Dix interval velocity for shear waves

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ABSTRACT

The RMS velocity for converted waves is used to calculate a Dix interval velocity for shear waves. In synthetic examples, we find that the calculated long-wavelength (low-resolution) shear velocity agrees reasonably well with log values.

INTRODUCTION

In seismic analysis, we often extract a low-resolution or macroscopic parameter, such as stacking velocity from the data. Estimation of the interval velocity from the stacking velocity is a common procedure in processing P-P data. We ask, can a similar procedure be developed for estimating shear velocity from converted-wave data?

We can find the converted-wave stacking velocity using a variety of methods, including standard velocity analysis which depends on the coherency of a hyperbolic stack. Once we have this stacking velocity, we can assume it is close to the RMS velocity and compute interval velocities from it. This is done using the standard Dix interval velocity calculation.

DIX INTERVAL VELOCITIES

Suppose that we have a layered medium (with layers i=1, N) having P-wave and S-wave interval velocities (α_i,β_i). Each layer has thickness z_i and a set of transit times: t_i^p for one-way P waves and t_i^s for one-way S waves (Figure 1).

The converted-wave RMS velocity is given by Tessmer and Behle (1988):

$$V_k^2 = \frac{\sum_{i=1}^{k} \alpha_i\beta_i t_i}{T_k} \text{ , where } t_i = t_i^p + t_i^s \text{ , and } T_k = \sum_{i=1}^{k} t_i \qquad (1)$$

Following standard procedures for computing the Dix interval velocity (e.g., Sheriff and Geldart, 1983), we have:

$$V_k^2 T_k - V_j^2 T_j = \sum_{i=1}^{k} \alpha_i\beta_i T_i - \sum_{i=1}^{j} \alpha_i\beta_i T_i \qquad (2)$$

If k = j + 1, then $$V_{j+1}^2 T_{j+1} - V_j^2 T_j = \alpha_{j+1}\beta_{j+1} T_{j+1} \qquad (3)$$

$$\alpha_{j+1}\beta_{j+1} = \frac{V_{j+1}^2 T_{j+1} - V_j^2 T_j}{T_{j+1} - T_j} \tag{4}$$

and

$$\beta_{j+1} = \frac{V_{j+1}^2 T_{j+1} - V_j^2 T_j}{\alpha_{j+1}(T_{j+1} - T_j)} \tag{5}$$

So knowing the converted-wave traveltimes bounding the interval of interest, the converted-wave stacking velocities, plus the P-wave interval velocity allows computation of the S-wave interval velocity.

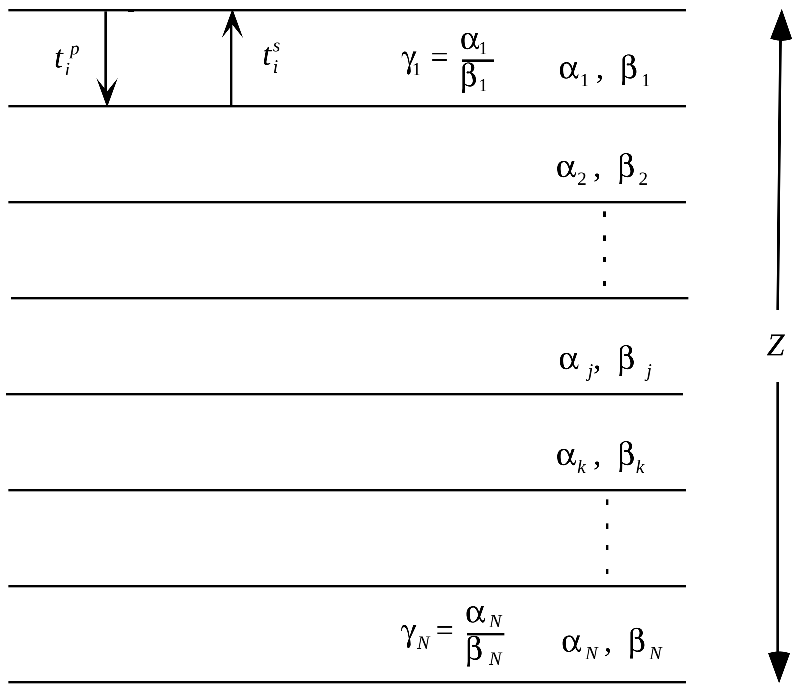

Fig. 1. Plane-layer elastic medium with N layers.

