Virtuous Circle of Seismic Interpretation Attributes

Luis Vernengo and Eduardo Trinchero
Pan American Energy LLC, Buenos Aires, Argentina
lvernengo@pan-energy.com

Abstract

The main challenge for a seismic interpreter is to extract maximum amount of information from seismic data and integrate that with other relevant data so that an accurate reservoir model of the subsurface prospect can be conceived. This implies evaluating and comprehending seismic events, their spatial behavior and interrelation and understanding the subsurface geo-architecture in the area of interest. For achieving such objectives, the seismic interpreters make use of high end interpretation workstations, where the seismic data are analyzed, integrated with well and other geological data and visualized in a practical and realistic way that other members of the team can understand. But this represents only one part of the modern seismic interpreter's job. The other challenge for the seismic interpreter is to devise creative and convincing workflows for analyzing the seismic data and its integration as mentioned above. Significant progress has been made during the search or advancement of such new approaches.

Attributes More Useful than Conventional Seismic Amplitudes

The motivation in pursuing such advancements has been due to belief that a seismic interpreter's routine task must include comprehending and analyzing novel and non-traditional ideas, which reflects the individual's creativity. Vernengo and Trinchero (2015) described an amplitude volume technique (*AVT*) workflow that calculates the root-mean-square (rms) of the amplitudes by choosing a definite analysis window, and then rotate the phase of the data by -90^{o} by using the mathematical operation of Hilbert transform. This calculation of the input seismic data yields somewhat higher amplitudes of frequencies in the bandwidth of the input data. A variation of this approach called high-frequency *AVT* was also described, wherein the workflow is applied to input seismic data after its bandwidth is broadened, i.e. includes frequencies at the lower and higher end of the spectrum also. Interpretation carried out on the resulting data (AVT or AVT_{HF}) or attributes generated on these data exhibit more detail and are suggestive of other points of view that have a positive impact on the comprehension of the structural and stratigraphic elements in the subsurface architecture. In Fig. 1(a) it is shown that a segment of a seismic section from Golfo San Jorge Basin in Argentina, and compare it with its equivalent AVT_{HF} section, where the Deep Necomian deposits stand out clearly as indicated with the blue arrow. The display not only facilitates the correlation of the fault lineaments as seen on the section through different sediment sequence patterns, but exhibits the ease with which they can be interpreted.

Similarly, in Fig. 2(a), a horizon slice is shown from a seismic volume close to the top of a channel-like feature of an intrusive body, which was spilled out when it was at the surface. The seismofacies signature of the intrusive body as well as its spatial disposition is seen clearly in Fig. 2(b) while it's clear expression is seen on the AVT_{HF} section shown in the inset.

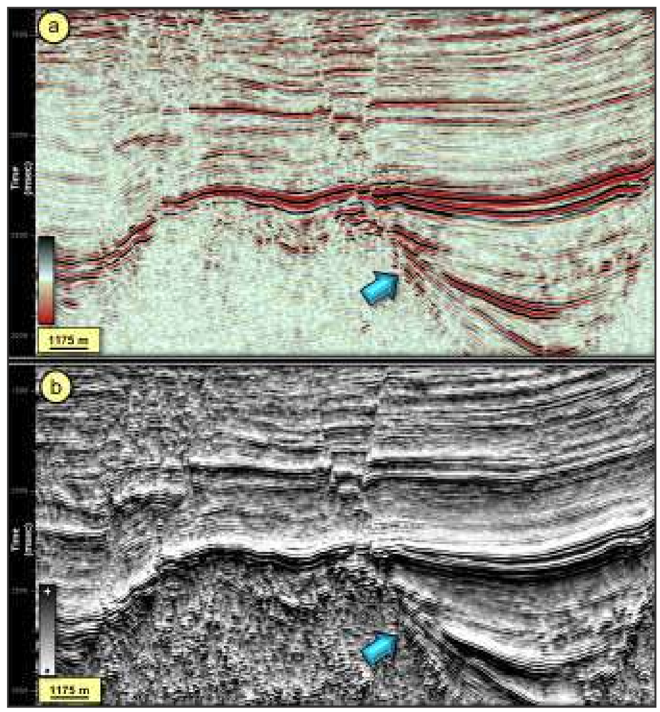

Fig. 1: (a) Segment of a seismic section showing deep Neocomian deposits (blue arrow) from the Golfo San Jorge Basin, Argentina, and (b) the equivalent section from the AVT_{HF} attribute. Notice, the clear correlation of the discontinuities seen on the latter section, and the ease with which interpretation can be carried out on it.

