Velocity Dispersion Estimation

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Summary

In this work, we explore the feasibility of estimating velocity dispersion based on velocity analysis of pre-stack seismic data. We tested the methodology on a set of synthetic CMP gathers with different central frequencies. Pre-stack synthetic seismic data was generated from a model that consists of 509 homogeneous and isotropic layers and includes a periodically layered zone.

The results show that the velocity variation due to multiple scattering ranges from 4% to 28%. Most of the values are higher than 10%, which is a realistic uncertainty in velocity analysis.

Introduction

A dispersive medium acts as a filter that attenuates the wave and introduces amplitude and travel time distortions. Those distortions may be a source of misinterpretation of seismic data for hydrocarbon detection. Velocity dispersion in layered media is caused by multiple scattering. Seismic scattering depends on the relative scales of the wave and layer thickness, and may be measured in terms of the variation of the velocity with frequency.

If velocity dispersion is estimated accurately, seismic data can be corrected and more accurate rock and fluid properties can be estimated from seismic amplitudes. The objective of this research is to test a simple methodology for velocity dispersion estimation and better understand how the content of seismic data is affected by multiple scattering.

Here, we applied forward modeling based on the 1.5-D invariant imbedding method in a geological model that includes a periodically layered zone. Layers were assumed isotropic and homogeneous.

Methodology

For a given stratified media each harmonic component of the elastic wave travels at different velocities. The methodology adopted for testing the feasibility of estimating velocity dispersion is to compute the interval velocities of a set of CDP gathers with different central frequencies.

First, a set of CDP gathers with different central frequencies is generated using a full wave equation algorithm. The stacking velocities for each CDP gather are estimated using a conventional velocity analysis method.

Once the stacking velocities are estimated, they are converted to interval velocities using the Dix equation. Finally, the velocity fields are compared for velocity dispersion estimation.

Synthetic Model

We tested the feasibility of estimating velocity dispersion on a multilayer synthetic model. The model used to generate the pre-stack synthetic seismograms consisted of 509 homogeneous and isotropic layers with Vp, Vs and density shown in Figure 1. A set of synthetic CDP gathers were generated using high order multiples and no intrinsic attenuation. The source was a Ricker wavelet with a central frequency that varied from 30 Hz to 65 Hz; the wavelength in the periodically layered zone ranged from 20 to 45 meters.

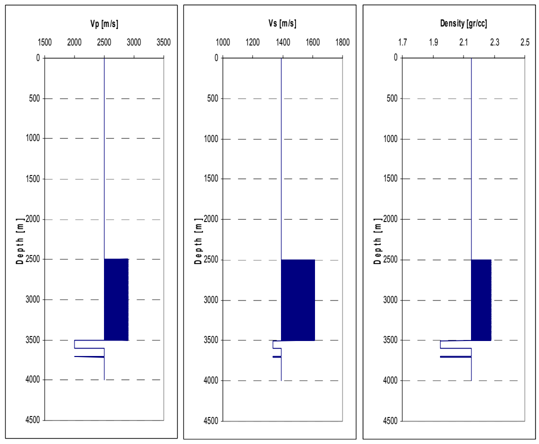

Figure 1. Model Parameters.

Figure 2 shows the synthetic gathers generated using the full wave equation algorithm. The first gather (left) was generated using a simple convolutional model for comparison purposes.

Results

A detail of the NMO corrected gathers with the real velocity model is shown in Figure 3. It can be seen that the convolutional model is perfectly corrected with the real velocity model. However, the full equation gathers show a zero offset time shift and residual NMO. Those differences are caused by the velocity dispersion in the periodically layered zone.

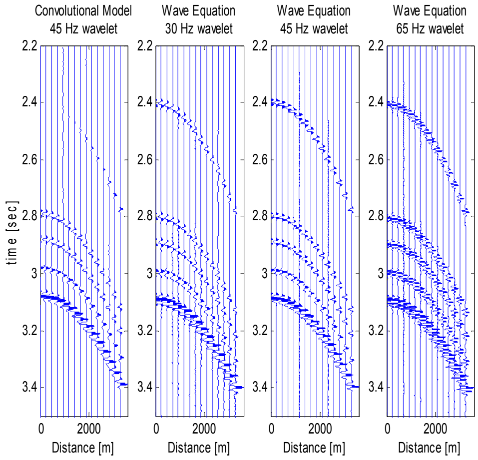

Figure 2. Modeled CMP gathers using 30 Hz to 65 Hz wavelets. The first gather (left) was generated using a simple convolutional model for comparison purposes.

