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A Practical Approach for Estimating Receiver Statics in 2D/3C Seismic Data Processing

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Summary

We present a practical approach to estimate the receiver statics associated with near surface shear wave propagation by investigating the lateral variability in the time events identified on the common receiver stack. Following the estimation of the receiver statics, we apply them along with the P-wave shot statics and show that considerable improvement is obtained in addressing the linear noise in the pre-stacked data, further enhancing the velocity analysis.

Introduction

In converted wave seismic data processing an important step is the evaluation of the receiver statics for the horizontal components. The near surface, both in seabed and in land acquisition, is frequently associated with low, laterally varying shear-wave velocities, with far more complex variability than the P-wave velocities, impacting severely on the frequency content of the seismic data processing products. The importance of addressing the receiver statics for the converted wave analysis has been well stated in the literature. However, methods for estimation of the statics component are still emerging and their applicability is yet to be tested. Here we analyze further the estimation of receiver statics from smoothed time events on the common receiver stack of the converted wave section.

Method

A time event (T_E) on a common receiver stack ("CRS") is modeled by three components: structural (geological) component (T_G), receiver static component (ΔT_R) and noise (ΔT_N):

$$T_E = T_G + \Delta T_R + \Delta T_N \qquad (1)$$

The structural component is considered to be laterally variable and smooth, and approximated by the long wavelength component of each CRS time event:

$$T_G \approx LP(T_E) \qquad (2)$$

where LP() is a spatial low pass filter to be applied to a time event T_E, the minimum wavelength to pass the filter LP being of the order of the maximum useful offset at time T_E. This length arises naturally when we consider that the events in the common reciver stacks are measured by offsets in the range of the maximum negative offset to the maximum positive offset. This component is then removed from the CRS time event, and the residual components of all identified time events are further averaged to attenuate the noise component and to obtain the final receiver statics:

$$\Delta T_{R_i} \cong \frac{1}{NE}\sum_{j=1}^{NE}\left(T_{E_{ij}} - T_{G_{ij}}\right) \qquad (3)$$

using the following approximation:

$$\sum_{j=1}^{NE} \Delta T_{N_{ij}} \approx 0, \text{ for each } i \in \{1, NR\}, \qquad (4)$$

where *NE* is the number of identified (and picked) time events, *NR* is the number of the receivers, *i* the index of the receiver and *j* is the index of the time event. Before averaging the residual components from different time events at the same receiver *i*, providing that three or more time events were picked, the residuals $\Delta T_{R_{ij}}$ (*j*=1 to *NE*) are statistically classified and outliers omitted in the average: the mean and standard deviation of all available residuals at a receiver is calculated, and only the residuals that cluster within a standard deviation from the mean are included in the final estimation of the receiver statics. The clustering radius can be increased or decreased, as a parameter.

Example

The above method of estimating the receiver statics was tested on a 2D line of multicomponent seismic data acquired by CREWES in 2008 (Suarez et al., 2009). The processing flow used for calculating the common receiver stack of the radial component of this 2D/3C seismic data set is shown in Figure 1. The shot statics were previously estimated by processing the P-wave component.