Seismic attributes computed on AVT_{HF} data benefit from the enhanced interpretation detail that they exhibit. In Fig. 3 shows a segment of a seismic section depicting the signature of an intrusive body, and its equivalent expression on the AVT_{HF} section. The overlaid well-log curves from four wells correlate very nicely with the signature on the AVT_{HF} section. In Fig. 3(c), an equivalent section from the complex trace attribute apparent polarity run on the input seismic data is exhibited, where it is difficult to decipher the signature of the intrusive event and its correlation with the well log curves.

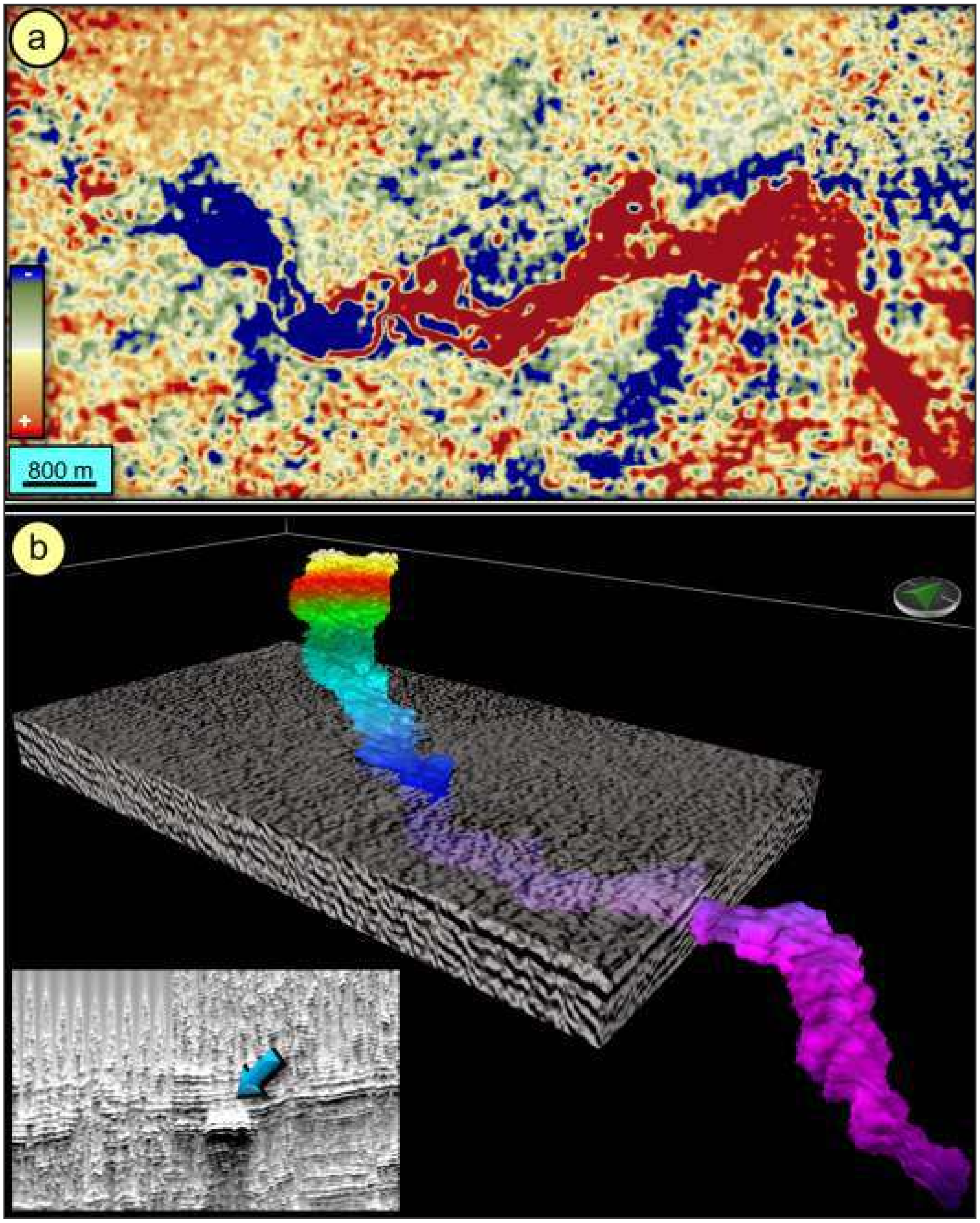

Fig. 2: (a) A horizon slice from a seismic volume close to the top of a channel-like feature of an intrusive body, which was spilled out when it was at the surface. The spatial disposition of the intrusive body in three dimensions is seen clearly, as well as its expression (light blue arrow) on the AVT_{HF} section in the inset.

Finally, Fig. 3(d) exhibits the equivalent apparent polarity section computed on AVT_{HF} data. It is noticed, how the apparent polarity signature aligns with the log curves and can be interpreted accurately.

Next, it is demonstrated through examples, how different attributes can be visualized together and result in a value-addition exercise. Fig. 4 shows a vertical section from Golfo San Jorge Basin, Argentina, from the AVT_{HF}volume that has been co-visualized with the ant-tracking volume using transparency. Notice, how many visible discontinuities line up with the ant-tracking volume lineaments in red, and highlights the potential of AVT_{HF} technique in identification of the different level of faulting and the structural configuration. *(*Ant-tracking is an image processing procedure that can be run on discontinuity attributes for gaining higher resolution in terms of lineaments, and is available in a commercial interpretation package*)*.

In Fig. 5, a horizon slice is shown from a coherence volume that exhibits the signature of a dyke (indicated with a blue arrow). The yellow line in the lower coherence slice indicates the location of the covisualized section shown in Fig. 5(b), which shows the visual impact of the intrusive body filling the feeder zone and going up to the final emplacement (light green coloured zone, pointed with yellow arrow).

