Application of Volumetric Seismic Attributes for Structural Interpretation of Eocene Conglomerates, Mexico.

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AASPI Attribute-Assisted Seismic Processing and Interpretation http://geology.ou.edu/aaspi

1. Introduction

The area of study is located in the western margin of Veracruz Tertiary Basin, southwestern Mexico. One of the major challenges in the area is that the complex fault system compartmentalizes the field; additionally, there are faults below seismic resolution that are not identified until the well is tested.

The purpose of this study is to delineate the structural framework of a submarine Eocene conglomerates reservoir. The methodology consisted of three phases: First, structural oriented filtering to preserve the edges; second, extraction and analysis of volumetric attributes of similarity and curvature based; third, multiattribute analysis on time slices to assist the structural interpretation.

This analysis will help to better understand observed reservoir compartmentalization.

2. Geological Setting

Veracruz Tertiary Basin was generated at the foreland of Sierra Madre Oriental (formed during Laramide Orogeny). The primary structural element of the study area is that of a fault propagation fold, which is part of the frontal buried thrust belt known as "*Plataforma de Córdoba"*. This anticline was formed by syntectonic deposition and is affected by normal faulting, which compartmentalize the oil field.

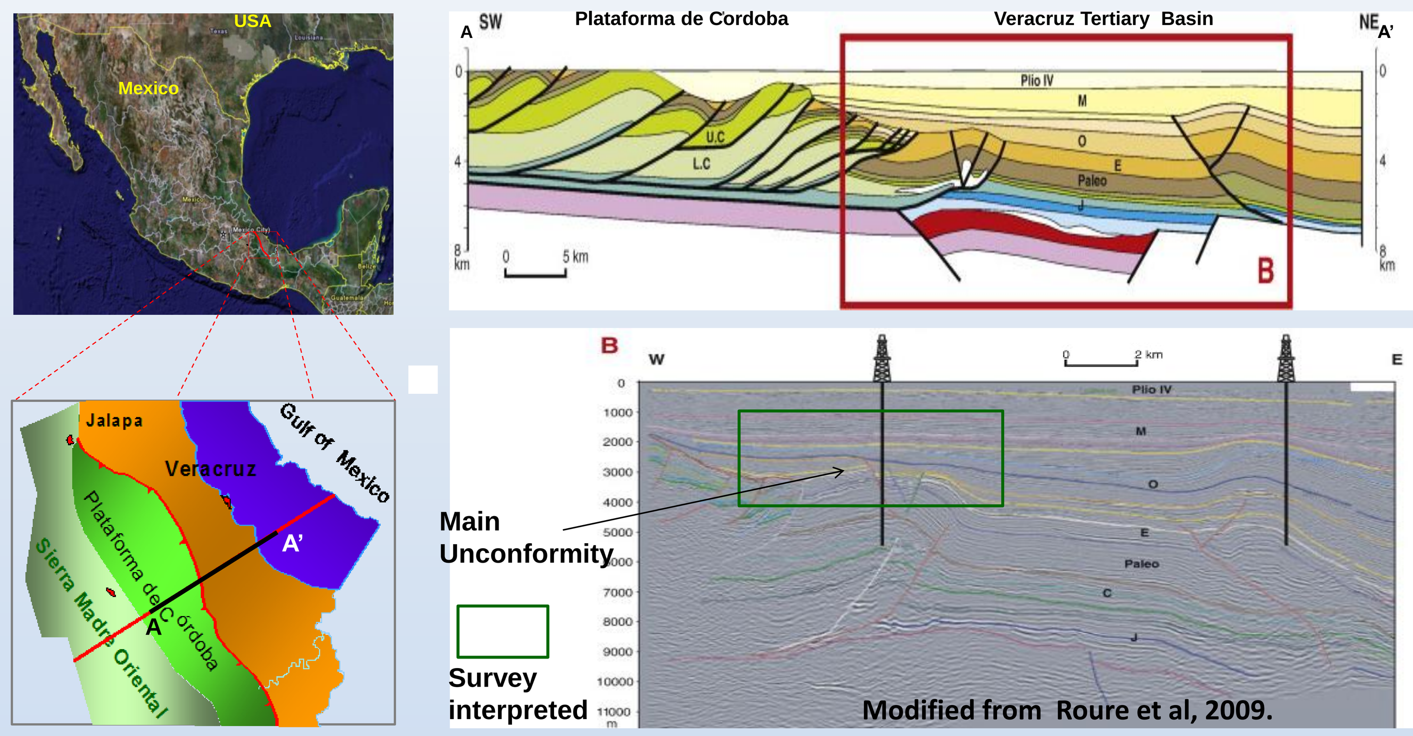

Figure1. Location of the field of study. The structural section A-A' shows the structural style of "Plataforma de Córdoba" and Veracruz Tertiary Basin; the area marked with a red rectangle (B) corresponds to the vertical seismic section.

The lithology underlying the main unconformity is Eocene calcareous conglomerate interbedded with calcareous sandstone and shale, which overlies Paleocene shale. The sedimentary sequence overlaying the main unconformity is made up Miocene sandstone-shale intercalations, Well data probe that Oligocene was eroded at the middle of the anticline.

3.Data quality and conditioning data workflow

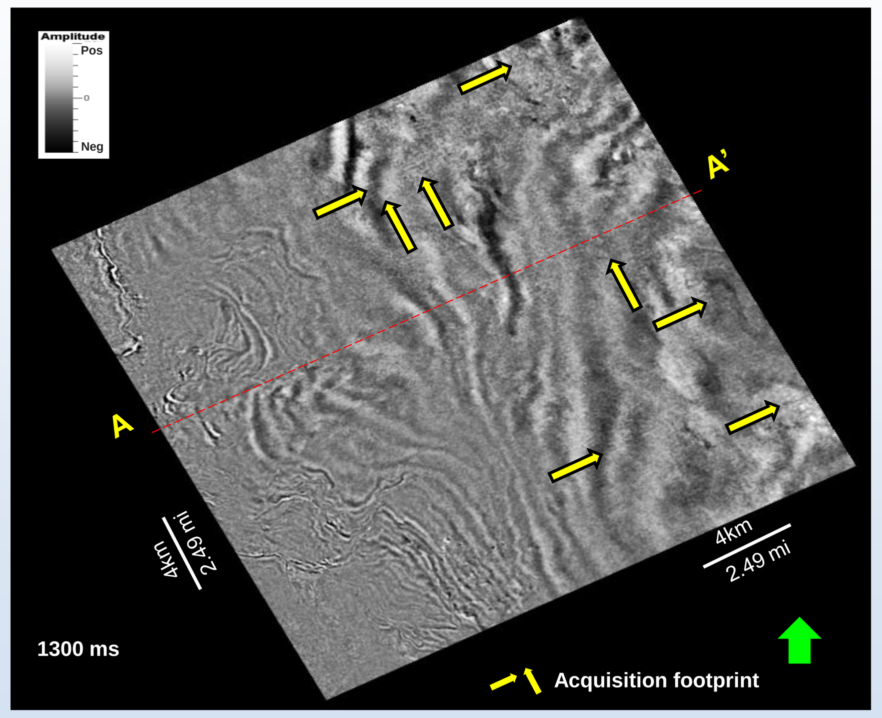

Figure 2. Time slice at 1300 ms showing acquisition footprint, which contaminates the shallow section but it heals with depth. At the area of interest (2000-3000 ms) the footprint is not severe.

