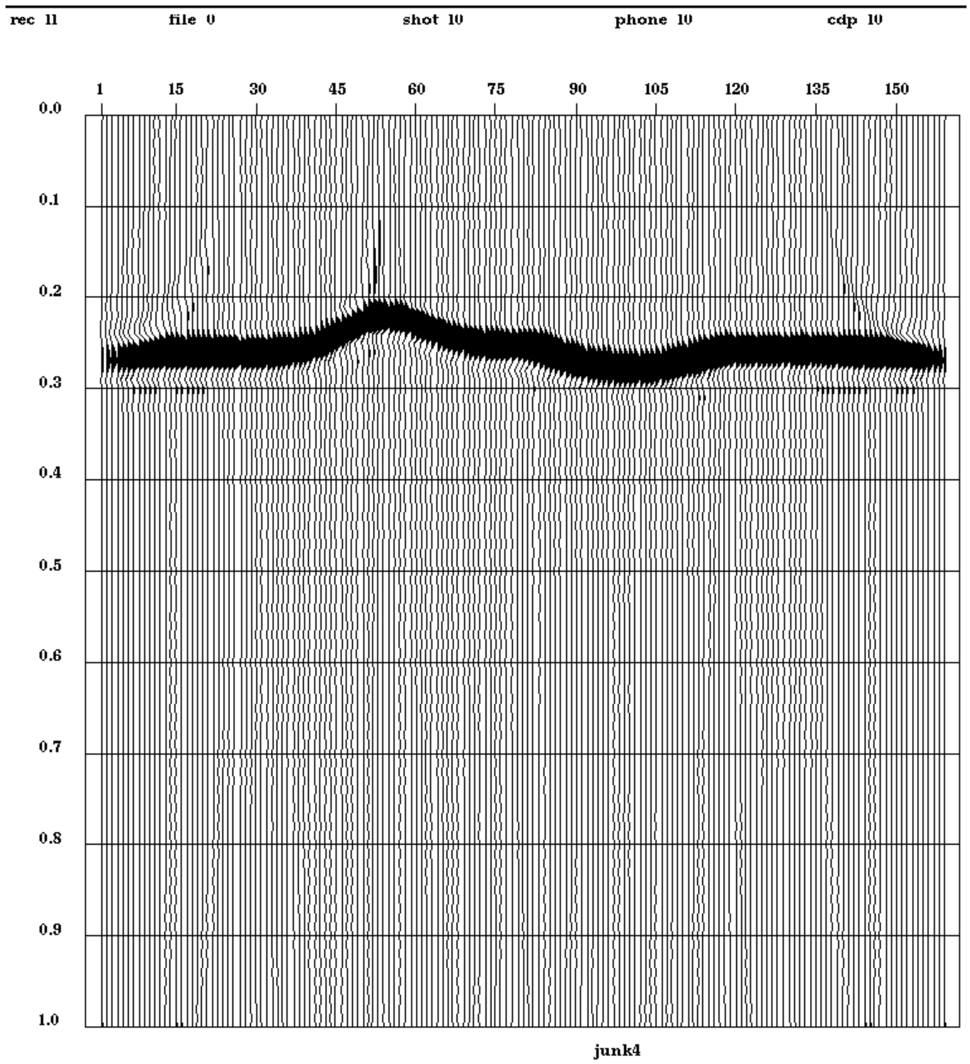

Fig. 14. Image wave modeled at 220 ms from the velocity model shown in Figure 9.

