[PS]A Seismic-Structural Interpretation, on the Identification of Possible Causes in the Formation of Gas Chimneys in Colombia's Offshore*

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Abstract

The presence of hydrocarbon seepages, both liquids and gases in the Colombian offshore, is a phenomenon that occurred naturally and continuously. In fact, it is a dynamical characteristic of hydrocarbon system due mainly to the vertical and/or lateral hydrocarbon migrations. Recently, this migration process has been approached by means of seismic attributes, specifically Gas Chimney. Geologically speaking, they could be treated as valves that release gases throughout faults and permeable sediments. Gas chimney has been matched with geochemical analysis coming from gases in piston core samples, thus generating a strong correlation with hard data de-risking offshore exploration analysis in most cases.

The main goal was to develop an integrated and comprehensive geological and geophysical analysis throughout 3D structural interpretation and attribute calculations, expecting to improve the knowledge and understanding of the nature of gas chimney formation and its possible relation with a petroleum system in a Colombia's offshore area. Previous work in the area let the exploratory process with a moderate possibility of a hydrocarbon reservoir, and the gas chimney analysis played a relevant role on that positive statement, however the gas chimney seems to have some relation with the complex geological structure. A 3D structural interpretation was one focus of effort, trying to identify the role of faults in hydrocarbon migration, to detect the migration routes, and to find the seismic events that could be the source rock location. Other evidences were collected by means of sea floor observations, like pockmarks, mud volcanoes and mud diapirs.

Based on the seismic data, combined with the regional geological knowledge, we could determine a break-forward, shear imbricate fault-bend fold system. From the integrated analysis, we observed that the chimney did not have a large lateral extent, and exists along the whole thrust fault,

which reveals that there is a large influence of the faults in the migration routes. Moreover, through the application and combination of seismic attributes, we could differentiate a preferential anomaly in the low frequency ranges, by the application of spectral decomposition analysis. This kind of anomaly has been found to be associated with gas reservoir in many cases worldwide. Finally, we detected on the seafloor the presence of typical sea floor morphological features, usually related with seepages of gas from the subsurface.

A SEISMIC-STRUCTURAL INTERPRETATION, ON THE IDENTIFICATION OF POSSIBLE CAUSES IN THE FORMATION OF GAS CHIMNEYS IN COLOMBIA'S OFFSHORE

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ABSTRACT

The presence of hydrocarbon seepages, both liquids and gases in the Colombian offshore, is a phenomenon that occurred naturally and continuously. In fact, it is a dynamical characteristic of hydrocarbon system due mainly to the vertical and/or lateral hydrocarbon migrations. Recently, this migration process has been approached by means of seismic attributes, specifically Gas Chimney. Geologically speaking, they could be treated as valves that release gases throughout faults and permeable sediments. Gas chimney has been matched with geochemical analysis coming from gases in piston core samples, thus generating a strong correlation with hard data de-risking offshore exploration analysis in most cases.

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REGIONAL SETTING – COLOMBIA'S CARIBBEAN OFFSHORE AREA

The study area is located in the southern area of the Colombian Caribbean offshore, specifically within the accretionary prism. This zone is the result of the transpressional collision between the Caribbean and South American plates.