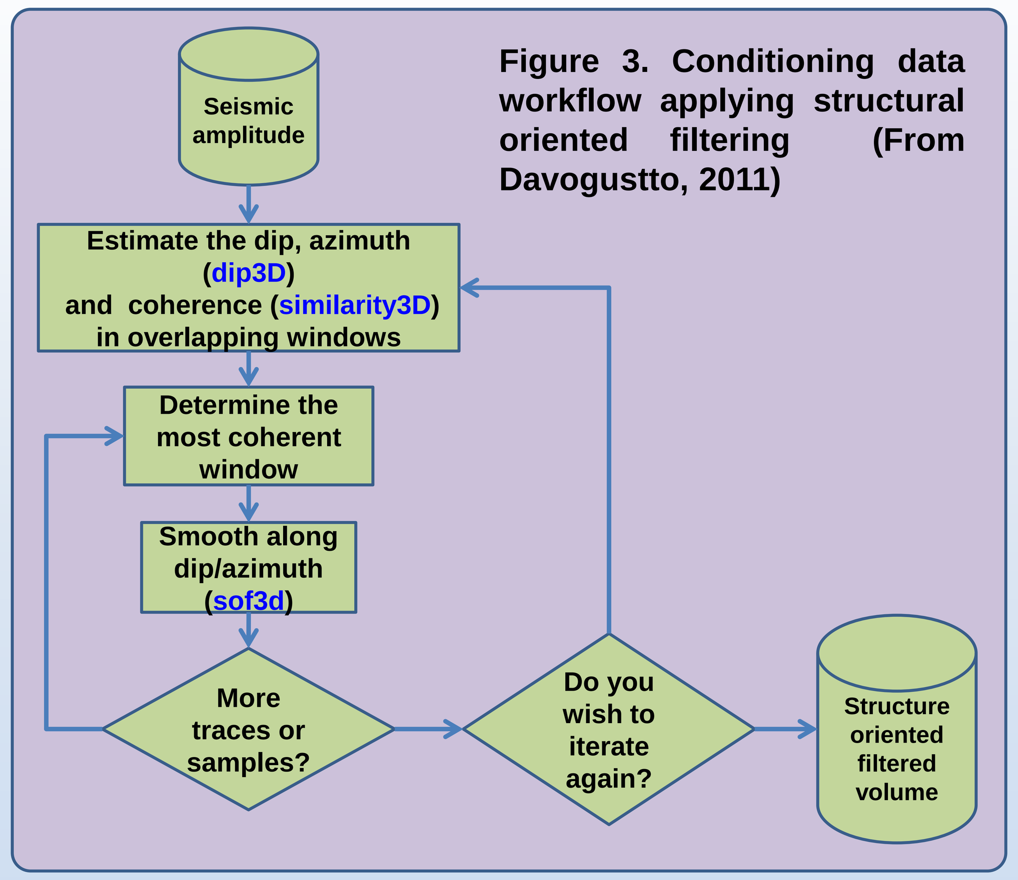

Figure 3. Conditioning data workflow applying structural oriented filtering (From Davogustto, 2011)

The data quality is good, there is no aliasing associated with large dips. Acquisition footprint is present especially at shallow levels but it is not severe at the objective zone. For this reason, I will not remove it from data since I may remove the signal as well. Figure 3 shows the flowchart for structured oriented filtering (SOF) that I applied to enhance edges.

4. Data Conditioning results

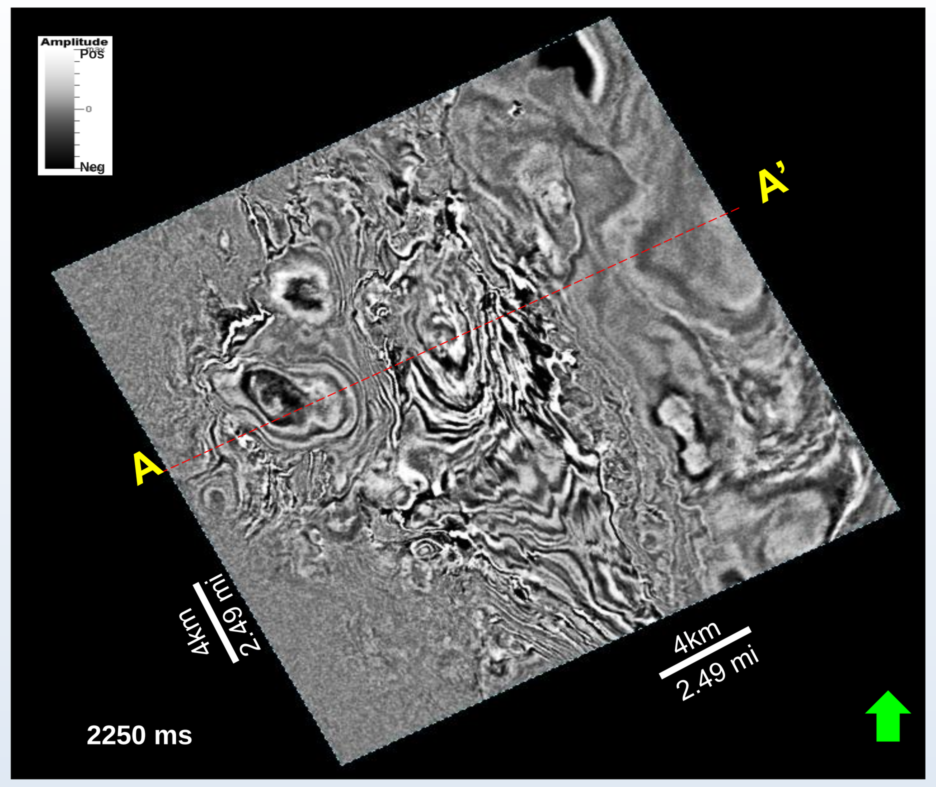

Figure 4. Time slice of original amplitude data at 2250 ms showing the area of interest (2000-3000 ms)

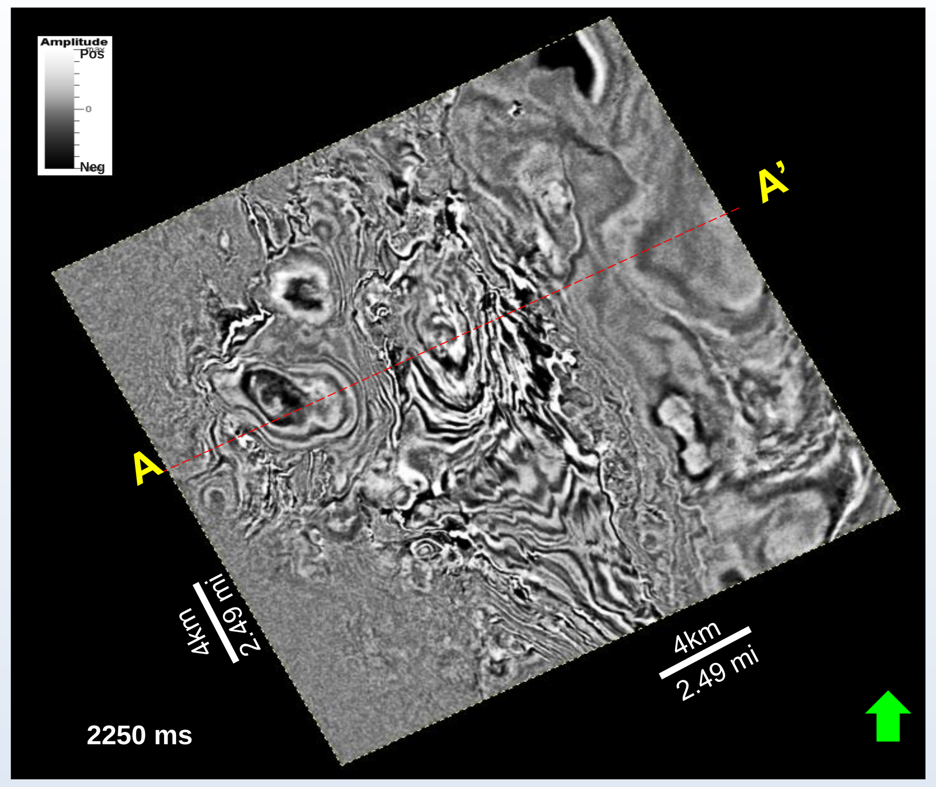

Figure 5. Time slice at 2250 ms after two iterations of structural oriented filtering.

