Prestack Vp/Vs scanning and automatic PS-to-PP time mapping using multicomponent seismic data

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Abstract

This paper discusses the development and application of a prestack method that scan for the average vertical velocity value, V_p/V_s (γ_0), and the stacking velocities of multicomponent seismic (MCS) data using a converted-wave (PS) non-hyperbolic traveltime equation. The procedure entails computing semblance as a function of two variables namely, the PS velocity, Vps, and γ_0 with respect to the PS zero-offset time $t_{ps0.}$ The results are displayed in 2D plots. The scanning procedure is tested using numerical data sets and real MCS data sets from the Blackfoot Field in southern Alberta. The algorithms work well with either shot gathers or the asymptotic conversion point (ACP) gathers. It is observed that the γ_0-log from the scanning procedure, agrees reasonably well with the γ_0 values from the well log of Well-09-08 that is located at the ACP gather location. In addition, when this γ_0 estimate is used for PS-to-PP time mapping, the time difference between the computed and actual PP at the target level time is found to be 20 ms; being an error of less than 2%.

Introduction

A number of authors have discussed the benefits offerred by PS-wave exploration; however, certain problems, such as determining γ_0, χαν stand between us and the realization of these advantages. Because of this, recovery of γ_0 has become a step in multi-component data processing and interpretations. Several workers have used different methods for the recovery of γ_0. For example, Gaiser (1996) developed a post-stacked cross-correlation method. The method is automatic and is based on correlating PP and PS stacked data sets. Stewart et al. (2003) alluded to a time-isochron method using interpreted PP and PS sections. Like Gaiser's method, this too is post-stack method that depends on correlating PP and PS events. Thomsen (1999) suggested visually correlating events of the same structural attitude on both PP and PS stacked section; this too, is also a post-stack method. The post-stack methods can work well but may fail with complicated sections, when PP and PS data have very different wavelets, or events of opposite polarity. In view of this, there is need to find an alternate prestack solution to the problems associated with P- and PS-wave correlation. In this paper we present a prestack method of estimating γ_0 via velocity analysis using a converted-wave, non-hyperbolic traveltime equation.

Methodology

By combining the PS-wave traveltime equation of Thomsen (1999) and the PS stacking velocity approximation of Tessmer and Behle (1988), we obtain a PS traveltime equation:

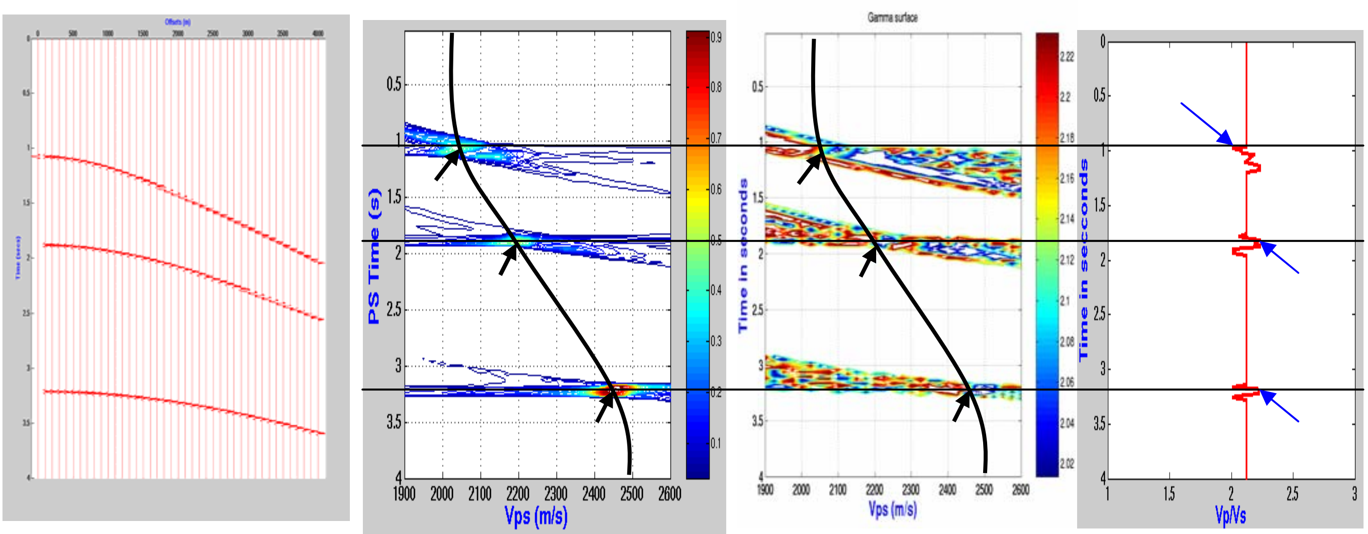
$$t_{ps}{}^{2}(x) = t_{ps0}{}^{2} + \frac{x^{2}}{V_{ps}{}^{nmo\,2}} - \left(\frac{(\gamma_0 - 1)^{2}}{4(\gamma_0 + 1)t_{ps0}{}^{2} V_{ps}{}^{nmo\,4} + \gamma_0(\gamma_0 - 1)V_{ps}{}^{nmo\,2} x^{2}} \right), \qquad (1)$$