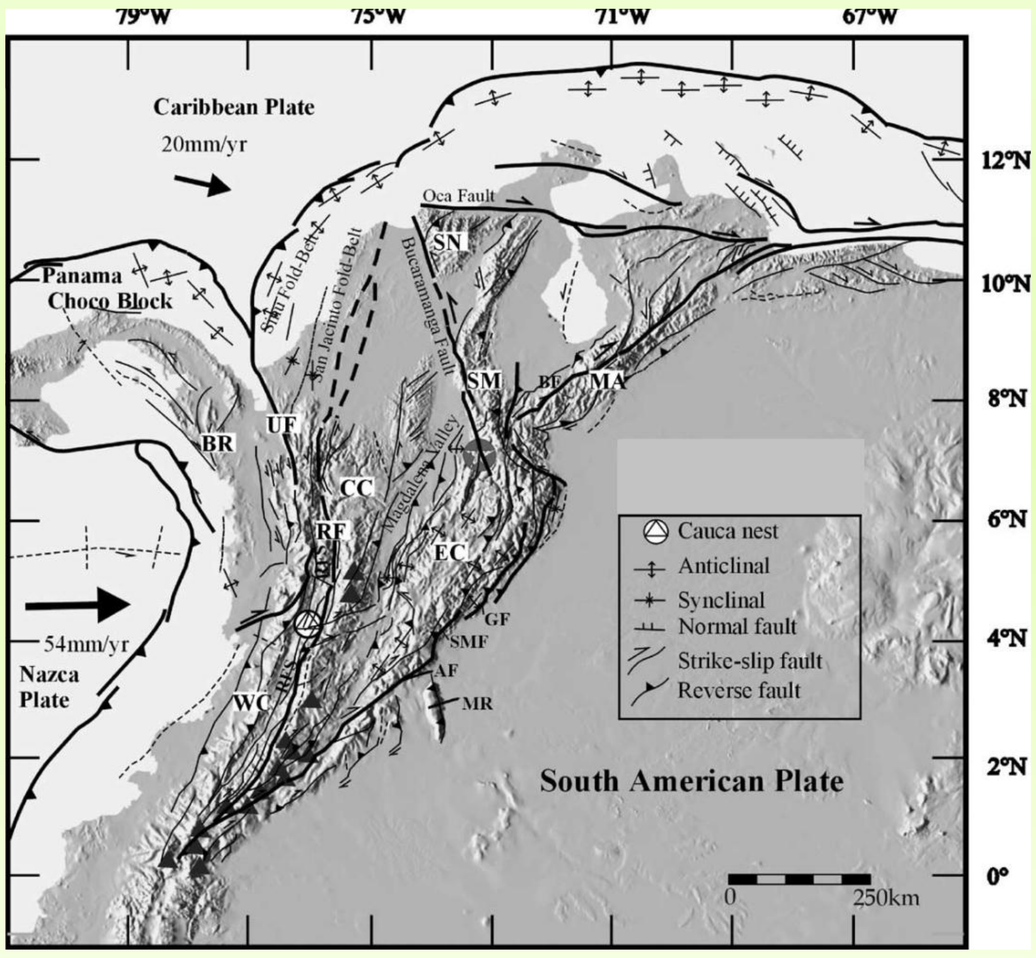

Figure 1. Colombian Caribbean Offshore. From Cortes,(2005).

THE PURPOSE OF THE STUDY

The presence of hydrocarbon seepage, both liquids and gases in the Colombian offshore is a phenomenon that occurs naturally and continuously. In fact, it is a dynamic characteristic of hydrocarbon systems due mainly to the vertical and/or lateral hydrocarbon migration. When these migrations with gas presence occur, they are called Gas Chimneys. They could be considered as valves that release gases throughout faults and permeable sediments.

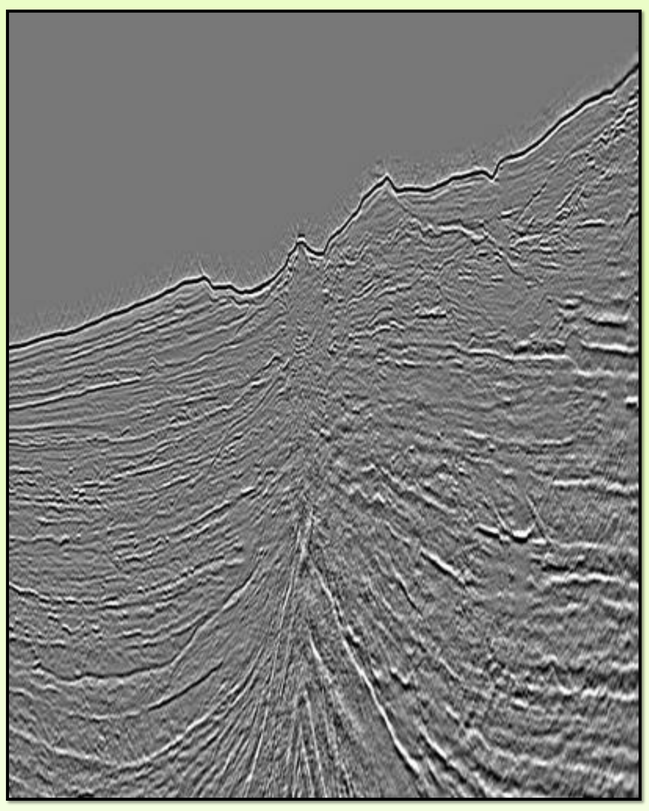

Figure 2. Seepage in the Colombian offshore .