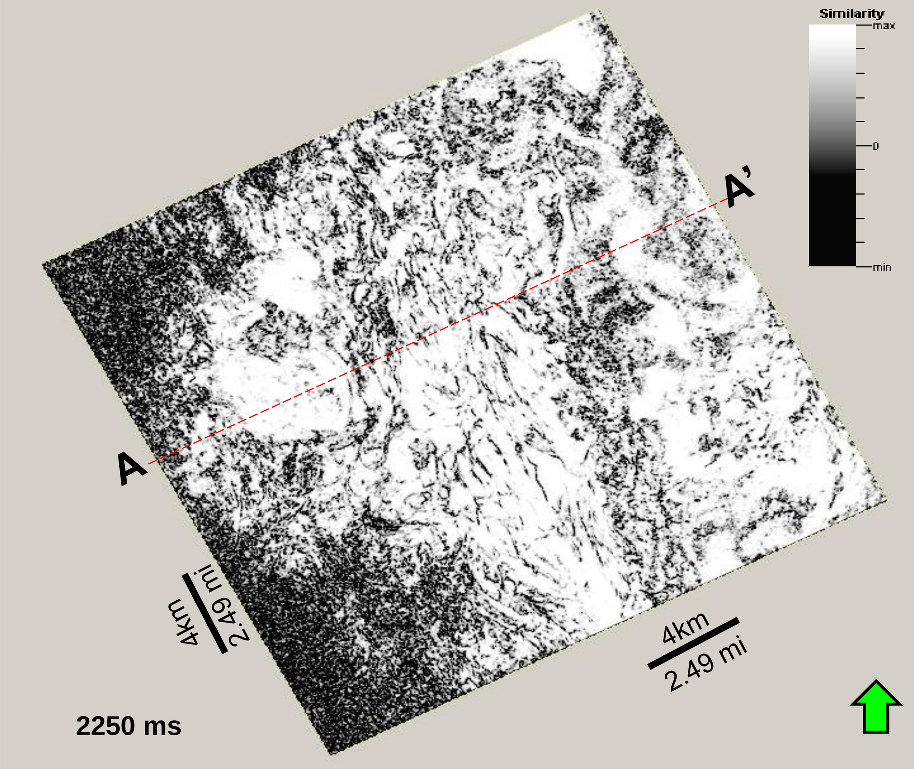

Figure 6. Time slice at 2250 after two iteration of structural oriented filtering.

Similarity attributes serve as quality control of data conditioning because the edge enhancement after SOF is highlighted on these attributes rather than amplitude data .

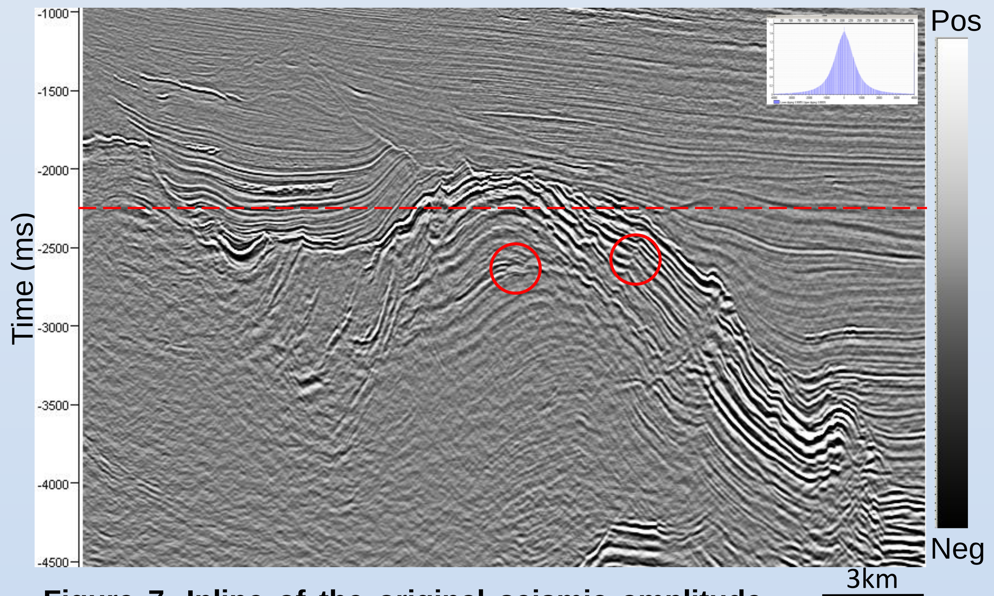

Figure 7. Inline of the original seismic amplitude data

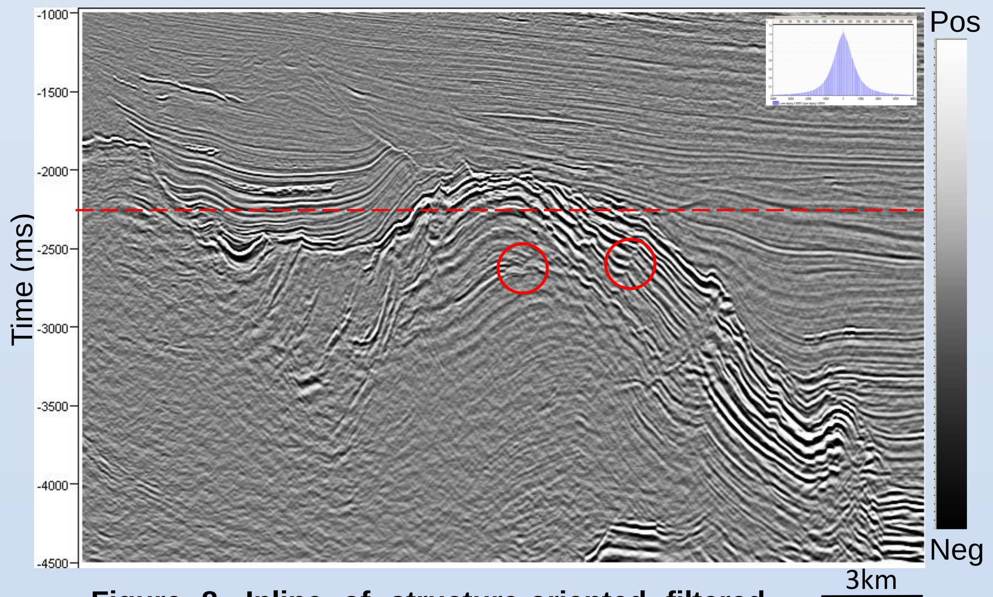

Figure 8. Inline of structure-oriented filtered data (2 iterations)

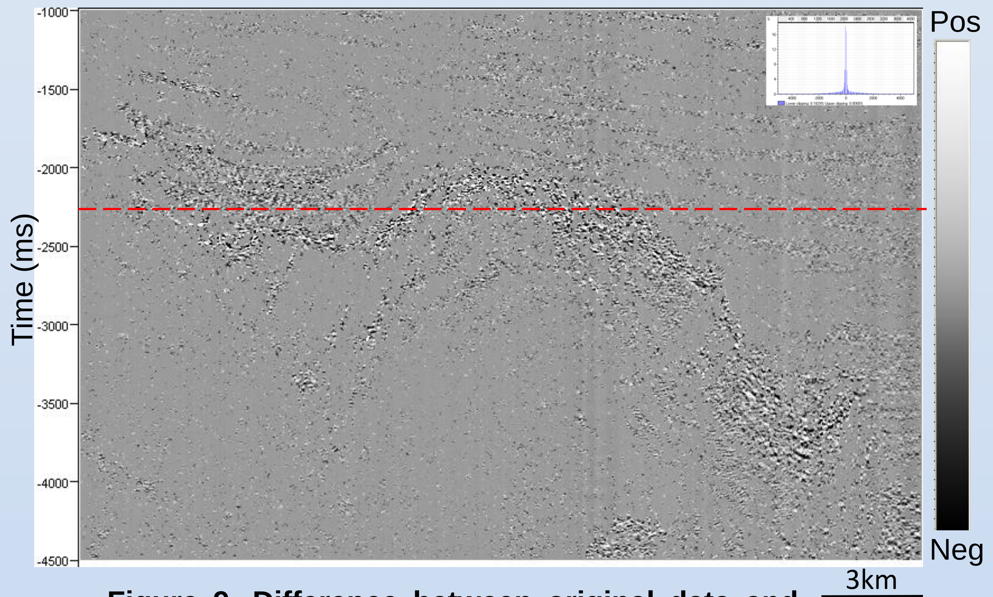

Figure 9. Difference between original data and structured oriented filtered volume after 2 iterations.

Circles in Figure 4 and 5 shows a comparison between the original and filtered data which preserved the edges. The difference in Figure 9 corroborates that I only extracted noise, the amplitude scale is 10% of the original and filtered data.

