DOI:10.1190/1.1885425

Event registration and Vp/Vs correlation analysis in 4C processing

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Summary

Accurately calibrating P-wave and PS-wave seismic sections is achievable using the currently available tools for event registration. This in an important step in wider use of multicomponent seismic data as it enables better interpretation and use of the combined data sets. It is also becoming more and more important in processing of multicomponent data as VTI anisotropy and Kirchhoff prestack time migration are included in the processing sequence. In this paper, we will look at the different tools for obtaining correct and accurate Vp/Vs ratios and discuss how including event registration in the processing sequence can improve the imaging as well as improve the quality of the Vp/Vs function.

Introduction

Efficient and accurate calibration of P-wave and PS-wave seismic sections is critical to the processing and interpretation of multicomponent data. This requires the determination of an average, vertical Vp/Vs (or γ_0) to correctly transform from one time reference to another (e.g., compressing from PS-wave time to two-way P-wave time). This compression (or stretch) is not only important for accurate interpretation of the different data volumes, but is also important for a variety of processing steps such as long-period static corrections, CCP-binning, Kirchhoff prestack time migration, and prestack depth imaging.

Historically, this event registration has relied on identifying similar features in the PP and PS data. This in itself can be difficult in certain areas, while straightforward in others. However, it is still the starting point for the event correlation.

Identifying the same events on PP and PS

Identifying the same geological horizons in the PP and PS data is probably the best way to ensure that the resulting Vp/Vs ratio function is correct. In certain areas where there are a small number of seismic markers this can be fast and attractive way to get a good overall Vp/Vs ratio function to start with. This is illustrated in figure 1, where a PP and PS section from a North Sea 4C survey is displayed. It is straightforward to recognize the corresponding events in the two sections despite the difference in frequency content.

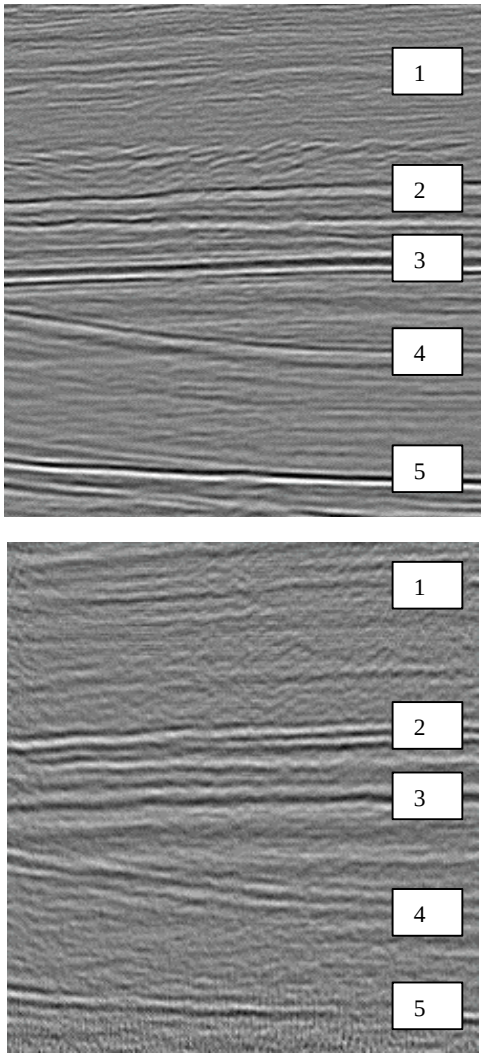

Figure 1: Example of event-correlation from the North Sea PP data (top) and PS data (bottom) with indication of markers used in correlation.

The PS section in Figure 1 has been compressed in time to facilitate the comparison with the PP data.

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Fault registration on PP and PS data

In some areas, we find the number of events in the seismic data so high that it is difficult to pick corresponding markers. For instance, on the data in Figure 2, we have typical Gulf of Mexico sand/shale sequences consisting of a large number of individual events. In this case, fault registration on the PP and PS data is a good alternative to getting a reliable starting Vp/Vs-ratio.