The purpose of this study was to understand the nature of gas chimney formation, and its possible relation with a petroleum system in the Colombian Caribbean offshore area.

There were three main challenges: 1) to produce a structural interpretation of the area in order to identify the role that geological faults could have played in the migration of hydrocarbons; 2) to detect the migration routes and; 3) to find the seismic horizon that could represent the source rock .

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SEISMIC INTERPRETATION

FAULT INTERPRETATION

Interpreted faults present an inverse movement resulting in a break-forward imbricate system. Six main faults can be recognized which were named in the interpretation from NW to SE with the number 1 to 6 respectively **(Figure 3**). The oldest thrust fault "6" appears folded by the underlying youngest thrust sheet related to fault "1".

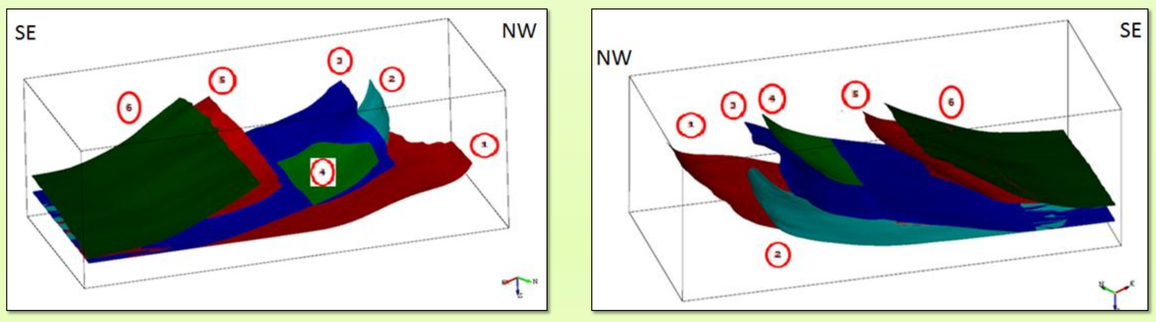


Figure 3. Interpreted faults.

STRUCTURAL MODEL

Based on the seismic interpretation in conjunction with the regional geological knowledge, it was possible to determined that one key factor is its active deformation and strong compressive character, dominated by inverse faults, which turn into a break-forward shear imbricate fault-bend fold system. A broad anticline in the shallow thrust sheet overlies a synclinal bend on the thrust fault and growth strata show evidences of limb rotation, indicating that tectonic activity is contemporary with sedimentation.

HORIZON INTERPRETATION

Four significant reflectors were interpreted in the 3D volume: Basement, top Oligocene (?)-Miocene, top Pliocene, and sea level (**Figure 4**).