5. Single Attribute Analysis

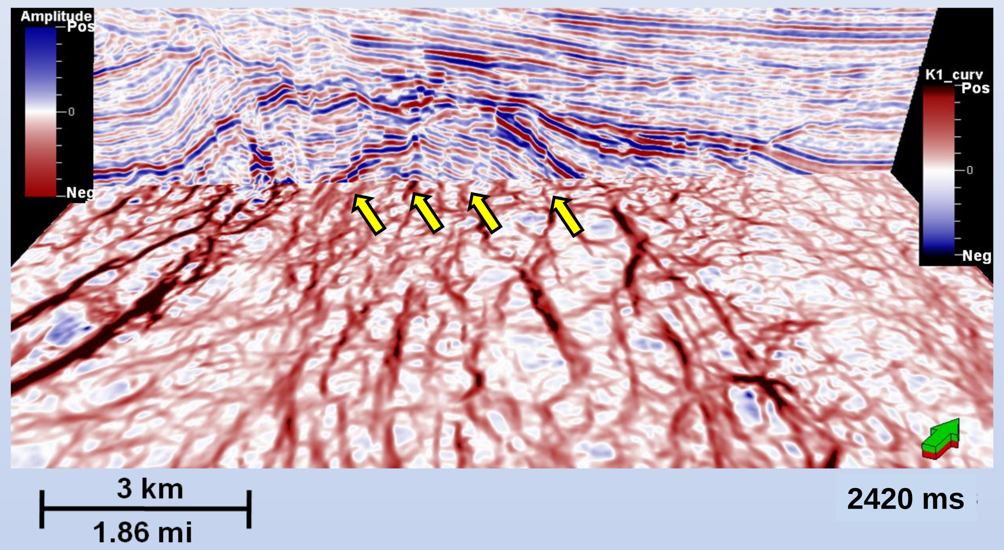

Figure 10. Amplitude Vertical section display with k1 most-positive curvature time slice. Yellow arrows show fault-related patterns.

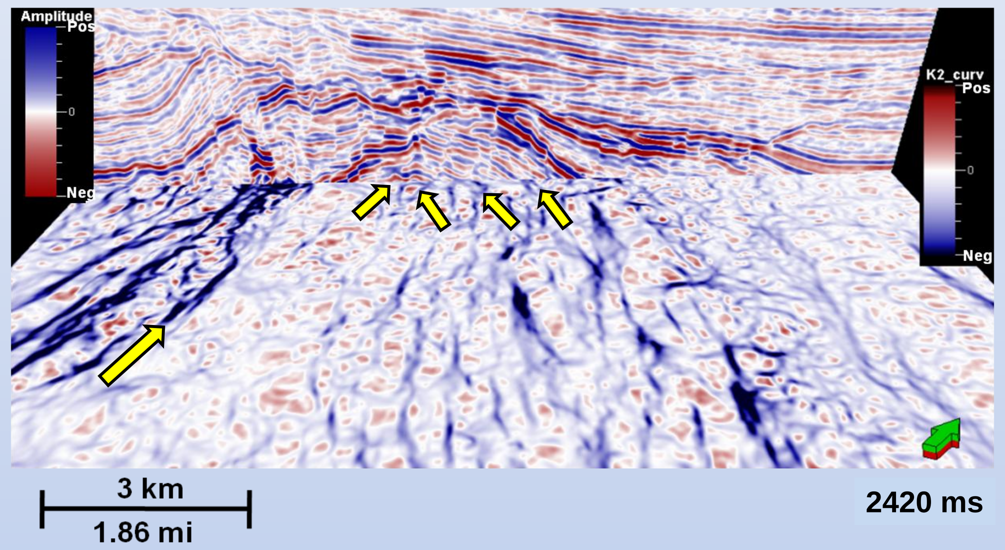

Figure 11. Amplitude Vertical section display with k2 most-negative curvature time slice. Yellow arrows show fault-related patterns.

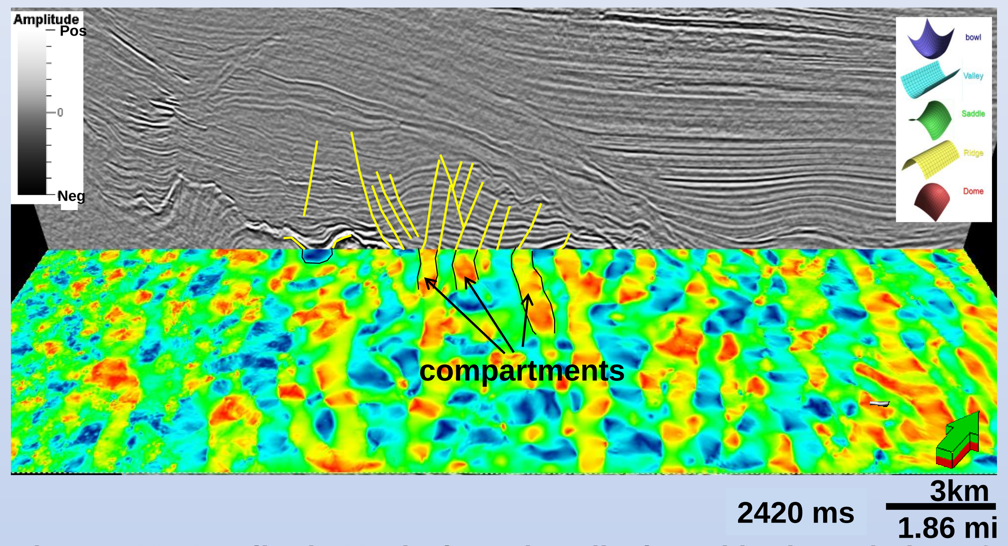

Figure 12. Amplitude Vertical section display with shape index of long-wavelet curvature. Ridge-related patterns correlate with blocks in between faults.

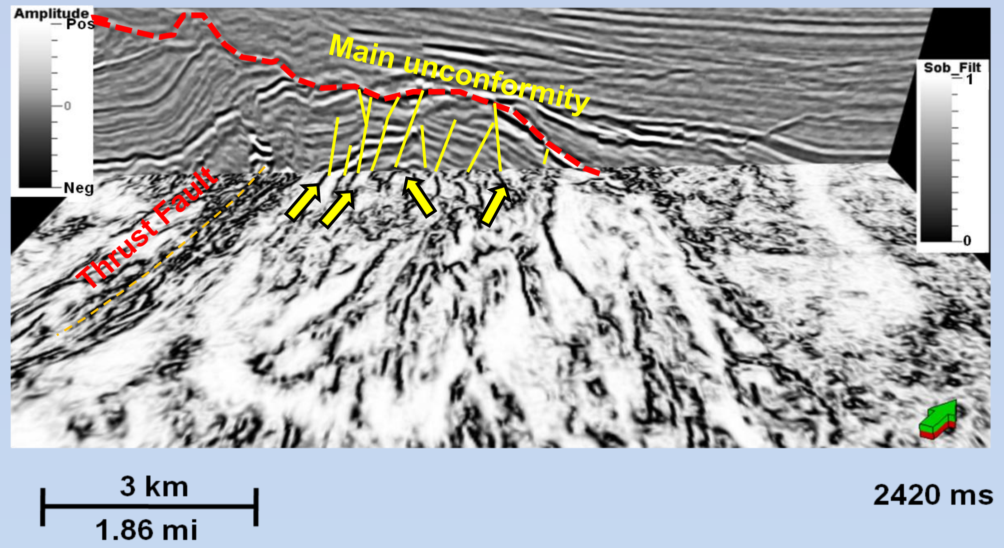

Figure 13. Vertical section display with Sobel filter similarity time slice. Yellow arrows show fault-related patterns.