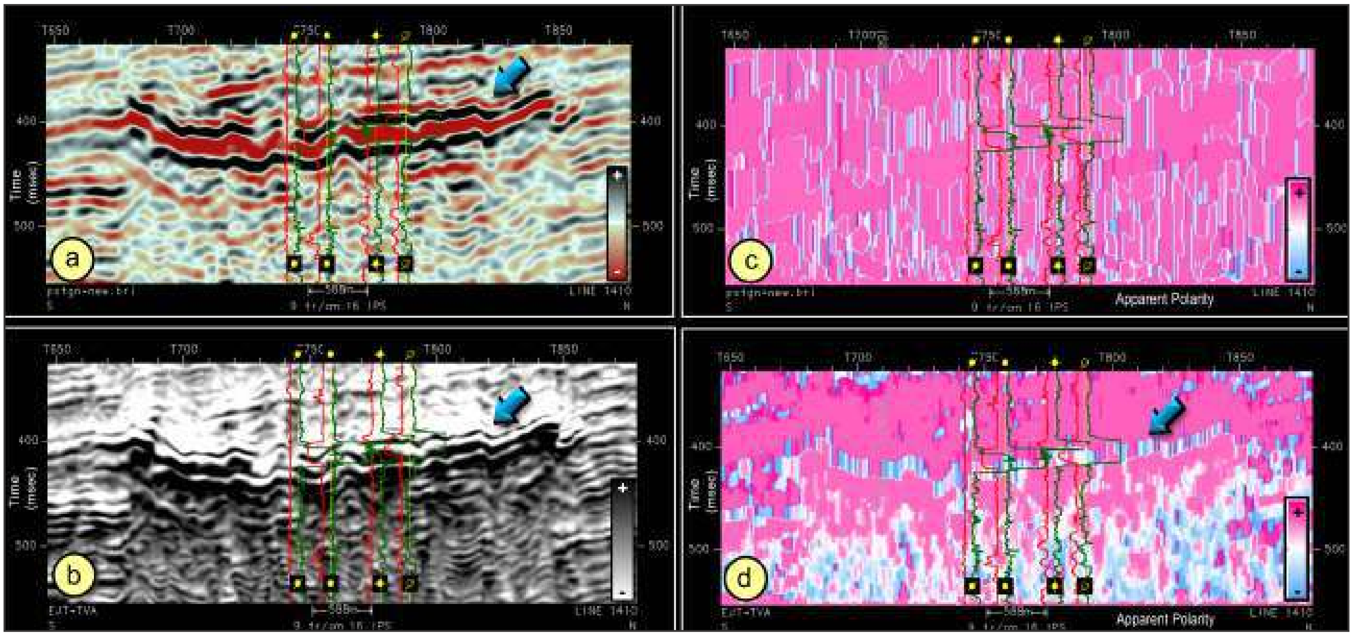

Fig. 3: (a) Segment of a seismic section shows the expression of an intrusive body, and (b) its equivalent expression on the AVT_{HF} attribute section. The enhanced visual display correlating nicely with the four well log curves overlaid (resistivity in green and spontaneous potential in red) is worth noting. (c) The equivalent section from the complex trace attribute apparent polarity generated on the seismic data in (a). It is difficult to decipher the signature of the intrusive event and its correlation with well log curves. (d) The equivalent section of apparent polarity generated on AVT_{HF} data shown in (b). Notice how the apparent polarity signature aligns with the log curves and can be interpreted accurately.