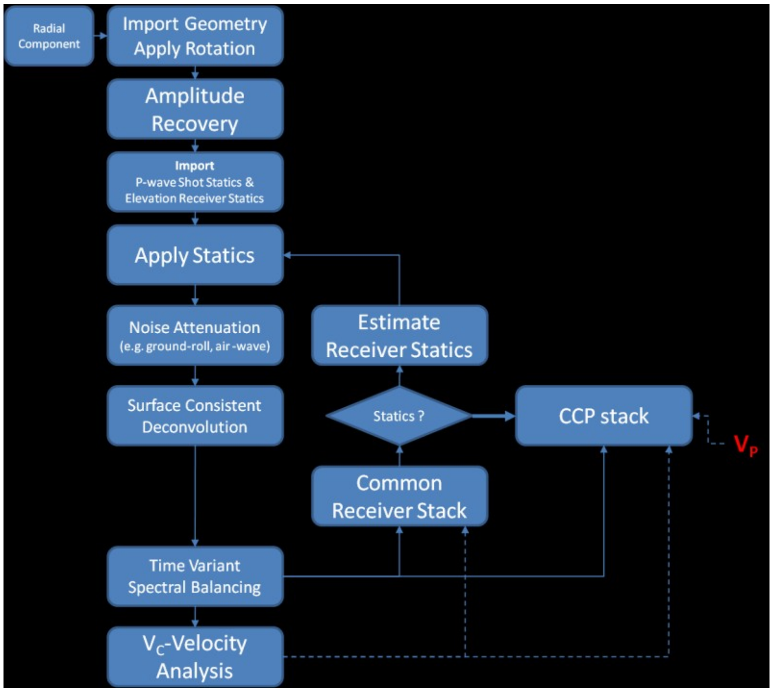
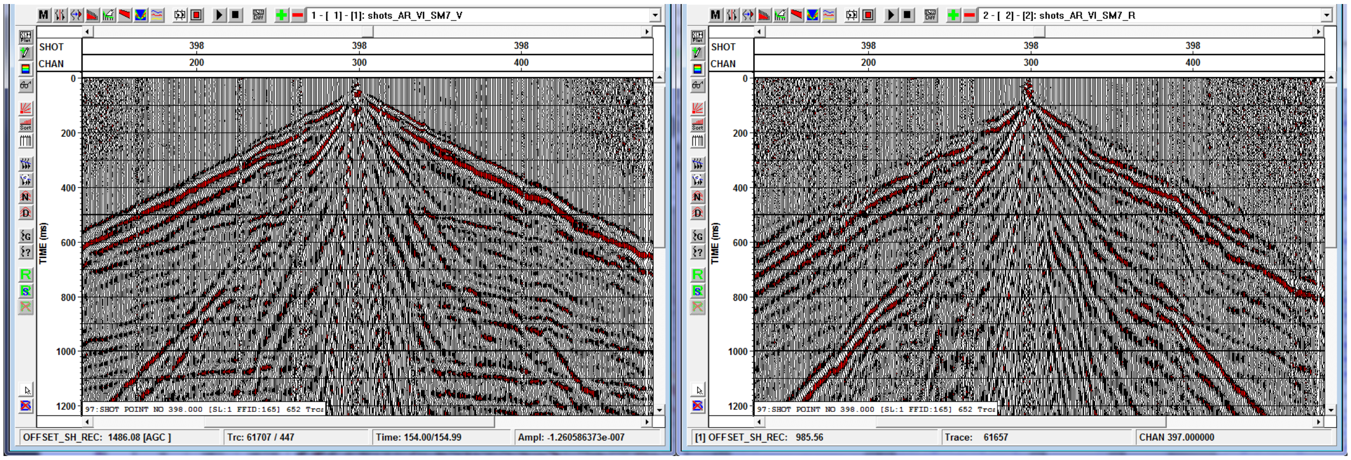


Figure 1: Processing flow to estimate the receiver statics from the Common Receiver Stack of the radial component

Prior to estimation of the receiver statics, a linear noise removal may be very difficult (Figure 2). We suggest that this step be performed as soon as possibleafter a first approximation of receiver statics is available.

In our tests we estimated the C-wave velocity (V_C) in a similar fashion to P-wave velocity analysis, the main difference consisting in the use of a different NMO correction (Slotboom, 1990). All the involved procedures (e.g. common velocity stacks and semblance) were based on the true surface formulation, using Slotboom NMO. Given the high noise level in the CRS in the first cycle, we applied a principal component based de-noising technique (4DDEC) prior to picking time events on this CRS (Figure 3).

These receiver statics were compared with the corresponding P-wave receiver statics (Figure 4), where we noticed a far higher range for the PS-wave receiver statics (about 160 ms vs. 20 ms in the case of the P-wave version). There is little to no correlation between the two versions of statics, and simply scaling the P-wave receiver statics would not lead to satisfactory results. The processing cycle was repeated, and clear improvements are shown in the time variant spectral balancing section comparison (Figure 5). The Common Conversion Point ("CCP") stack is estimated based an improved C-wave and existing P-wave velocity models (Figure 6). Matching horizons on both stacked sections provided a way to further estimate the Vp/Vs ratio.



a) b)

Figure 2: Shot gathers of the vertical (a) and radial (b) 3C components. Larger statics are obviously affecting the radial component, and linear noise removal may not be satisfactory