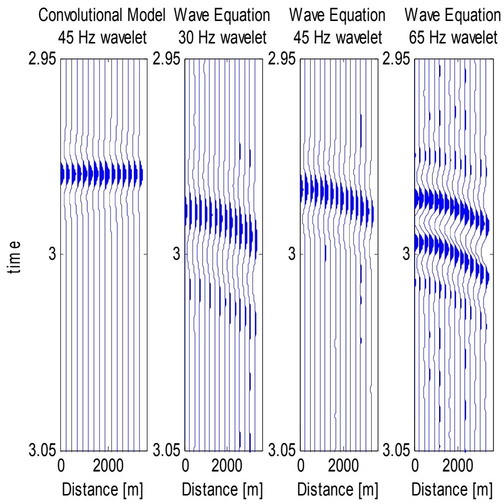

Figure 3. Modeled CMP gathers NMO corrected for 30 Hz to 65 Hz wavelets. A zero offset time shift and residual moveouts was observed for the wave equation models. The convolutional model is perfectly corrected using the real model velocity profile.

Figure 4 and 5 show semblance panels for the 45 Hz and 65 Hz full wave equation model. The velocity picking was performed using conventional processing software. The resulting interval velocities from Dix equation are summarized on Table 1.

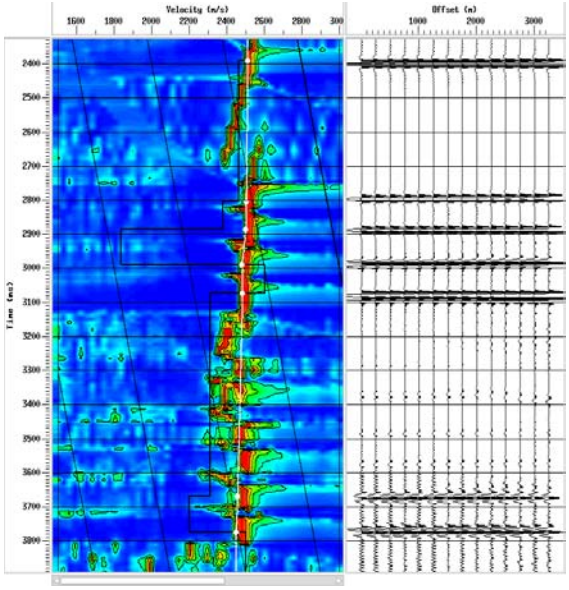

Figure 4. Semblance panel for the 45 Hz full wave equation model.

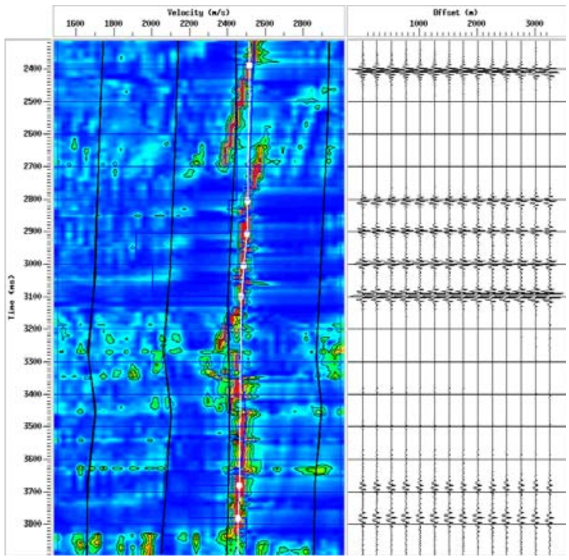

Figure 5. Semblance panel for the 60 Hz full wave equation model.