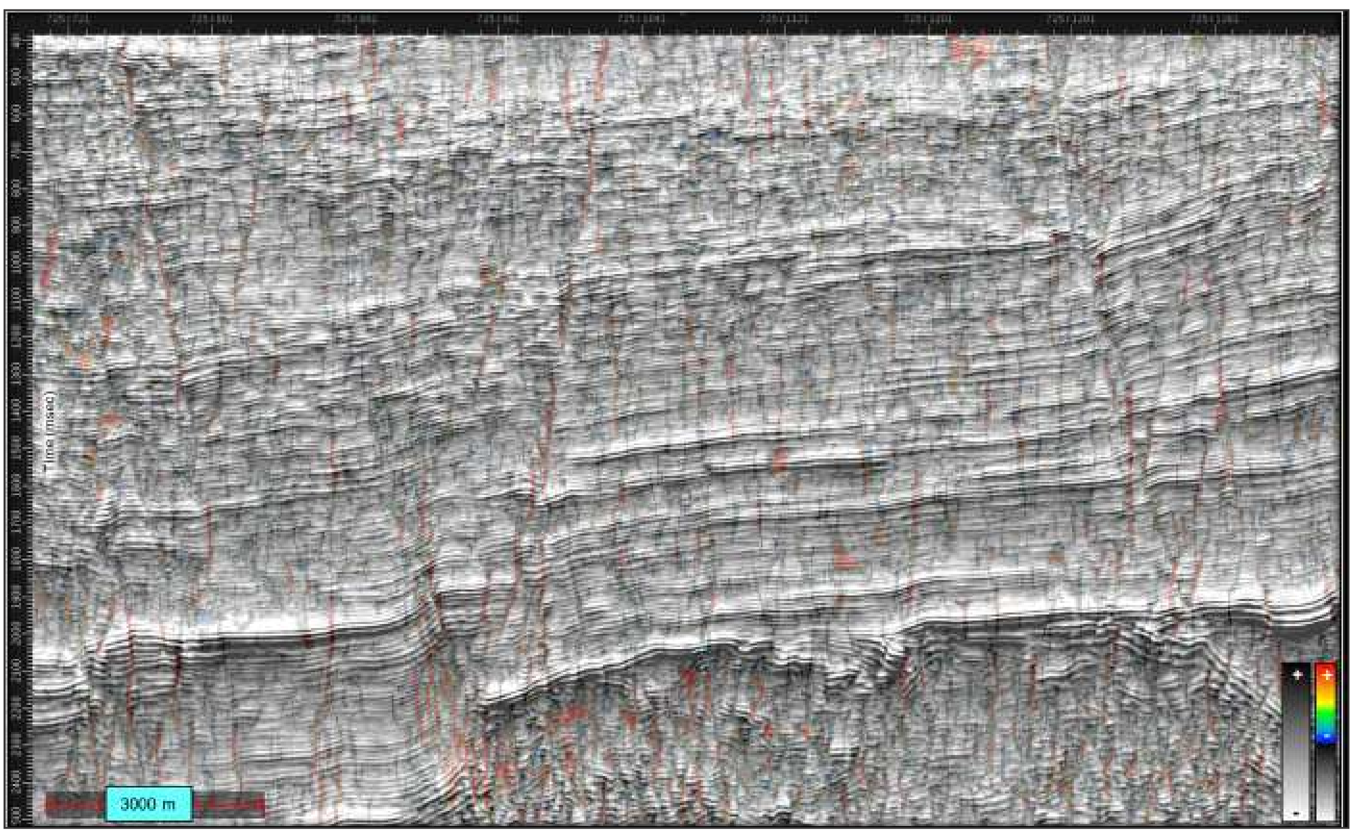

Fig. 4: Segment of a section from the Golfo San Jorge Basin, Argentina, showing the covisualization of AVT_{HF} and the ant-tracking result. The image demonstrates the potential of AVT_{HF} in identification of the different level of faulting, the structural configuration and the lateral and vertical relationships of the faults.