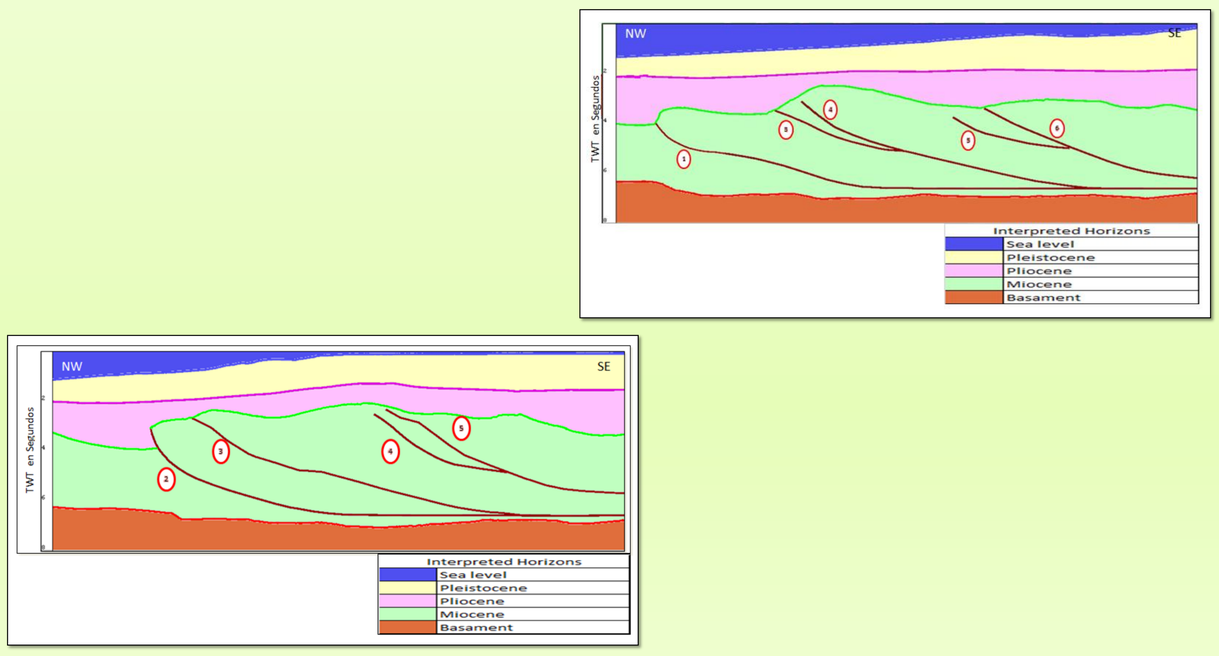


Figure 4. Interpreted horizons.

SEA FLOOR TOPOGRAPHY INTERPRETATION

From the detailed interpretation of sea floor topography we recognized the presence of possible mud volcanoes, located directly over the target area (**Figures 5, 6** and **7**).

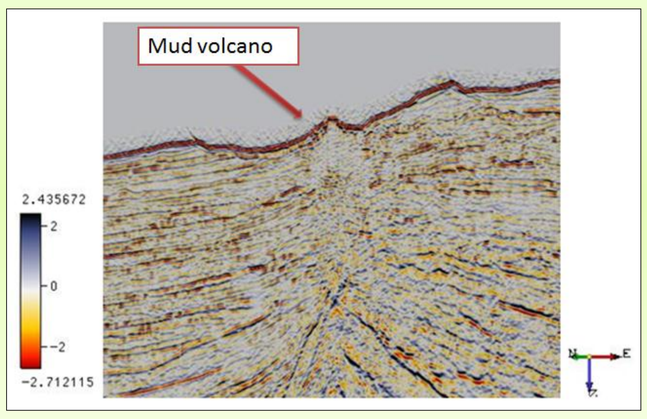


Figure 5. Seismic section with mud volcano.

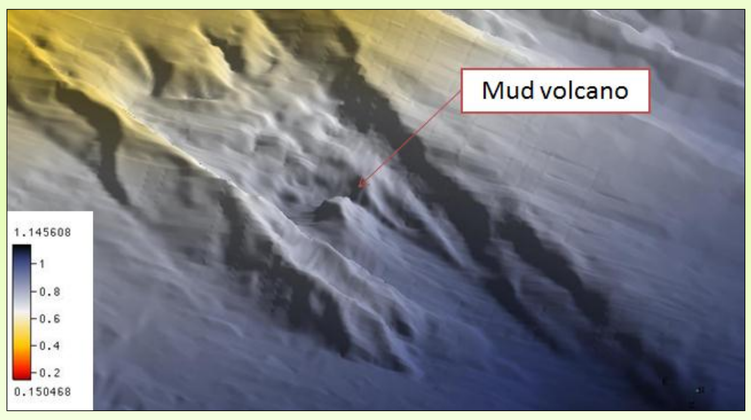


Figure 6. Sea floor with mud volcano.

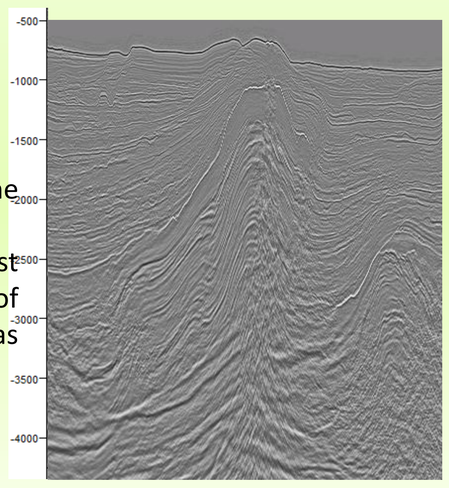
Figure 7. Sea floor with mud volcano.