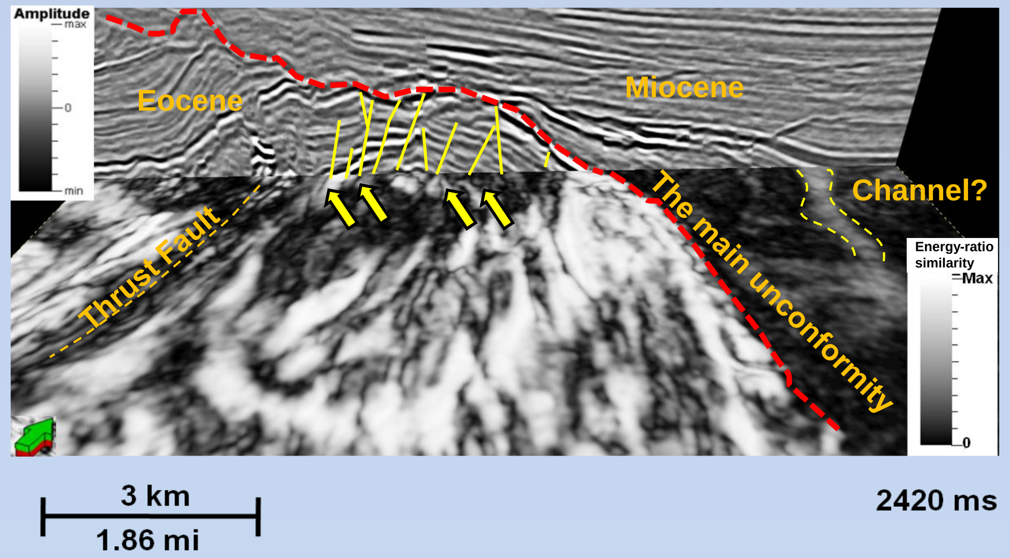

Figure 14. Vertical section display with coherence energy time slice. Yellow arrows show fault-related patterns

Single attribute analysis allows to identify what kind of lineaments enhance each of those, then we can define what attributes co-render. The main unconformity is well delineated by energy ratio similarity. Curvature delineates some flexure and fault patters. Sobel filter similarity delineate fault patterns. The index shape could be used to define the compartments for well placement, since there is a good correlation between fault position and edge of the shape.

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6. Multiattribute analysis

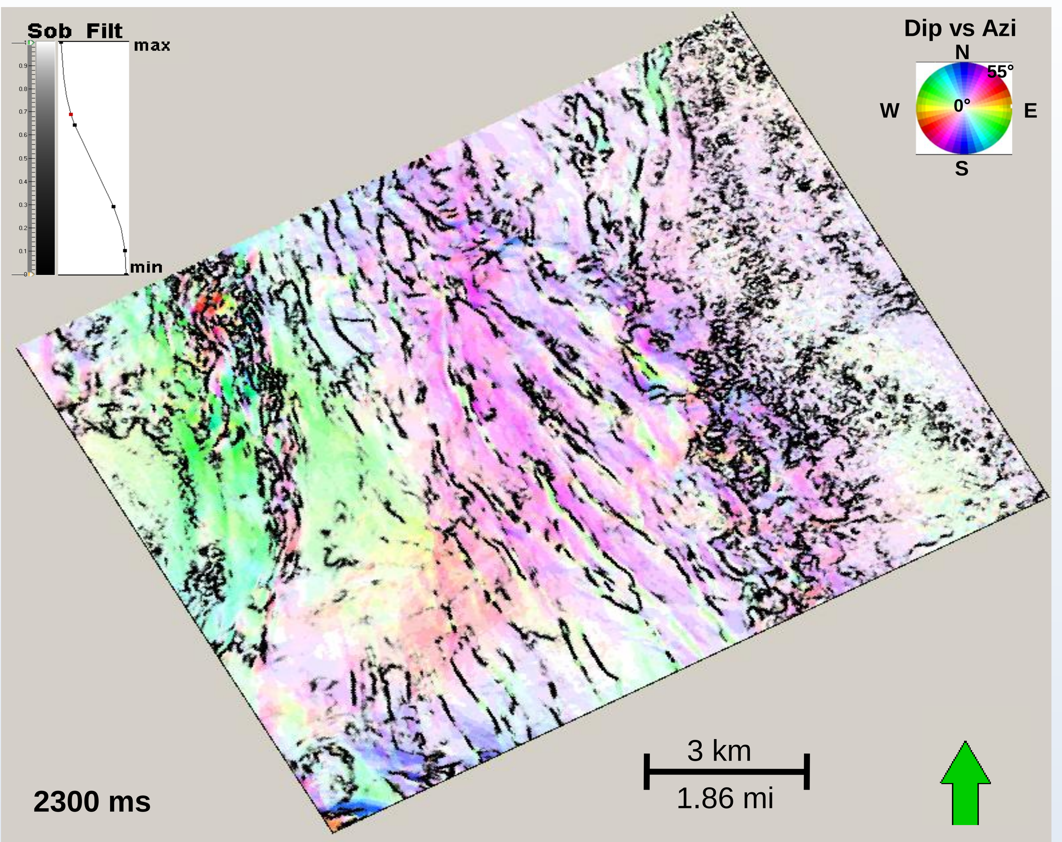

Figure 15. Dip vs Azimuth co-rendered with Sobel filter similarity. Dip versus azimuth is represented by a 2D color bar, where azimuth is plotted against hue and magnitude

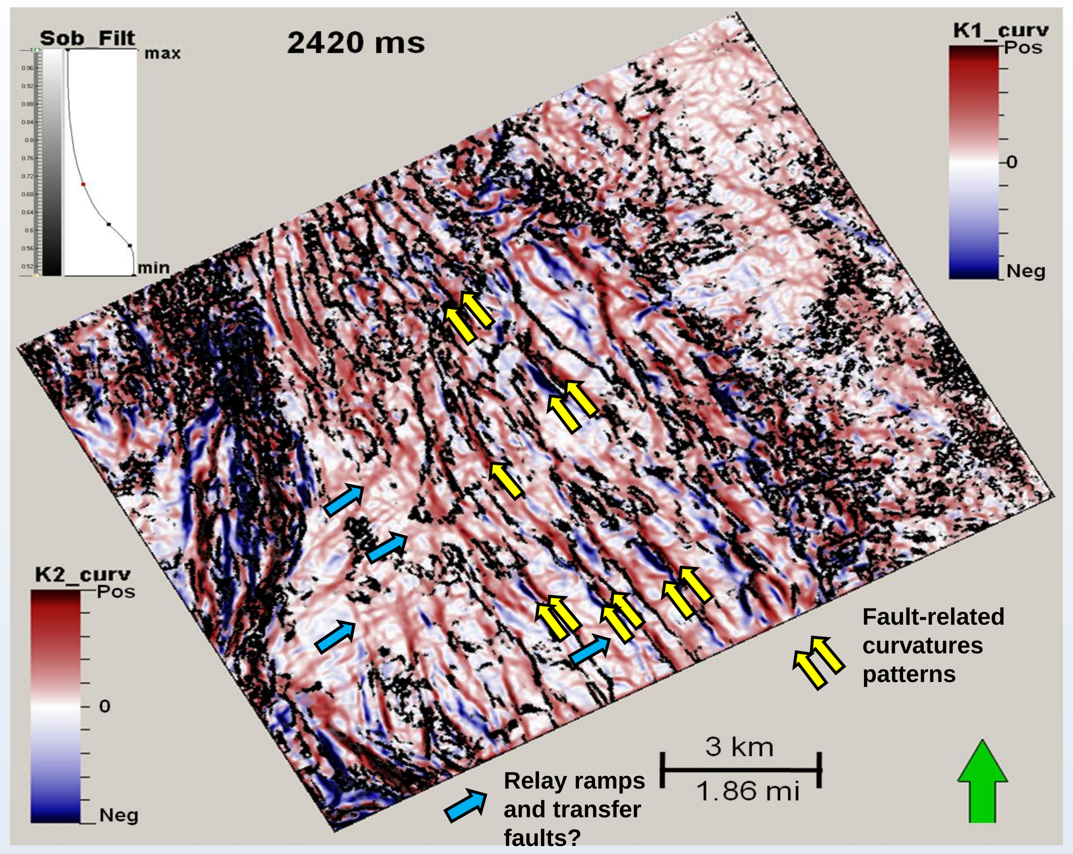

Figure 16. k1 and k2 curvatures co-rendered with Sobel filter similarity. Faults patterns are bounded by both curvatures, Most of curvatures features delineate both sides of faults marked by low similarity; other curvature features enhances patterns associated with high coherence.