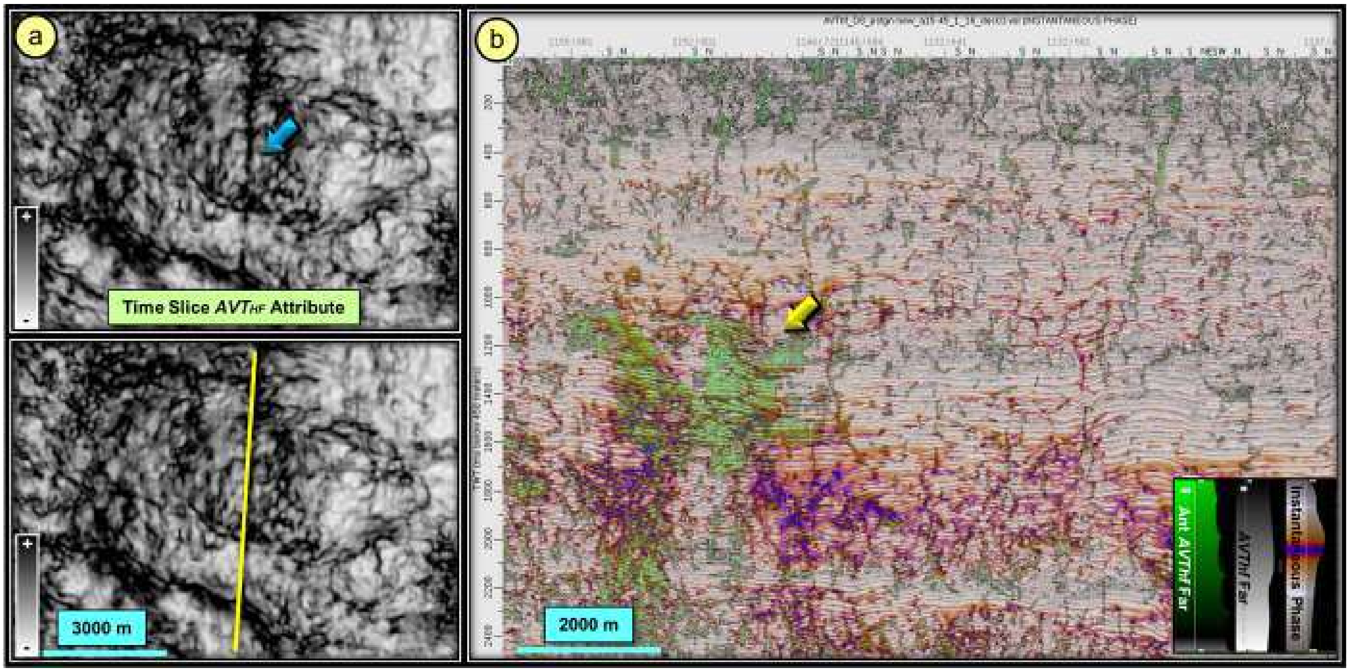

Fig. 5: (a) A horizon slide from the coherence volume shows the signature of a dyke (indicated with a blue arrow). The yellow line in the lower coherence slide indicates the location of the covisualized section shown in (b), which shows the visual impact of the intrusive body filling the feeder zone and going up to the final emplacement (light green coloured zone, pointed with yellow arrow)

Second-derivative Method for Accurate Structural Interpretation

Often the bandwidth of the seismic data being interpreted does not exhibit enough continuity or resolution for a satisfactory interpretation. In such cases, the second derivative computation of the input seismic data can help. It may be mentioned here that when the first derivative is generated, its phase gets rotated by -90°. When the second derivative is generated, the phase of the seismic data gets rotated by -180°. Visually, this means that the polarity of the traces is inverted, or that the peaks become troughs, and vice-versa. In terms of interpretation, enhanced reflection continuity in the seismic data is noticed, which is helpful, particularly in areas with disrupted or poor reflections, or for the data with diminished lateral variations, where horizon picking is difficult. This aspect is illustrated in Fig. 6, where it is shown a 3D perspective view correlation for a PSTM sections to the right, and the second derivative attribute section to the left. Some frequency enhancement of the data is notice on the second derivative section, which can definitely help.

Sometimes, instead of running the second derivative on the PSTM seismic data, if it is run on the amplitude envelope attribute, the resulting attribute can minimize thin-bed tuning and aid the interpretation of major depositional strata or lateral lithologic variations. Fig. 6(b) shows the same 3D perspective view correlation for the PSTM section to the right, and the second derivative attribute section to the left. Any picking of the horizons would be facilitated on this section. A considerable enhancement in the frequency content and enhanced signal-to-noise ratio are noticed, which are

Fig. 6: (a) A 3D perspective view comprising the PSTM seismic inline to the right, and a crossline from the second derivative of PSTM data, which shows an incremental enhancement in frequency. **Fig. 6(b)** The same 3D perspective view but with equivalent second derivative on envelope attribute data shown to the left. This display enhances the reflection detail and hence the interpretation of subtle events and geobody geometries.