GAS CHIMNEY (CLOUD) DETECTION

A low amplitude chaotic zone (a possible gas cloud) was observed in a seismic cube throughout the Caribbean zone. Detection of these gas clouds or chimneys was needed to understand their 3D morphology and areal extent. The method of highlighting these gas chimneys is described below.

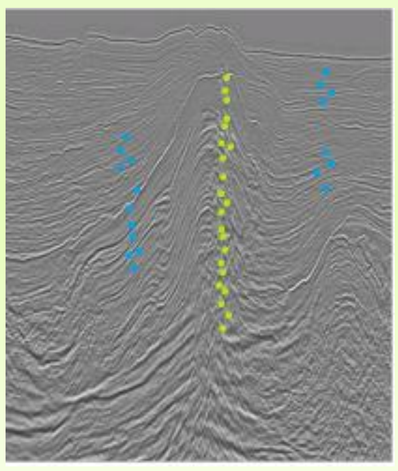
Step 1:

Scan through the seismic data, finding the most obvious zones of suspected gas chimneys.



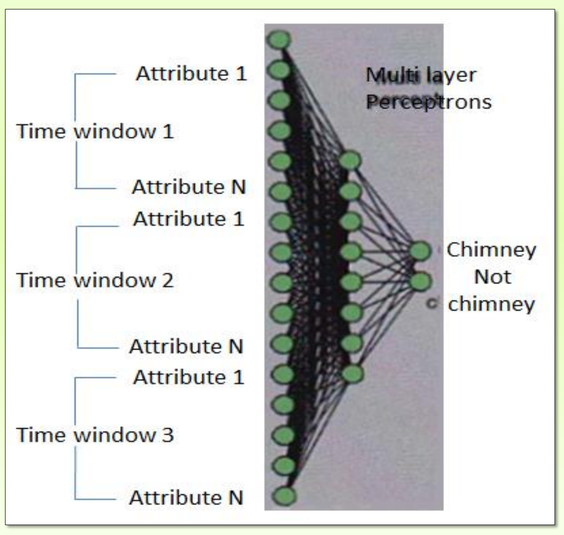
Step 2:

Pick examples of chimneys and non-chimneys on key lines and traces.



Step 3:

Determine a set of attributes which can highlight these chimneys. Since chimneys are vertically aligned, key attributes are chosen in windows above and below the pick sites. These attributes are then calculated at the picked locations, and the results are fed into a neural network. The trained neural network is then applied to the seismic volume to create a chimney probability volume.



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Results of Chimney Processing

Combining the results of chimneys detection and the seismic interpretation, key features around the fault zone were identified such as the circular pattern of the chimneys.

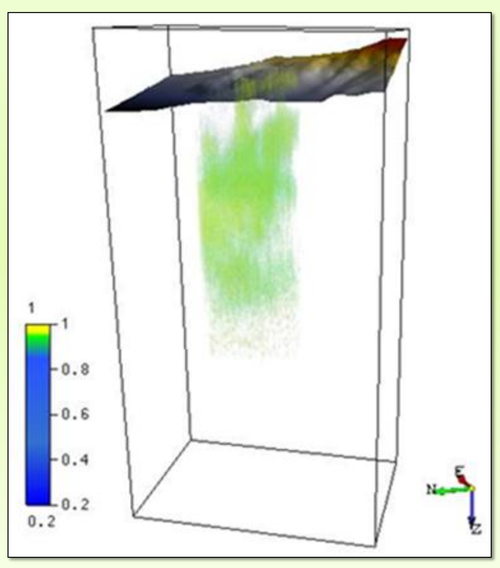

Figure 8. Interpreted gas chimney.