30 Hz		45 Hz		60 Hz	
Time	Vint	Time	Vint	Time	Vint
2391	2604	2399	2588	2389	2615
2805	2380	2793	2409	2804	2410
2885	2197	2890	2103	2907	1917
2990	2601	2988	2271	3004	2006
3074	2312	3087	2378	3099	2409
3669	2200	3682	2314	3680	2198
3774	2500	3768	2500	3781	2500

Table 1. Interval velocities from Dix equation. Red cells show the areas where important velocity dispersion was observed.

It can be seen that the seismic interfaces located just beneath the periodically layered zone display velocity dispersion. The velocity variation ranges from 4% to 28% with most values higher than 10%. Figure 5 shows the comparison of the interval velocities for the model with those estimated from the synthetic gathers.

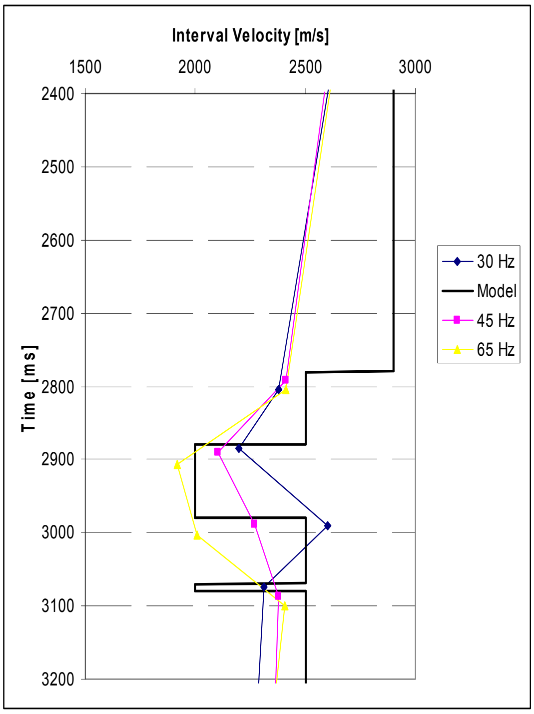

Figure 5. Comparison of the interval velocities for the model (black) with those estimated from the synthetic gathers.

Conclusions

1. A significant variation in apparent p-wave velocity is shown on the synthetic gathers for seismic interfaces located beneath the periodically layered zone. However, the deepest thin bed does not display any velocity variation with frequency.

2. The velocity variation due to multiple scattering ranges from 4% to 28%.

3. This method should be tested using a set of field CDP gathers with well control.

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References

Carcione, J. M., KosloffS, D. and Behles, A., 1991. Long-wave anisotropy in stratified media: A numerical test. Geophysics, 56, 245-254.

Frazer, L. N., 1994. A pulse in binary sediment. Geophys. J. Int., 118, 75-93.

Kennet, B. L. N., 1974. Reflections, rays and reverberations. Bull. Seismol. Soc. Am., 64, 1685-1696.

Marion, D., Mukerji, T. and Mavko, G., 1994. Scale effects on velocity dispersion: From ray to effective medium theories in stratified media. Geophysics, 59, 1613-1619.

Mavko, G., Mukerji, T. and Dvorkin, J.,1998. The Rock Physics Handbook: Tools for Seismic Analysis in Porous Media. New York: Cambridge University Press.

EDITED REFERENCES

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REFERENCES

Carcione, J. M., D. Kosloff, and A. Behles, 1991, Longwave anisotropy in stratified media: A numerical test: Geophysics, **56**, 245–254.

Frazer, L. N., 1994. A pulse in binary sediment: Geophysical Journal International, **118**, 75–93.

Kennet, B. L. N., 1974, Reflections, rays and reverberations: Bulletin of the Seismology Society of America, **64**, 1685–1696.

Marion, D., T. Mukerji, and G. Mavko, 1994, Scale effects on velocity dispersion: From ray to effective medium theories in stratified media: Geophysics, **59**, 1613–1619.

Mavko, G., T. Mukerji, and J. Dvorkin, 1998, The rock physics handbook: Tools for seismic analysis in porous media: Cambridge Univ. Press.