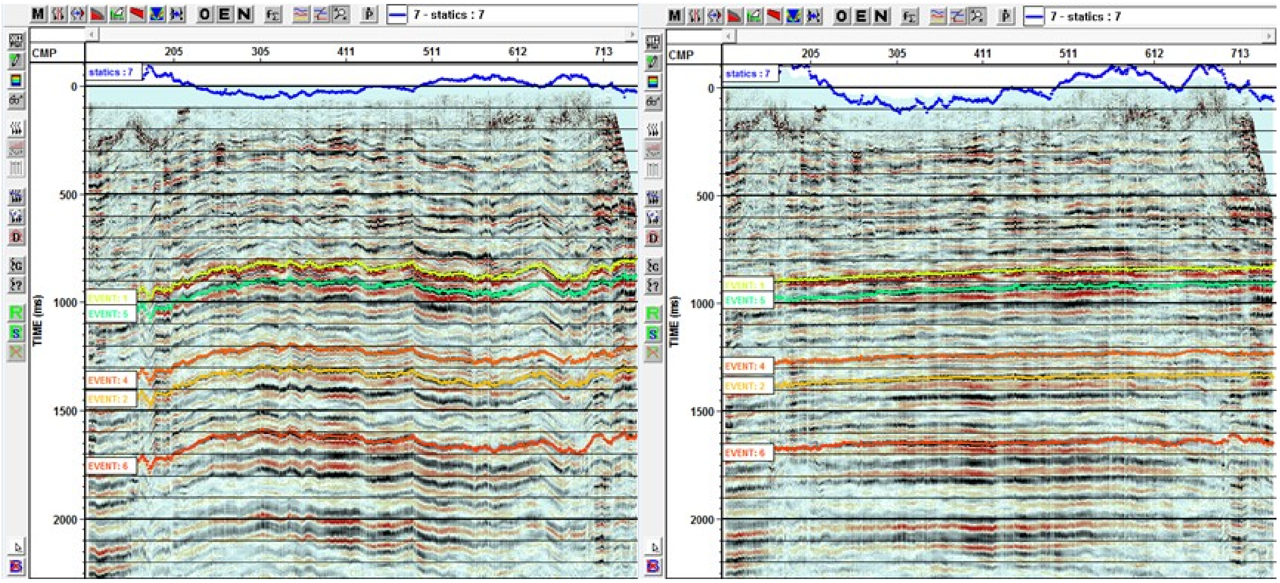


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Figure 3: (a) Picked horizons and estimated receiver statics on the 4D-DEC denoised version of CRS; (b) The same denoised version of CRS after applying the receiver statics.

Conclusions

The estimation of C-wave receiver statics from common receiver stack has been proved on a data set with a smooth geological background. The application of this method to more structurally challenging cases has to be tested.