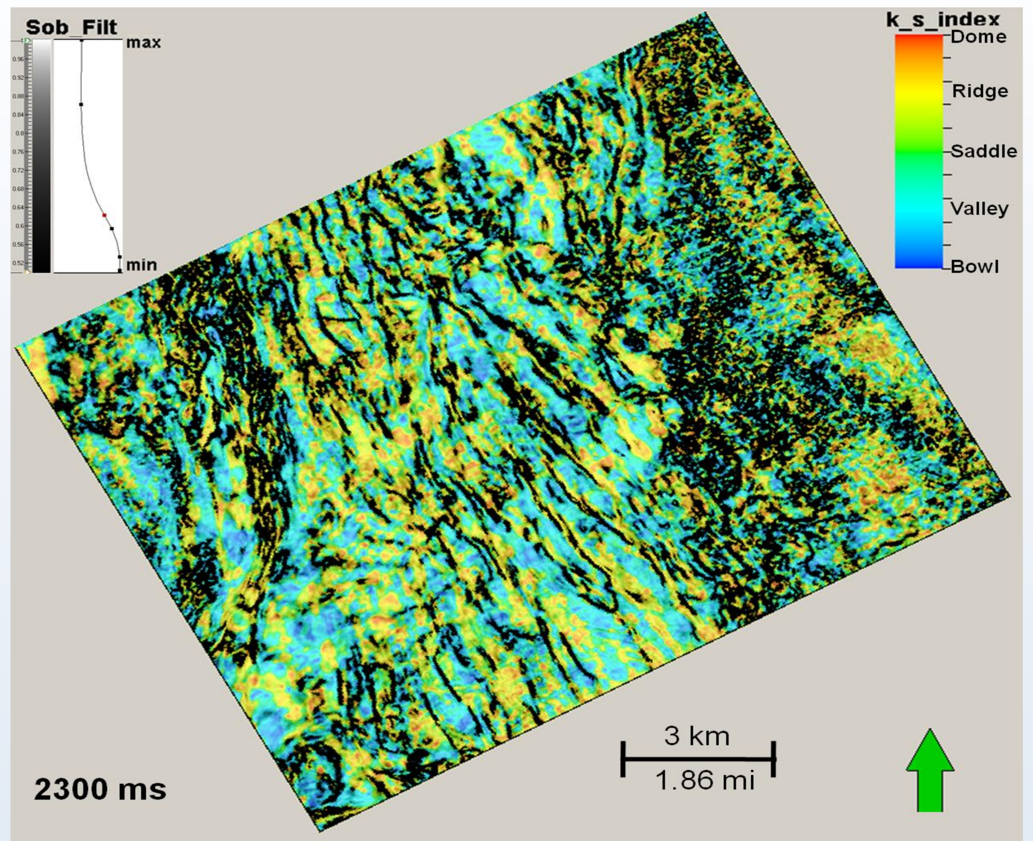

Figure 17. Shape index co-rendered with Sobel filter similarity . Ridges and valleys are the dominant patterns. The predominant geometry are ridges and valleys in between faults.

Multiattribute display on time slices is a powerful technique for structural interpretation; after individual attribute analysis some multiattribute were display in co-rendered mode to start the structural interpretation. Figure15, Figure 16, Figure 17, and Figure 8 show different attributes co-rendered with Sobel filter similarity. Fault lineaments are enhanced especially with most positive (k1) and most negative curvature (k2). Vertical displays (see Figure 19) were very useful to control fault interpretation.

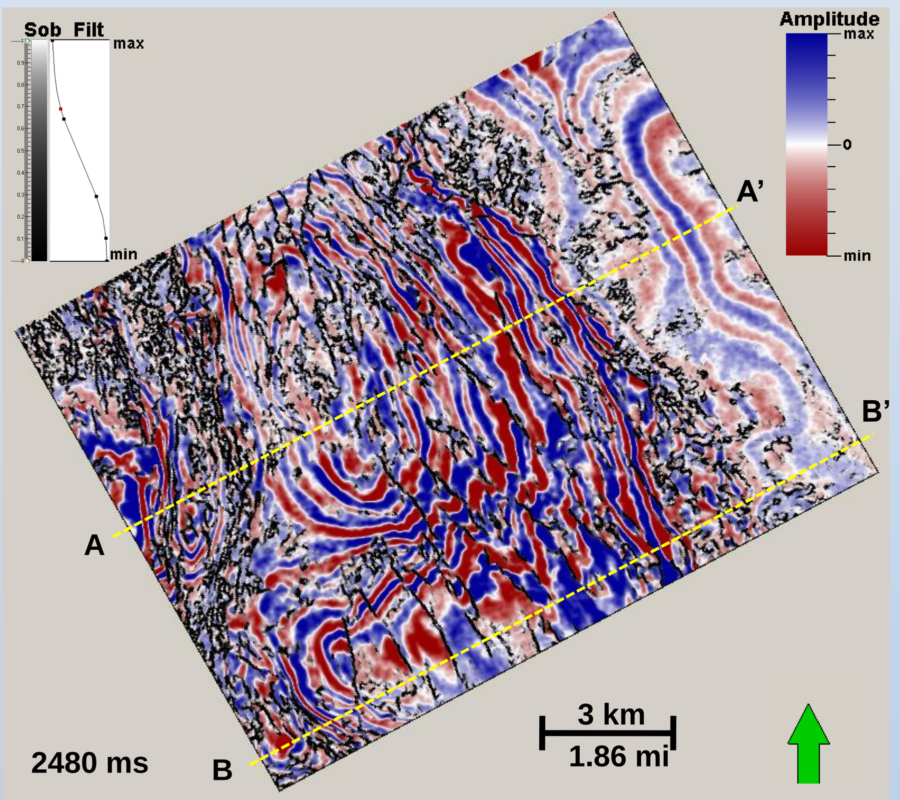

Figure 18. Amplitude time slice co-rendered with similarity. Base map for the 3 vertical section above.

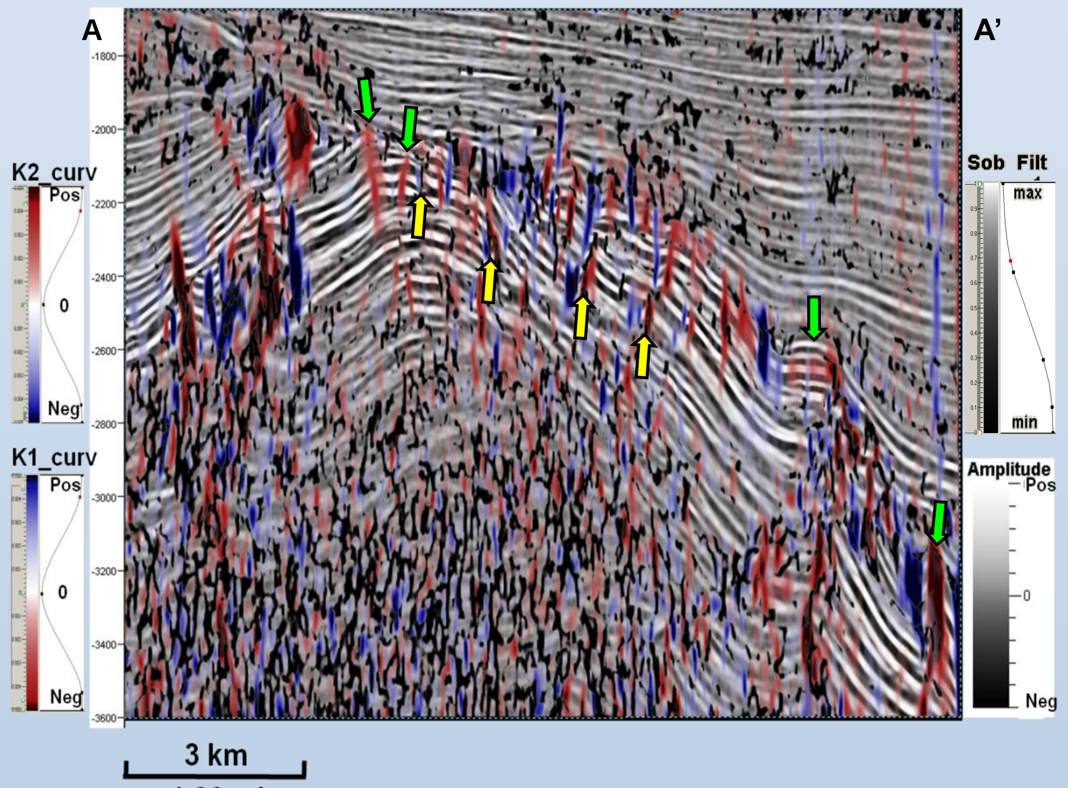

Figure 19. Amplitude vertical section AA'' co-rendered with k1, k2 and Sobel filter similarity . Yellow arrows point at fault-related curvature patterns, green ones point at pull ups.