SYNTHETIC EXAMPLE

An experiment is conducted to test the new Dix interval velocity equation for S waves. A well log (Figure 2), which consisted of a P sonic and a density log was obtained from the Blackfoot broad-band survey. An S sonic log was derived from the P sonic using a Vp/Vs value of 2. The P sonic, S sonic and density logs are then used to generate synthetic P-P and P-S gathers using the SYNTH algorithm (Lawton and Howell, 1992) as shown in Figures 3 and 4. A zero-offset P-wave synthetic (Figure 2) helps determine the timing of several geologic horizons for the P-P data. The timing of the horizons is then scaled using a value of 3/2 to derive the corresponding horizon timing for the P-S data.

Stacking velocities are next picked for both data sets (Figures 5 and 6), with great care taken to ensure that velocity knees corresponded to the correct horizons. The Dix interval velocities for P waves are computed using the Dix equation (Dix, 1955) and S velocities were computed using equation (5).

These velocities are compared to the actual velocities that were used to generate the synthetic data (Figure 7). Note that the P sonic and Dix P sonic have been plotted in P-S time for direct comparison. There is reasonably good correlation, in a low-frequency sense, between the true sonic logs and their Dix estimates through the range 700 ms to 1700 ms. There is poor correlation at 507 ms, both of the Dix estimates are below the low-frequency trend of the sonic logs (-1000 m/s for S and -500 m/s for P). This difference in velocity can be seen in the first two knees of the velocity functions of Figures 5 and 6. The true stack velocity picks should both be at higher velocities.

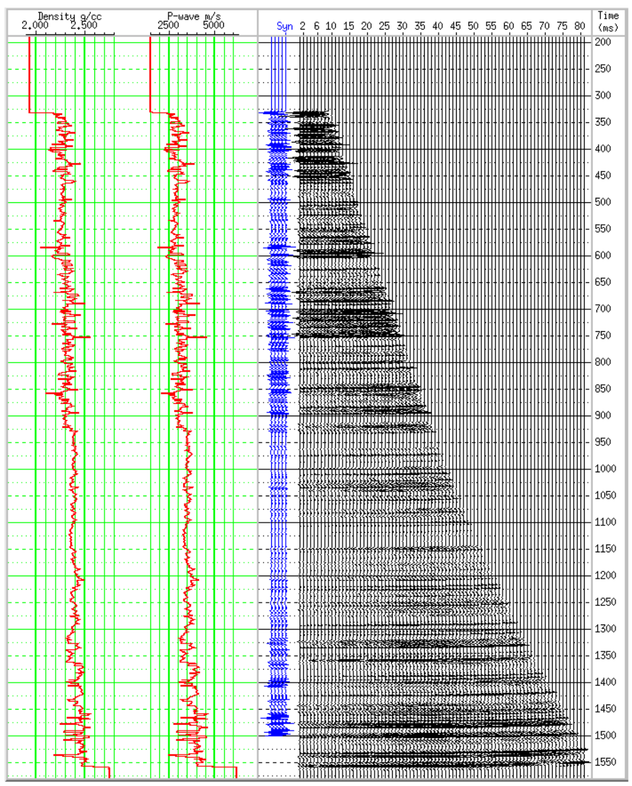

Fig. 2. Log and seismogram data from the Blackfoot survey. Shown are the density and sonic logs, zero offset synthetic (middle 5 traces), and the P-P data. The zero offset synthetic was used to correlate geologic horizons to seismic events on the P-P data.