Acknowledgements

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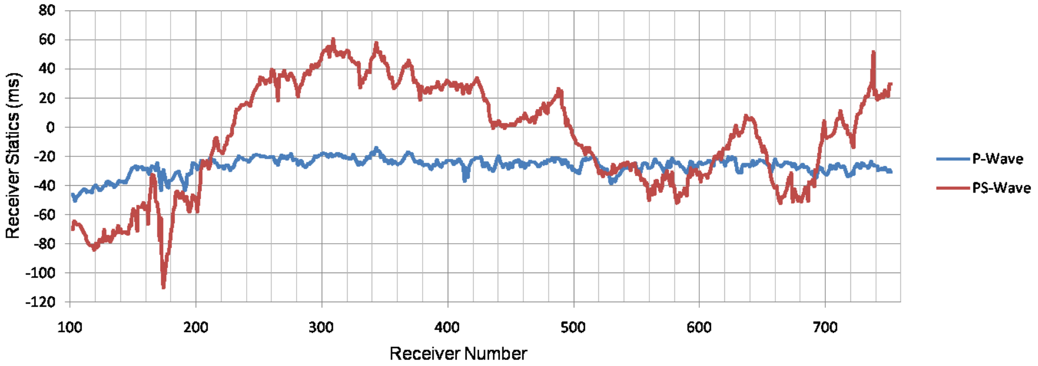
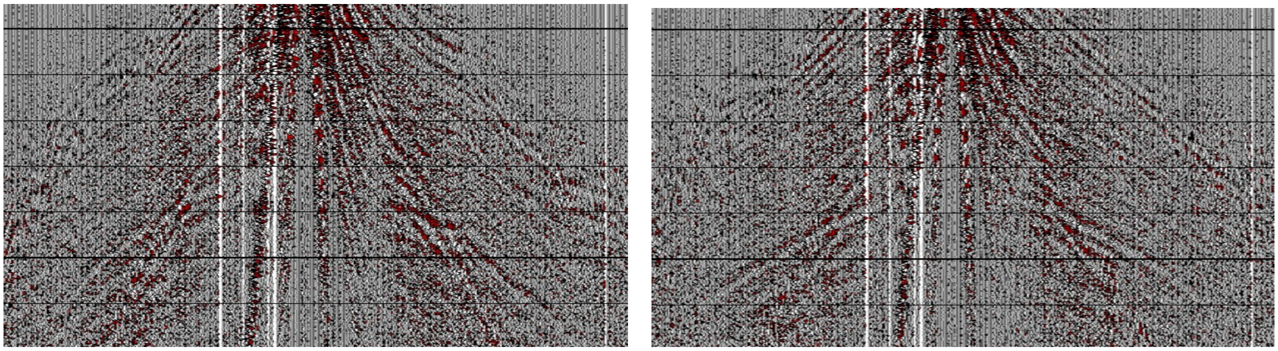
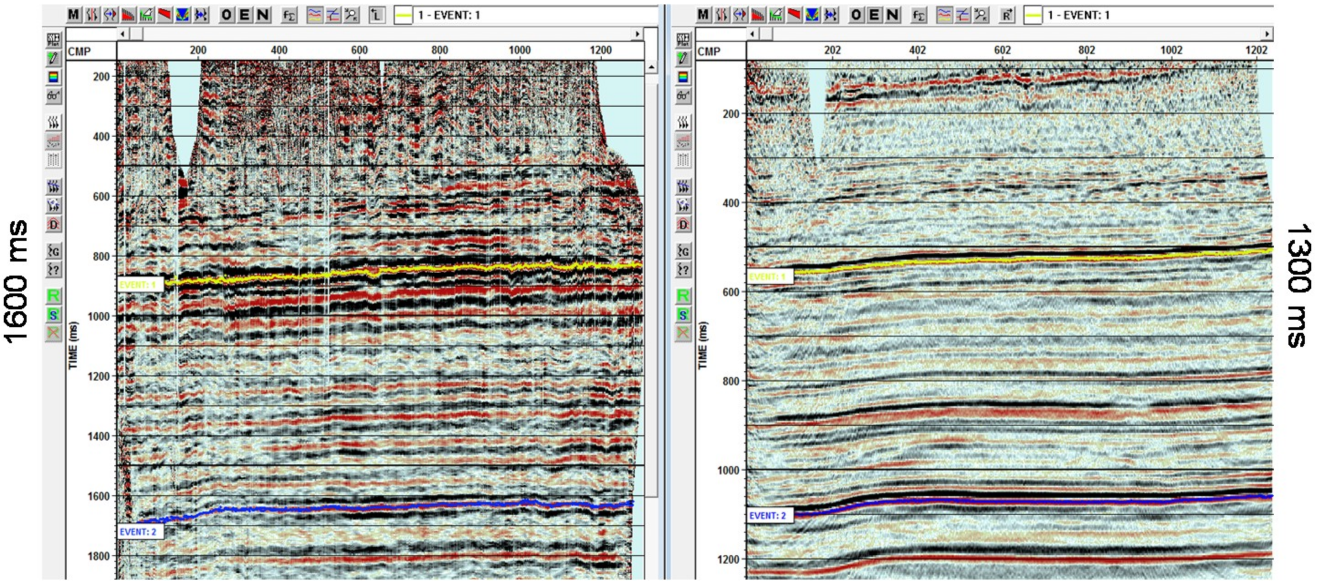


Figure 4: P-wave receiver statics are compared with the estimated PS receiver statics (receiver elevation statics not included)



a) b)

Figure 5: PS-wave time variant spectral balancing before (a) and after (b) application of the receiver statics



a) b)

Figure 6: Two matched time events on C-wave CCP stack (a) in PS time vs P-wave CMP stack (b) in PP time (relative vertical scale of the two section adjusted)

References

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