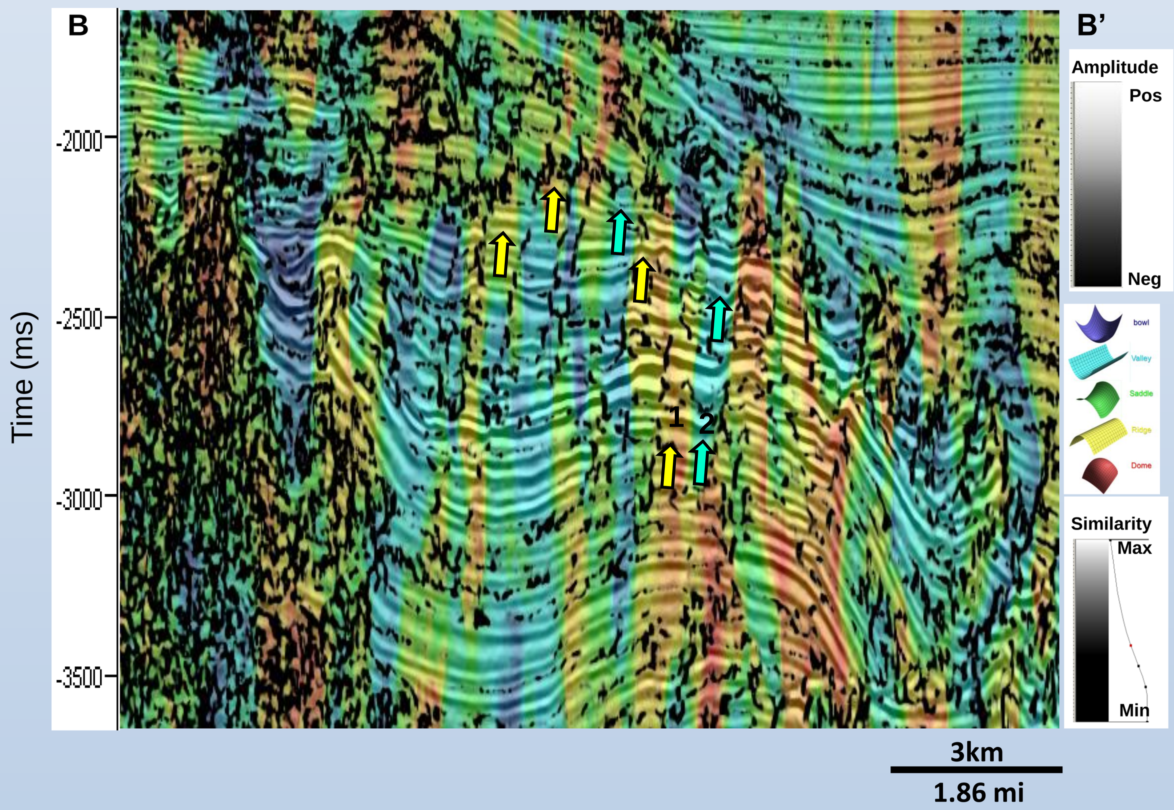

Figure 20. Amplitude vertical section BB' and time slice co-rendered with Sobel filter similarity and shape index. The arrows points at two compartments separate by faults with distinctive form (color coded by shape)

7.Structural Interpretation

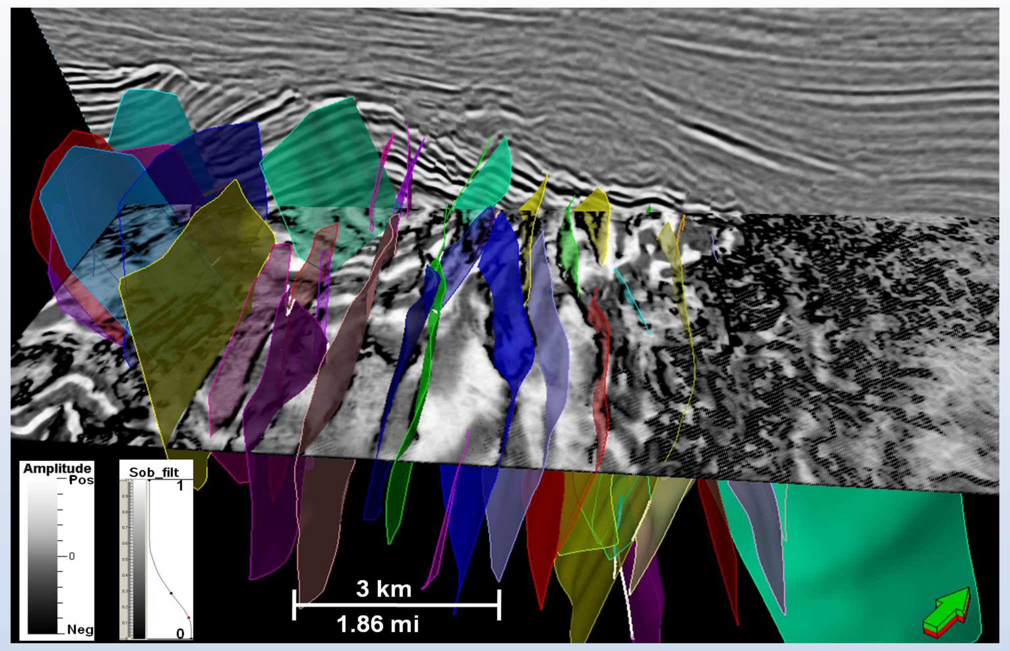

Figure 21. Amplitude Vertical Section with Sobel filter similarity time slice and fault interpretation.

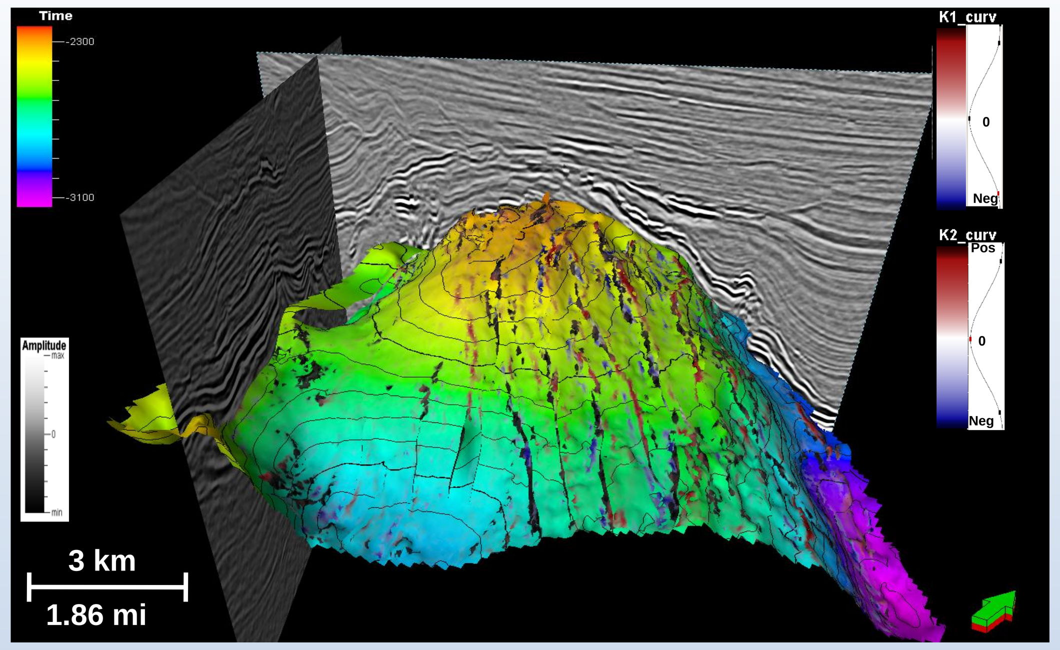

Figure 22. View of the surface in time co-rendered with k1 and k2 curvatures. The vertical sections displays amplitude seismic data. Some curvature patterns bounded faults, other are flexure-related.