Formation	Time (s)
BR	0.478
MR	0.674
2WS	0.895
BFS	0.953
MISS	1.100

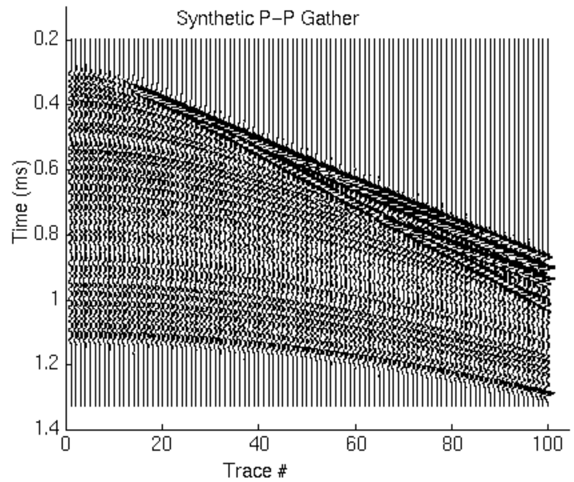

Fig.3. Synthetic seismic data, P-P component. Formation names are abbreviated as Belly River (BR), Milk River (MR), Second White Specks (2WS), Base Fish Scales (BFS), and Mississippian (MISS).

Formation	Time (s)
BR	0.717
MR	1.011
2WS	1.342
BFS	1.429
MISS	1.649

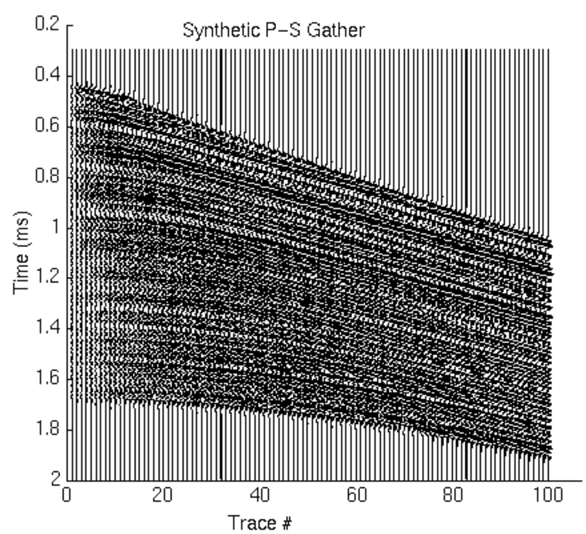

Fig. 4. Synthetic seismic data from SYNTH, P-S component. Formation names and times on left side. The times were derived by scaling the formation times of Fig. 2 by 3/2 to account for the longer P-S travel-time.

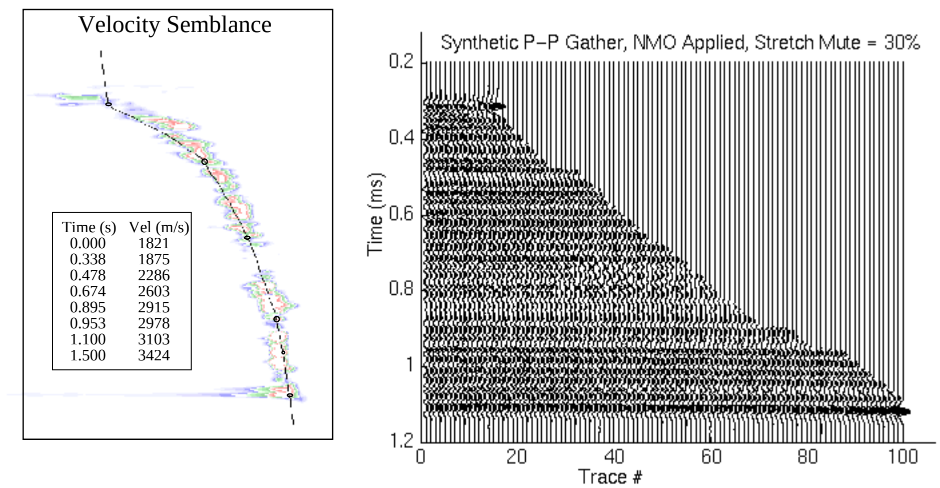

Fig. 5. Semblance velocity analysis of P-P gather. Horizon times and corresponding P-P NMO velocities on left.