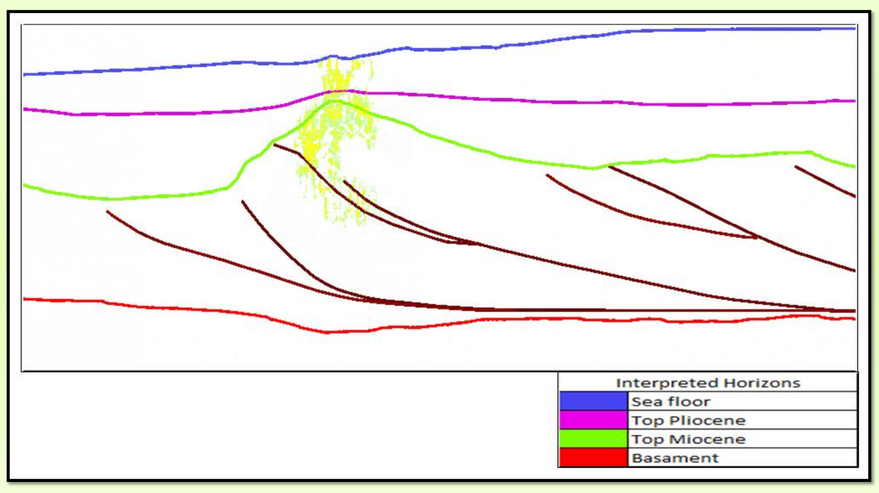

Figure 9. Combining the results of chimneys detection and the seismic interpretation.

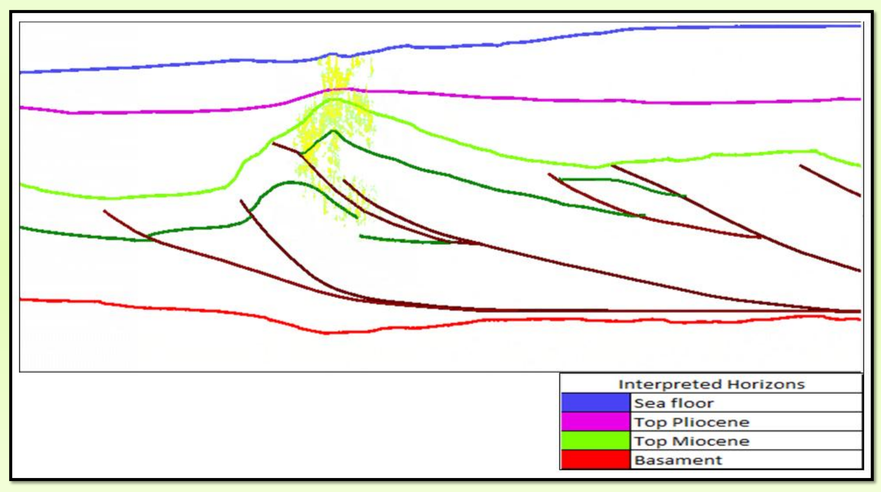

Figure 10. Combining the results of chimneys detection and the seismic interpretation with the seismic horizon that could represent the source rock.

Seismic Attribute

The attribute analysis was conducted to locate the gas presence. It was applied to the Pliocene top, Miocene top and a time-slice to 2000ms. These horizons are "crossed" by the presence of gas chimney.

Spectral Decomposition

This attribute is used as an indicator of hydrocarbons due to the attenuation of low frequencies. These frequencies were selected within the seismic bandwidth of amplitude spectrum; minimum 4Hz (Red), average 30Hz (Green) and maximum 50Hz (Blue), (**Figure 11**).