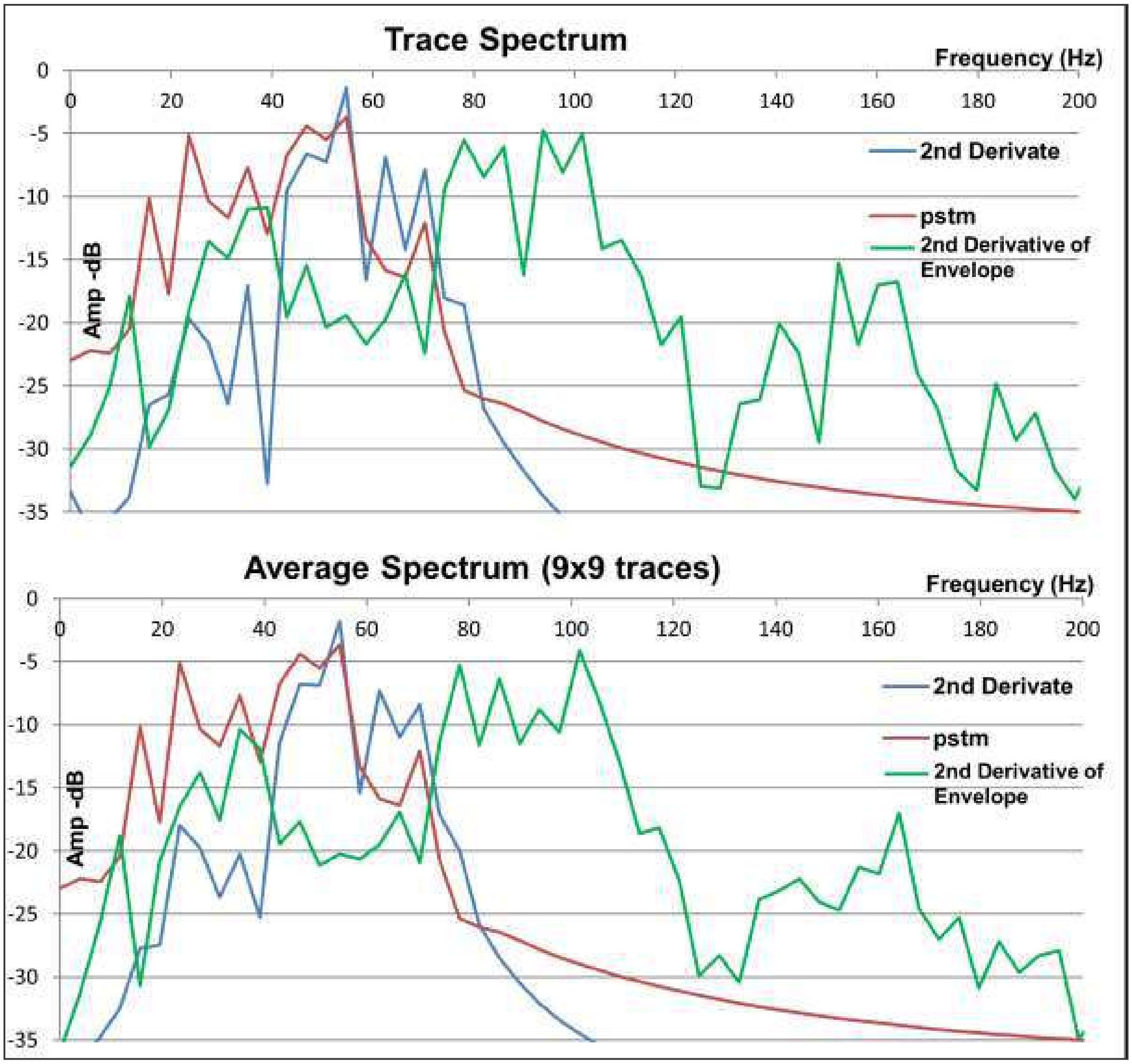

Fig. 7: (a) A comparison of frequency spectra of PSTM data, its second derivative, and second derivative of envelope run on a single trace in each. (b) The equivalent spectra to (a), but averaged over 9x9 traces. Clearly, the second derivative (blue line) acts as a low cut filter, but the second derivative on envelope exhibits a larger bandwidth.

beneficial for interpretation of greater detail as well as more insight into the geological context of the zone of interest.

Finally, Fig. 7(a) shows the frequency spectra of the input PSTM seismic data, its second derivative and then the second derivative of the envelope of the PSTM. In each case the spectrum was computed on a single trace. In Fig. 7(b), the equivalent spectra using 9X9 traces is shown. The second derivative acts as a low-cut filter, but the 2nd derivative on envelope exhibits a larger bandwidth.

Results and Conclusions

The enhanced visualization workflows described in this paper are useful for comprehending the overall architecture of the subsurface events. Of course, individual projects and their challenges will decide the level of creativity, innovation and length that the seismic interpreters are expected to go to, using the available tools in their arsenal.

The processes or attributes described in this article will be helpful for an interpreter and enable their task to be accomplished in less time. The saved time can be devoted towards reinforcing the play concept and/or refining the interpretation.

Acknowledgements

Authors would like to thank Pan American Energy LLC for permission to show the examples in this presentation, and to Satinder Chopra of Arcis Seismic Solutions, TGS, Calgary, for the review of several parts of this paper.Special thanks to Maximiliano García Torrejón and Ignacio Rovira for their contribution.

References

Vernengo, L. and Trinchero, E., 2015, Application of amplitude volume technique attributes their variations, and impact. The Leading Edge, SEG, October 2015, pp. 1246-1253.