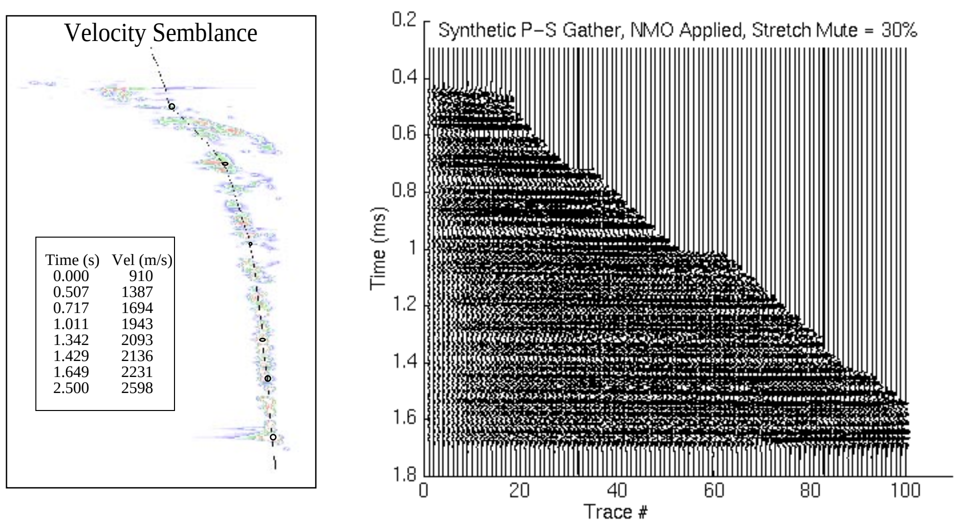

Fig. 6. Semblance velocity analysis of P-S gather. Horizon times and corresponding P-S NMO velocities on left.

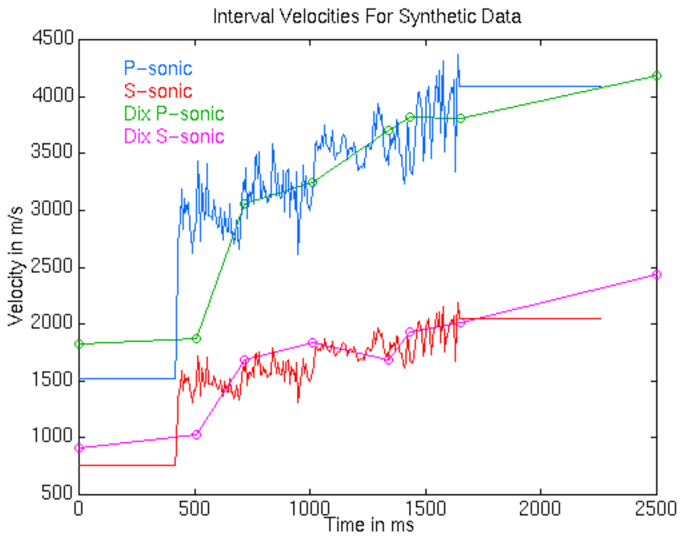

Fig. 7. Comparison of sonic logs to Dix estimates. The P sonic and Dix P sonic have been stretched to P-S time for direct comparison.

CONCLUSIONS

The RMS velocity for converted waves is used to calculate a Dix interval velocity for shear waves. In synthetic examples, we find that the long-wavelength (low resolution) shear velocity calculated agrees reasonably well with log values. In future work, we intend to compare this Dix interval velocity with that derived from amplitude inversion of low-frequency data.

REFERENCES

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