Inserting Stratigraphic Deconvolution into the Possessing Flow to Improve the Resolution of AVO

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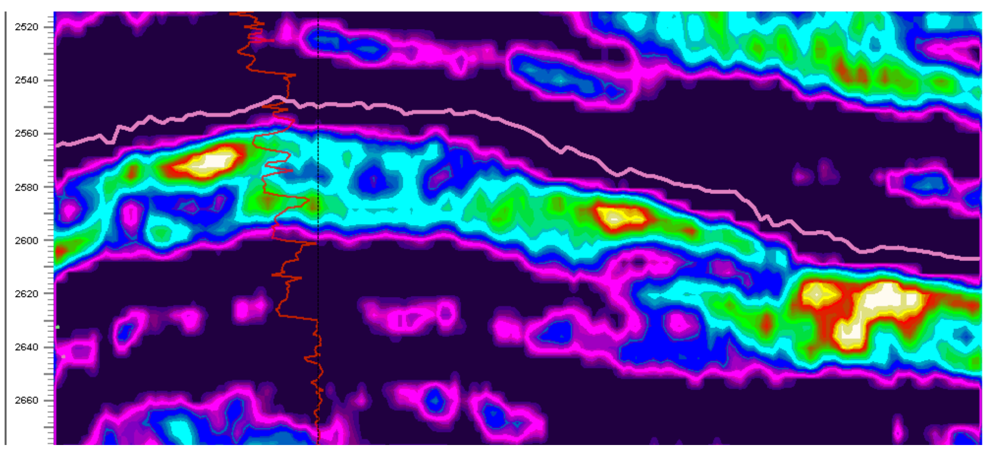
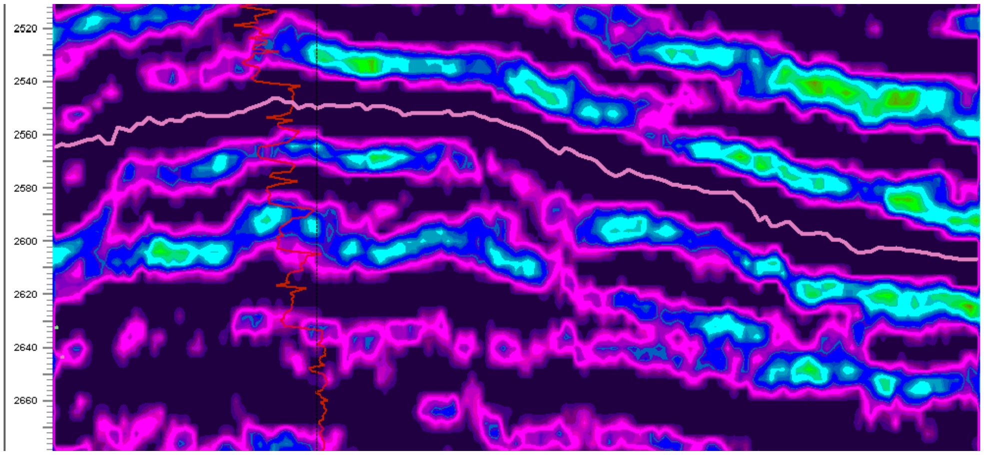
Summary

Stratigraphic deconvolution has proved to be an effective tool in enhancing the resolution of seismic data, but this enhancement process has been limited to stack data and cannot address the limitations imposed by limited resolution in gather traces that go into AVO analysis.

The match filter approach of stratigraphic deconvolution, because of its simplicity, may be able to address this resolution limitation of AVO.
The concept is to design the operator on fully processed stacked data, and then apply this operator to the unstacked traces of the gathers that are used in the AVO analysis.



The section above has been converted to the much higher resolution section below by the application of a Match filter using the VSP from the well as a reference.



If the same result can be achieved for unstacked data, AVO analysis of reservoirs that were previously beyond the resolution of gather traces, could now be done.

Theory and method

As the angle of incidence departs from normal, a larger and larger portion of the incident P wave energy is converted to S wave energy at a reflection interface. The interference between these two modes produces amplitude changes with changes in incident angle that help defines rock properties and fluid properties. This information is very valuable in assessing prospects and is routinely used in field development and other evaluations of petroleum and natural gas reserves.

The limitation of this method is the frequency resolution of the seismic data, because the analysis can only be performed on the amplitude of individual reflections, and therefore the events that can be analyzed by AVO are limited by the upper limit of the seismic resolution. Certain areas are plagued with near surface problems that limit the high frequency resolution of the seismic data. When the extent of the higher frequencies suppression is at the point that the resolution is too low for a response from the reservoir horizon; AVO analysis cannot be performed on that horizon.