The position of the fault in CDP and time is independent of the events it crosses and we can, therefore, establish a Tp/Ts function along the fault trajectory by combining Tp and Tps for the same CDP location. Corresponding faults on PP and PS data are illustrated in Figure 2.

Vp/Vs correlation method

The methods above for deriving the Vp/Vs-ratio function are based on picking only one value per event per trace. This picking might be affected by phase differences in the data or reflectivity differences between the P-wave and S-wave sections. Using the cross correlation of the data in a window can, therefore, be more robust and offers one way to quality control the picked values.

To help speed this process, a tool was developed to provide a robust means for determining γ_0 using a cross-correlation technique similar to conventional velocity analysis routines. The algorithm systematically compresses the PS-wave data volume over a range of γ_0 values and cross-correlates it with the P-wave. The resulting values are then displayed and interpreted in any interactive velocity analysis software package as shown in Figure 3. In this figure, the cross-correlation values are shown and can be picked much like with semblance velocity analysis. Also, note the deviation between the initially picked Vp/Vs trend and the maximum for the cross correlation in Figure 3b.

While this process yields a more regional correction curve, it does provide the processor and interpreter with a much better starting point for further, more detailed interpretation. In addition, an option exists within the software to evaluate a smaller, targeted time window for interval γ_0. This can be used for subsequent lithologic interpretation over a known reservoir interval. An example of this is shown in Figure 4, where the regional variation in the interval γ_0 indicates additional sand.

This process works on a pair of traces at a time (PP and PS) and can be run on large amounts of data relatively efficiently. The user defines the range of γ_0 values to scan over and the cross-correlation window size. The algorithm then systematically transforms the input trace and performs the cross correlation. Several pairs of traces can be combined to improve the robustness of the method in noisier areas.

A key step in the process is the matching of bandwidth between the two traces. This is often a challenge because, ideally, the frequency content should be equivalent after transformation. Often, this requires significant filtering of the high frequencies on the P-wave data. Another important parameter is the starting γ_0 "guide" function used for the scanning. The closer this is to the correct answer, the better the correlation. Also, Hilbert transformations of the data or the resulting correlation displays can ease the interpretation process and remove the possible effects of phase errors in the data.

Use of Vp/Vs functions in multicomponent processing

The Vp/Vs ratio functions are used at several stages in the processing of converted waves. With the move to more prestack time and depth migration of converted-wave data, the quality of these functions will become even more important for the final imaging results. Event registrations should, therefore, be regarded as a necessary integral part of multicomponent processing.

Including the event registration in processing will aid the processing of the data as well as deliver a good starting point for the subsequent interpretation. In addition, the Vp/Vs ratios can be QC'd in processing when combining them with processing velocities to look at S velocities and anisotropy (Kristiansen and Vetri, 2002). Particularly the interval velocity for the S-waves has been seen to be sensitive to errors in the event registration.

Conclusions

Event registration and Vp/Vs correlation analysis has been performed successfully in many areas throughout the world on land and marine multicomponent data, and for a variety of data qualities and geologic situations.

The estimation of γ_0 is an important step in both the processing and interpretation of multicomponent data, but it is important to integrate it in processing to obtain both the best imaging and the best event registration.

References

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Kristiansen, P., and Vetri, L., 2002, Extracting Anisotropy Information from 4C data: 10IWSA (10th International Workshop on Seismic Anisotropy).