where t_{ps0} is the PS-wave zero-offset traveltime, $V_{ps}{}^{nmo}$ is the PS-wave moveout velocity, and x is the offset.

Based on this equation, we developed a dual-parameter scanning algorithm, to scan for the average vertical velocity ratio γ_0, and the PS stacking velocity V_{ps}.

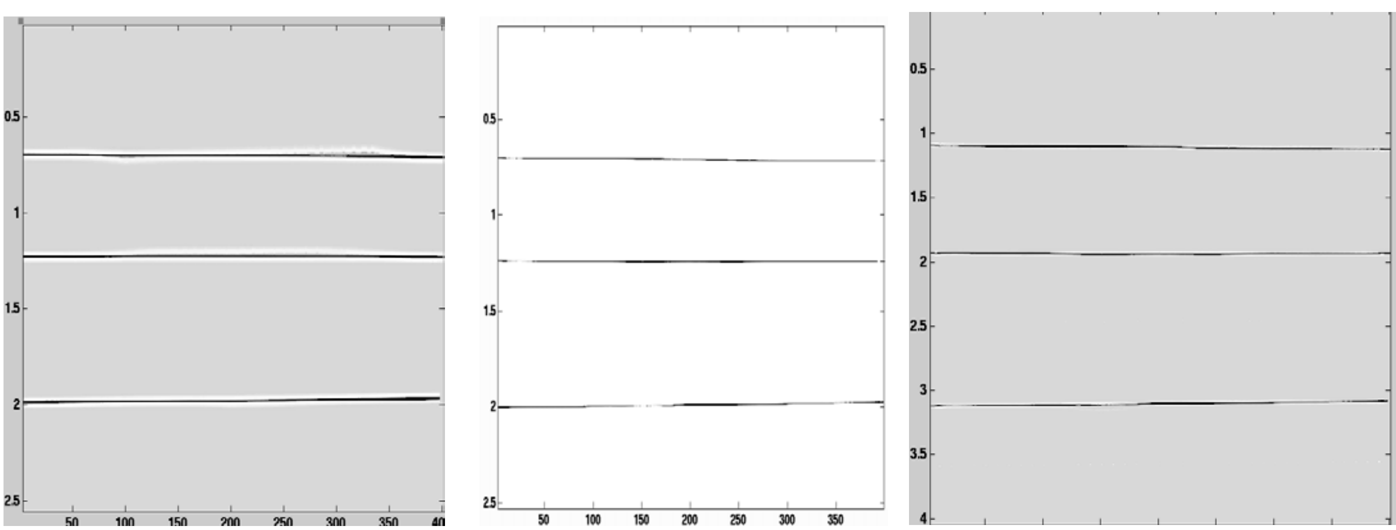
Results from numerical and the Blackfoot Field data

The algorithm was applied to a PS synthetic seismic record from a three-layer geologic model generated by the GX2 raytracing modeling package. Also, we tested the algorithm using seismic ACP gather from a 2D MCS data that was acquired by the CREWES Project in 1997, over the Blackfoot oil Field in southern Alberta. The results from these tests are shown in Figures 1 to 4.