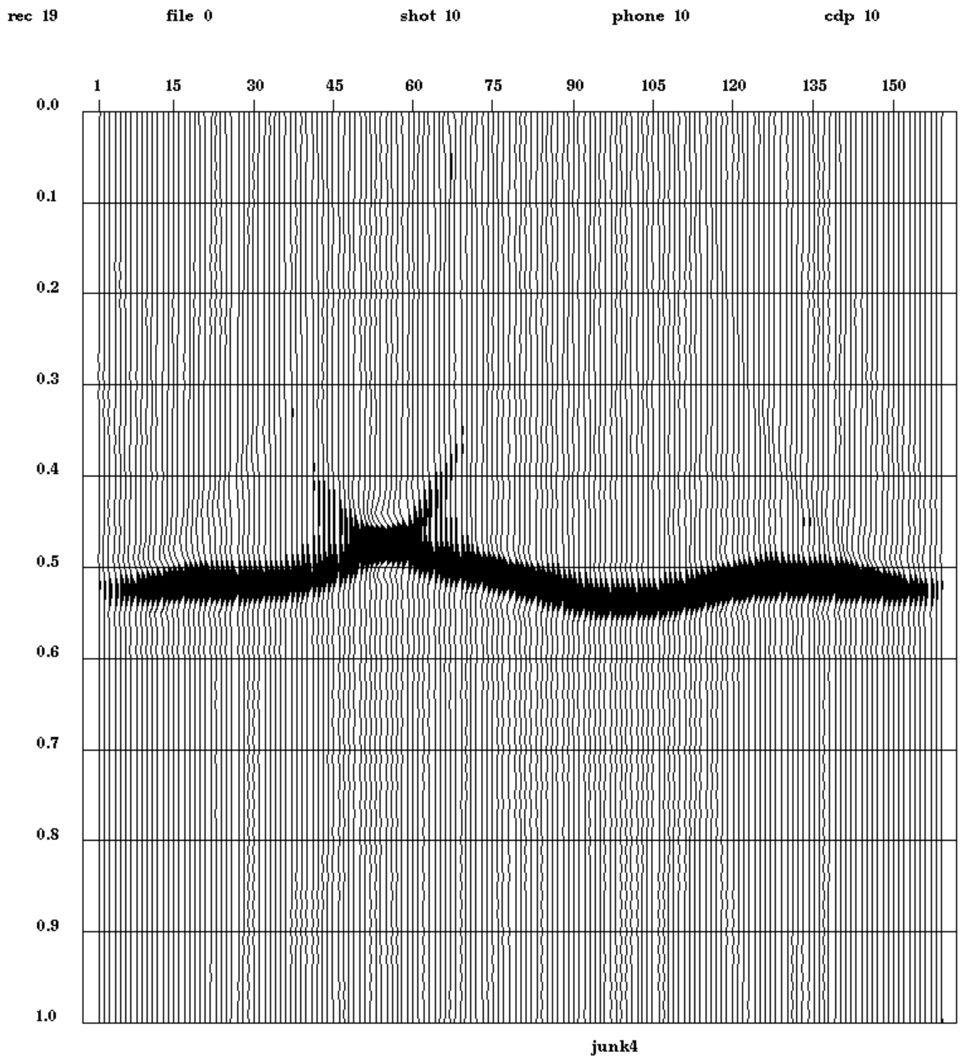

Fig. 15. Image wave modeled at 380 ms from the velocity model shown in Figure 9.

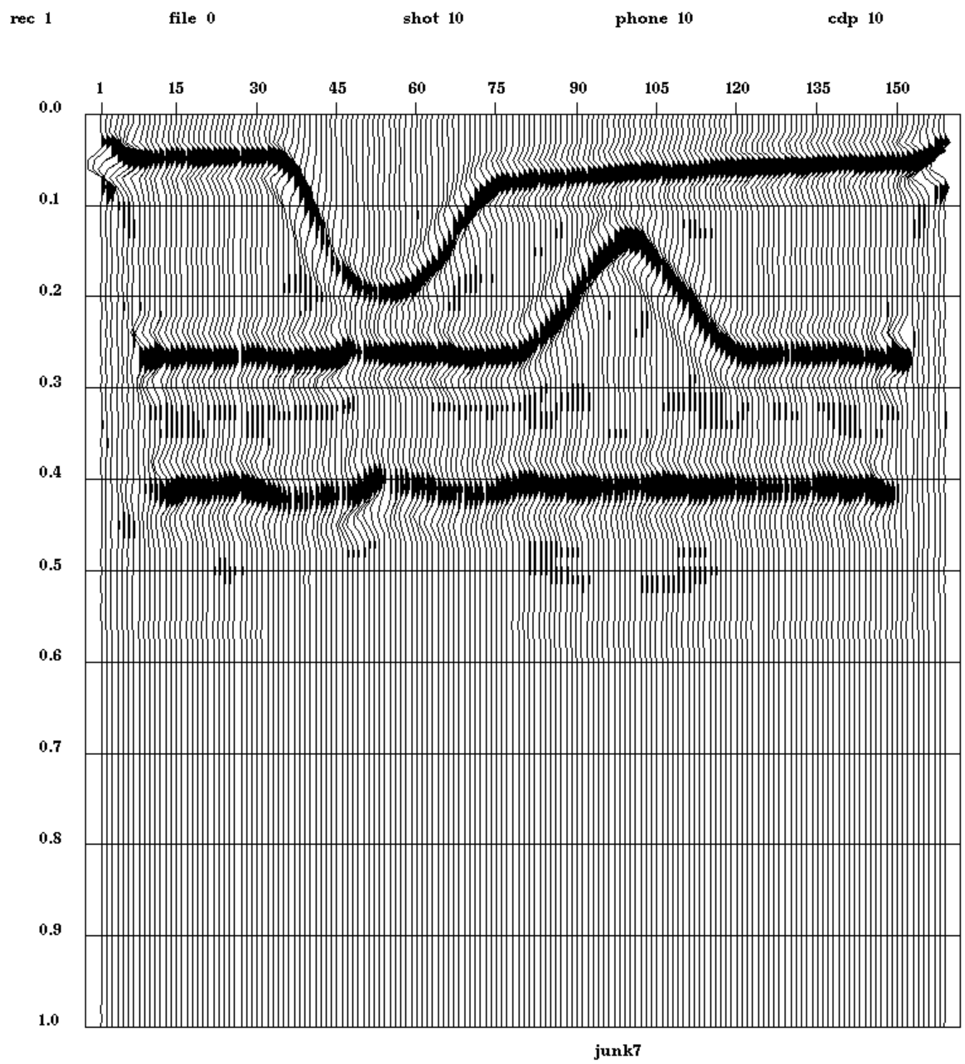

Fig. 16. Result of the image wave migration of Figure 11.