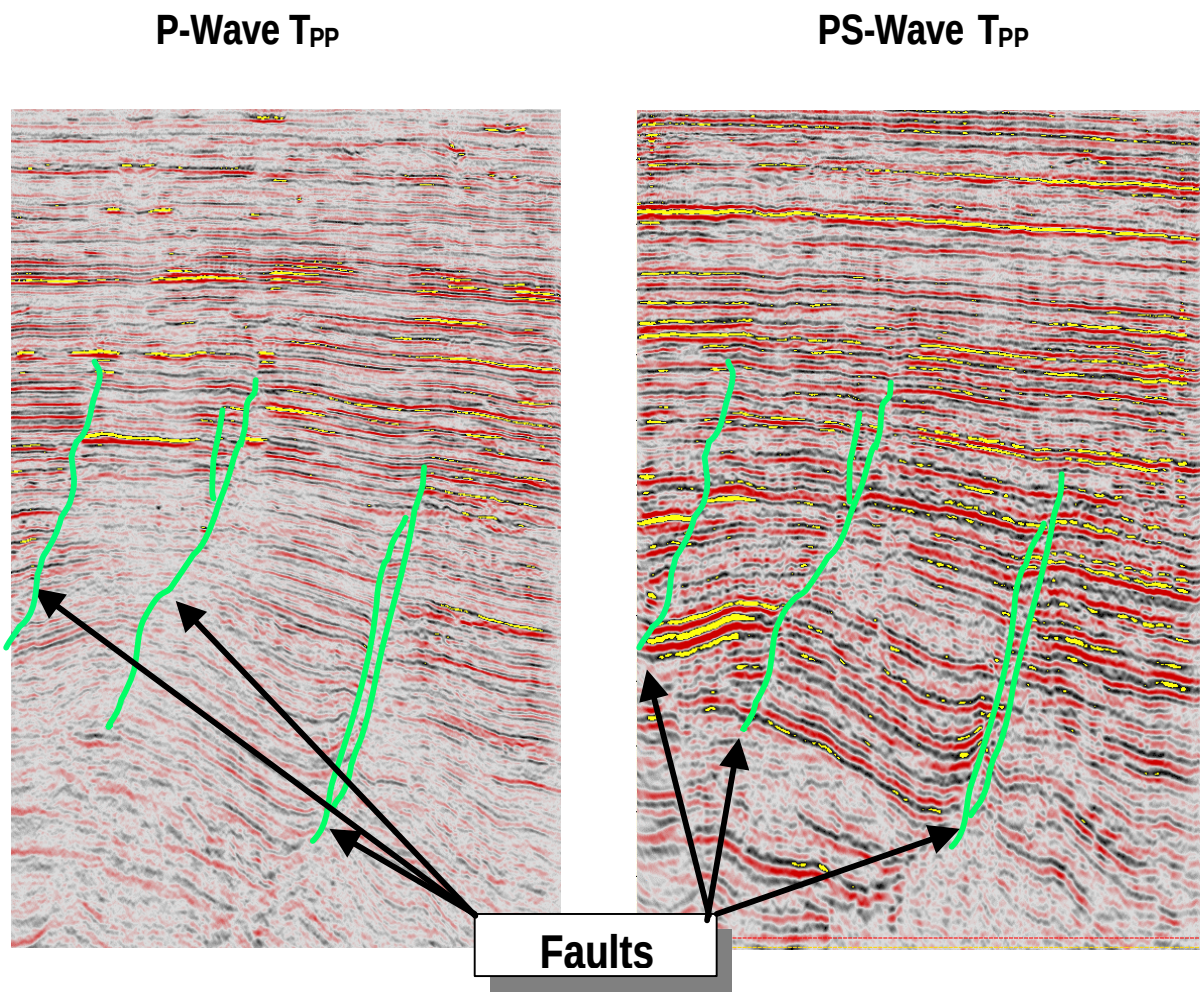

Figure 2: Example of fault registration on PP and PS data from the Gulf of Mexico.