Stratigraphic deconvolution in the form of match filters using VSP's or Synthetic Seismograms as reference traces has proven very successful in restoring the resolution to stacked data in these poor record quality areas, allowing basic amplitude mapping of reservoirs previously not represented by individual events. If the resolution of the individual traces in the gather could be brought up to the same level, these same reservoirs could be analyzed with AVO techniques. This paper looks at the possibility of using match filters as part of the processing stream to enhance the resolution of the traces used in AVO analysis.

The concept of a match filter is that the seismic trace and the VSP trace both contain the same reflectivity sequence; but in the VSP trace this reflectivity sequence is convolved with a perfect zero phase broadband wavelet, while in the seismic trace, this reflectivity sequence is convolved with a wavelet that is limited in frequency and has a distorted phase spectrum. A cross correlation of these traces provides the amplitude and phase differences of these wavelets over their common frequencies. An operator designed on these differences will restore the seismic wavelet to zero phase and flat spectrum matching the reference trace over the frequencies common to both traces.

The near surface conditions in some areas are such that ‘data based’ deconvolution is insufficient to restore the full resolution of the input energy. Typically the problem is the superposition of high frequency source generated coherent noise on the reflection energy. The deconvolution process sees this high frequency as part of the wavelet and the higher frequencies are not properly enhanced in the process. The net result is that the high frequencies, though still present in the data, are far below the ‘optical threshold’ and do not properly contribute to the resolution.

Since the deconvolution operation is performed in a surface consistent manner, the seismic wavelet, regardless of its distortion, should be distorted consistently throughout a 3D survey (or along an entire 2D line). If this consistency exists throughout a survey, then all that should be required to correct the traces in such a survey would be just a single operator.

The application of a match filter to stack data has certain limitations and these same limitations apply equally in using this approach to improve the resolution of gather traces. The upper limit of the frequency in the data defines the upper limit of the final product. This can be determined by using a significantly higher frequency wavelet in the reference trace than the upper limit of the recorded energy in the seismic data. Reflection energy changes phase smoothly, but noise does not follow this smooth change. The phase spectrum of the cross correlation of the high frequency reference trace with the seismic trace will change smoothly up to the frequency at which the noise dominates. At this point the phase becomes erratic indicating the upper frequency limit.

The fold variations and the stretching from dynamic corrections render the upper part of the seismic section unsuitable for stable match filter design and application. Typically this problem is restricted to the upper third of the section, but it is important to determine the window for the operator design specifically for each project because this limitation can be different from place to place.

These are the two important limitations of the process, but there are several other factors that need to be determined for optimal results. It is therefore critical to determine these factors in an interactive fashion, which is best done by the interpreter with an eye on the objective horizons. Using a match filter on a workstation as an interpretive tool has been very successful because this interactive determination of the match filter becomes part of the overall interpretation process. This is done after the data is fully processed with no further input from the seismic data processors, but for enhancing gather traces this must be just an intermediary step with the output going back to the data processors to use in further processing of the gather traces.

To use the match filter process to improve the resolution of the gather traces requires the same interpretive input, and without this type of input by the interpreter, it is highly doubtful that this process will achieve desired results. As this interpretive input now becomes part of the processing flow, it is advantageous to have the facilities to perform these interpretive tasks close to and compatible with the seismic data processing facility.

Essentially the procedure is identical to the conventional procedure used to prepare seismic data for AVO analysis except for the addition of an interpretive cycle within the processing flow. The data are fully processed to final stack using whatever processes and parameters give the optimum result. Post stack processes should be limited to filtering to remove low frequency noise and any high frequency artifacts that are beyond the range of the input source for VIBROSEIS data, as well as some sort of scaling to balance the amplitude of the traces. It is critical that no time variant processes such as time variant spectral whitening are applied, because processes that do not conform to convolution make the data less suitable for match filter application.

This final stack data is now transferred to a workstation where it is tied to a well with either a VSP or a synthetic seismogram. An optimum match filter is determined on the workstation by an interpreter and the operator for this match filter is saved.

This operator is now applied to the fully processed gathers at the processing center, and the gathers are further processed as required for AVO analysis. The net result should be higher resolution traces going into the AVO analysis with previously unattainable information now coming out.

This approach is still in the conceptual stage with no physical testing yet completed. I hope to show some results from the investigation of this process when the paper is presented, and discuss successes and/or shortcomings of this procedure at that time.

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References

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