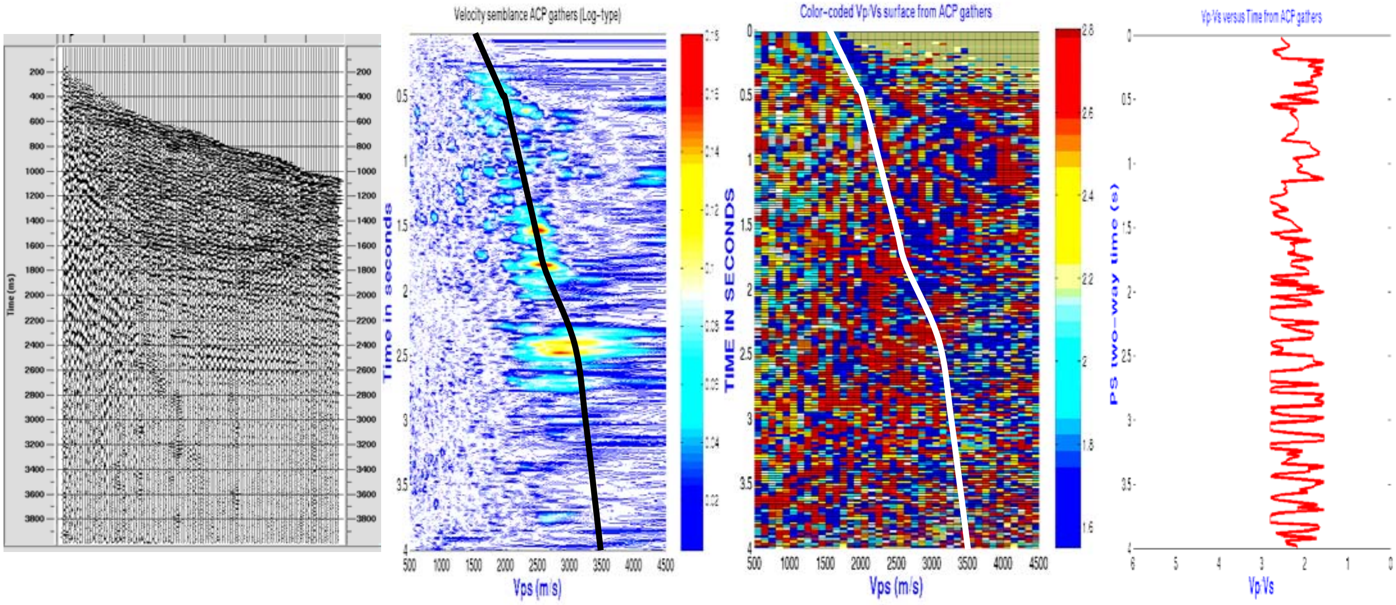
PS Synthetic shot record | Final 2D semblance | γ_0 2D contour | γ_0-time log

Figure 1. Results from the dual-parameter scanning using the synthetic shot record. From left to right are: the synthetic shot record; the final 2D velocity semblance from which the velocity function is picked (black curve); the 2D γ_0 panel on which is superimposed the velocity function; the γ_0-time log which is automatically plotted once the velocity function is transferred onto the 2D γ_0 panel. The γ_0 values (indicated by blue arrows) which were encountered by the velocity function that was picked at maximum semblance, are then interpolated to obtain a smoothed γ_0-function which is used to transform PS to PP time.