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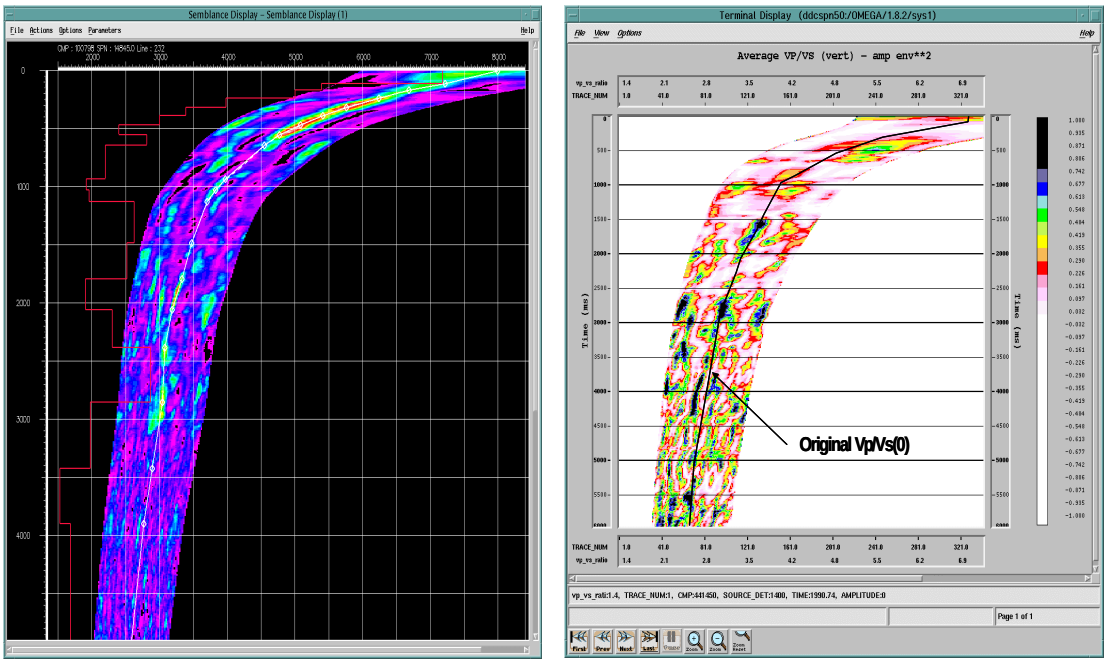

(a) **(b)**

Figure 3: Gulf of Mexico examples: (a) Vp/Vs correlation analysis for Eugene Island 3D/4C with supplied Vp/Vs(0) curve in black; (b) Vp/Vs correlation analysis for the MultiVision 2D/4C project in West Cameron

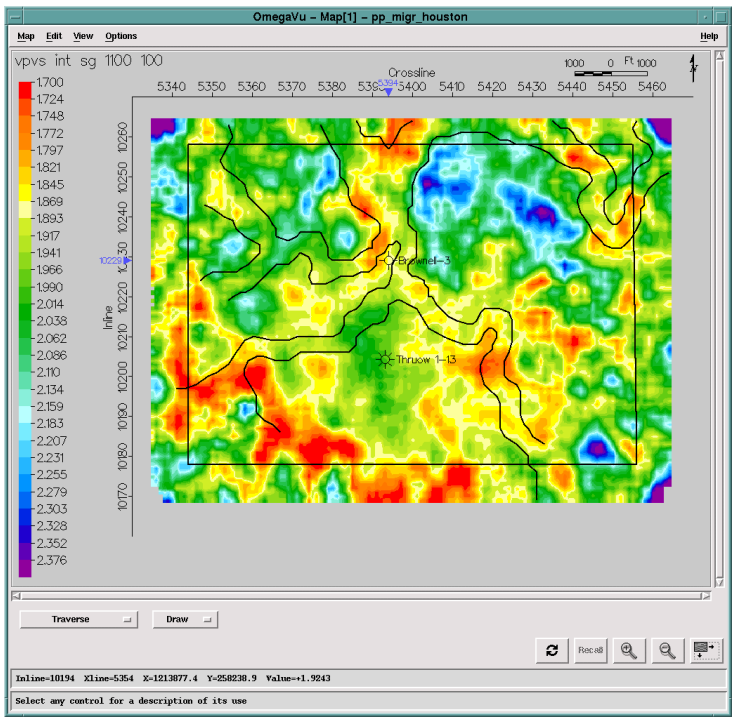

Figure 4: Interval Vp/Vs correlation analysis map from Cave West 3D/3C land survey. Black outline indicates channel boundaries interpreted from coherence volume. Red and yellow colors represent lower Vp/Vs, potentially indicating more sand.