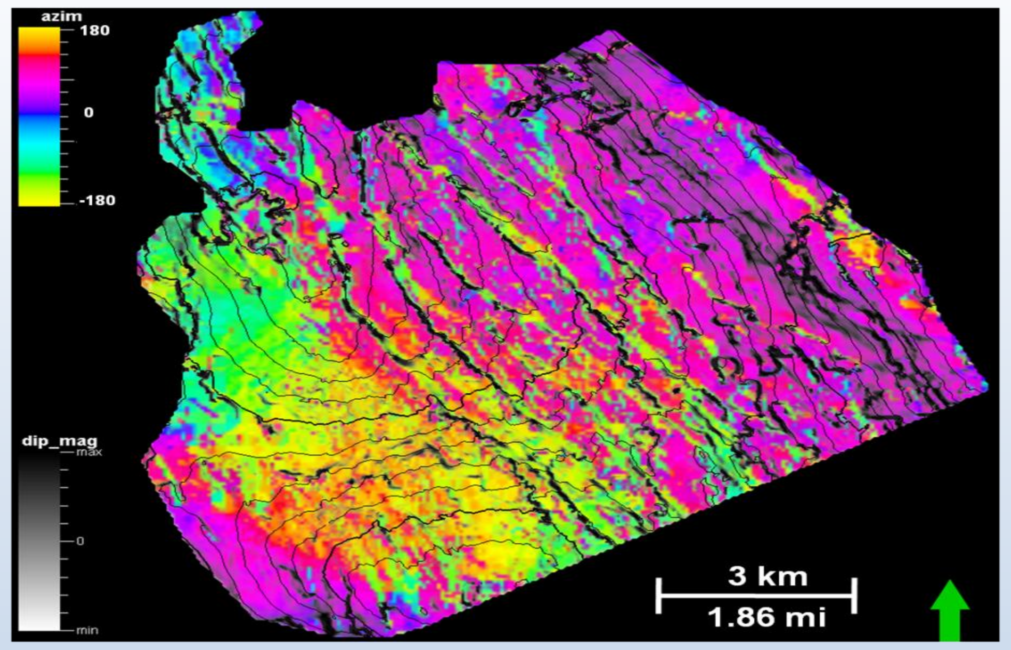

Figure 23. Map of dip azimuth co-rendered with dip magnitude of the interpreted horizon in Figure 22 The northwest irregular boundary is an unconformity.

The structural interpretation was assisted by multiattribute analysis. Figure 21 shows fault interpretation over a time slice of Sobel filter similarity. Figure 22 show the time structure interpretation co-rendered with horizon attributes of curvature and Sobel filter similarity. Figure 23 show the dip and azimuth horizon map co-rendered with Sobel filter similarity.

8.Structural Framework

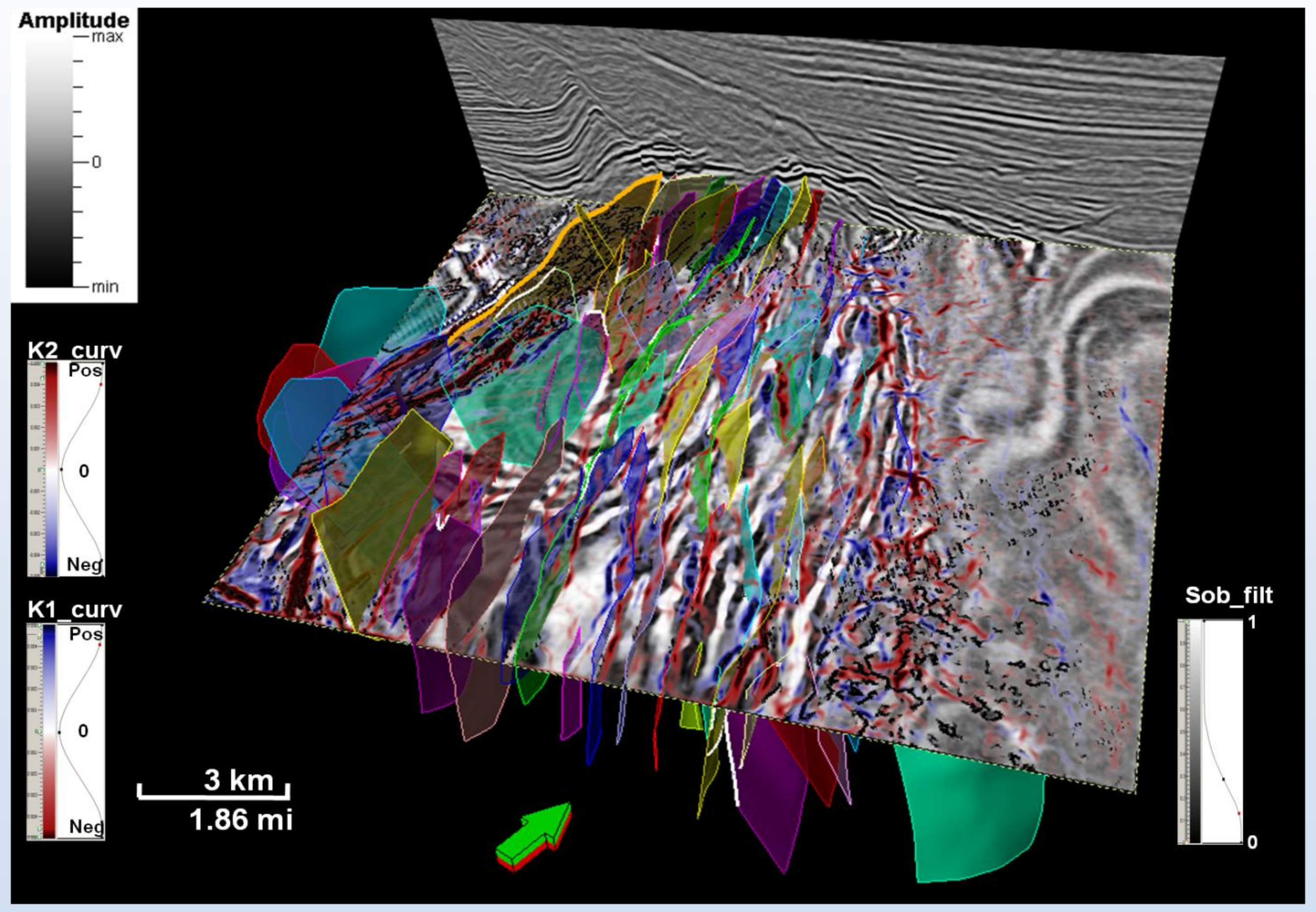

Figure 24. Faults converge toward center in the northwest area whereas the southeastern portion have a domino pattern. In the crest of the anticline, faults are less steep, they become steeper with depth. Sobel filter similarity, most positive curvature k1 and most negative curvature k2 enhance the fault system and show some features around that could be associated with fractures. There are some patterns where no faults are visible at seismic resolution.

9 Conclusions

- ✓ Structure-oriented filtered enhance edges, consequently volumetric attributes of curvature and similarity guided by azimuth and magnitude delineate the discontinuities better.
- ✓ Structural features are well emphasized in co-rendered multiattribute time slices. Multiattribute display delineate this pattern better than only using amplitude data.
- ✓ Sobel filter similarity provide a good correlation with the fault system although it emphasized the acquisition footprint if present. After well calibration, coherent energy attribute could be used as textural attribute to develop a neural network to separate conglomerates from shale.
- ✓ Curvature and shape index enhance some lineaments that are not evident in the amplitude data, specially near large faults, they could relate to fracture or faults that are below seismic resolution.

10.Acknowledgments

Thanks to PEMEX for providing the data and permission to pursue my Master's degree. Thanks to CONACYT and SENER for supporting my graduate studies at the University of Oklahoma. Thanks to Dr. Kurt J. Marfurt for his guidance, tutelage, and for the access to the AASPI software. Thanks to all AASPI members and sponsors. Thanks to my colleagues in PEMEX for their previous work and help in preparing the data and my PEMEX advisor, Ignacio Pereznegrón, for his encouragement. Thanks to Alejandro Cabrales Vargas, Oswaldo Davogustto, Roderick Perez, Tim Kwiatkowski and Yavuz Elis who helped me to process the attributes and gave me some advice.

PEMEX Petróleos Mexicanos · CONACYT Consejo Nacional de Ciencia y Tecnología · SENER Secretaría de Energía

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