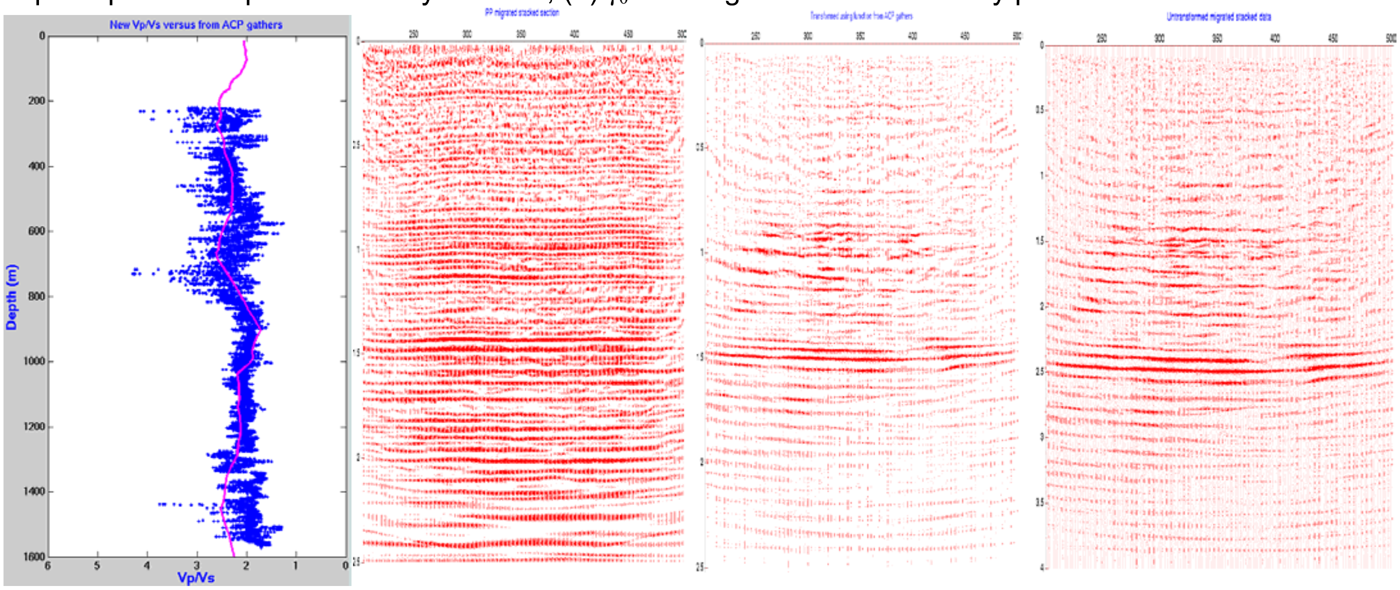
(a) (b) (c)

Figure 2. PS to PP time mapping. From left to right are (a) PP stacked data, (b) transformed PS to PP time stacked data, (c) untransformed PS stacked data. Note the difference in time scale between (b) and (c).



(a) (b) (c) (d)

Figure 3. From left to right are (a) seismic ACP gather, (b) 2D velocity semblance, (c) γ_0-panel on which is superimposed the picked velocity function, (d) γ_0-time log that is automatically plotted.



(a) (b) (c) (d)

Figure 4. From left to right are: (a) the comparison of the scanned γ_0-log (pink curve) and the γ_0-log from the Well-09-08 (blue curve); (b) PP stacked data; (c) transformed PS data using the scanned γ_0-log: the scanned γ_0-log was smoothed before using it to transform PS to PP time. (d) The untransformed PS stacked data. Note the difference in the time scale between (c) and (d).

Conclusions

A prestack stack method that scans for the average vertical velocity ratio γ_0 and the PS stacking velocities V_{ps} using a PS-wave non-hyperbolic traveltime equation has been developed. The algorithm work well with either the shot gathers or the asymptotic conversion point (ACP) gathers. The scanned γ_0-log agrees reasonably well with the γ_0-log from the Well-09-08 located along the seismic line at the seismic ACP gather location. In addition, when this γ_0 estimate is used for PS-to-PP time mapping, the time difference between the computed and actual PP time is found to be 20 ms; being an error of less than 2%.

References

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