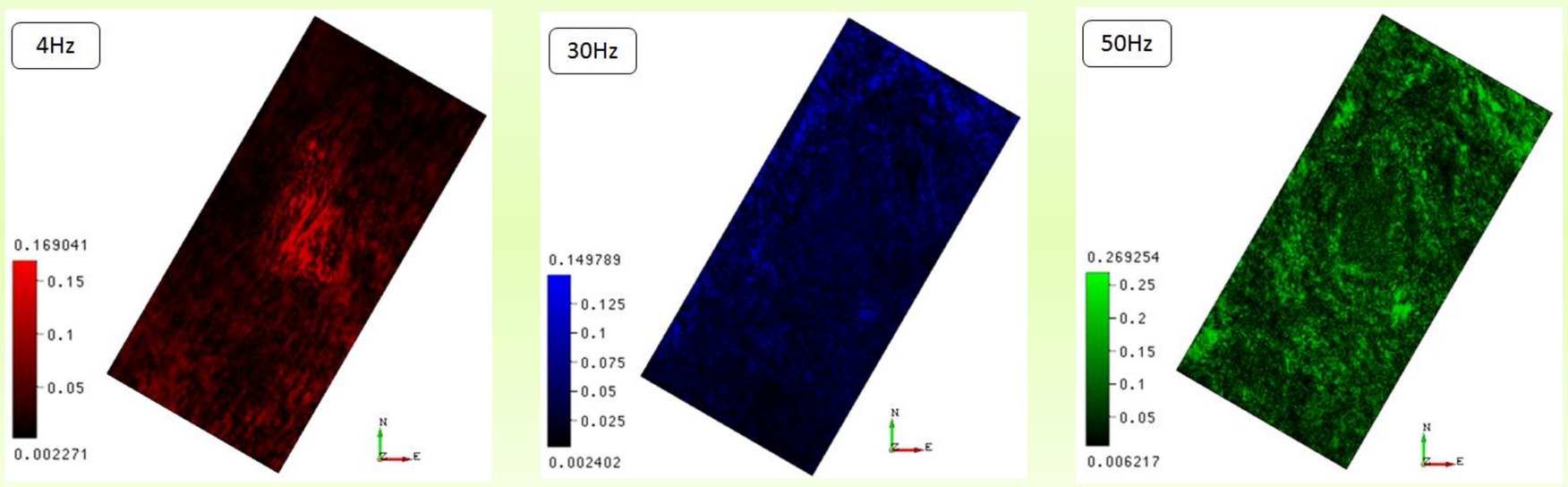

Figure 11. Spectral decompositions attributes at time-slice to 2000ms.

Instantaneous Frequency and Amplitude

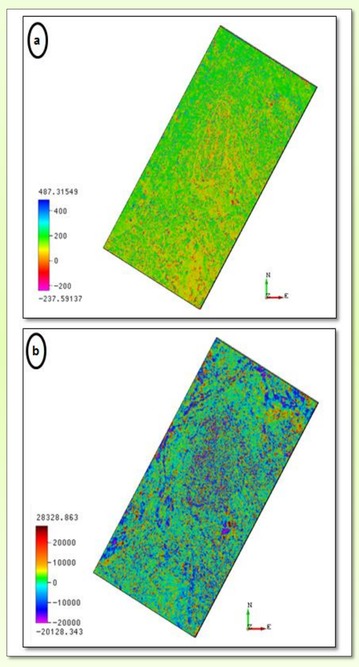

Figure 12. Attributes at time-slice to 2000ms (a) Frequency, and (b) Amplitude.

Similarity

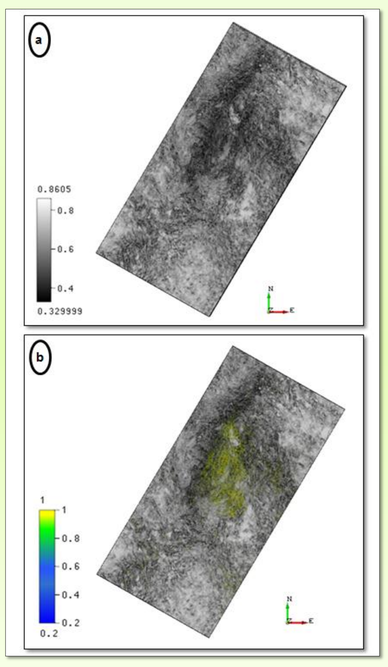

Figure 13. Attribute at time-slice to 2000ms (a) Similarity, and (b) similarity with the chimney superimposed.

Conclusions

- The structure is a break-forward shear imbricate fault-bend fold system.
- Data obtained, both in surface and subsurface, confirm that the highlighted chimney through this seismic processing, is related to the vertical migration of hydrocarbons.
- The fluid flow is occurring due to the presence of one fault in the anticline structure (generated by thrusting). Such migration was corroborated by the presence of a Mud Volcano in the sea floor, and by the piston core samples.
- Applying and combining seismic attributes could differentiate preferential lighting to the low frequencies, establishing the presence of low frequency shadows in the target, which can be related with the hydrocarbons presence.

References and Further Reading

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Acknowledgments

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Ecopetrol, una empresa que innova, transforma y gestiona su conocimiento