Seismic Attributes for 3-D Fracture Interpretation

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Summary

A methodology has now been proposed and described for fracture characterization and interpretation in a 3-D view display based on attributes combinations and visualization techniques. Seismic discontinuity attributes help with the interpretation of structural features, including faults and fractures. Because of their efficiency, *Semblance*, *Structure*, and C*urvature* are three key attributes that must be included in interpretation. The correct combination and sequence of these attributes can enhance the final goal of indentifying features that were not visible before.

The use of a correct visualization technique, such as Combo Mambo® and Volume Rendering, aids in particular to highlight, in detail, various faults and fracture networks, which can be correlated with the original amplitude volume as well as logs from wells, including image logs, production data, etc.

Interpretation using a 3-D display is one of the quickest methods for visualizing, analyzing, and characterizing the reservoir, thereby drastically reducing the cycle time of that process.

Introduction

The interest to seek fractures is incremented year after year in the energy industry, basically because of conventional reservoirs are declining and becoming matured, there is a necessity to put more attention on unconventional reservoirs. Fractures enhance dramatically the permeability in reservoirs specially if they are opened and connected doing a positive impact in the productivity of them.

Exists many type of attributes for fracture interpretation and each of them can predict and estimate the tendency of fracture network. But the right combination of them and ultimate visualization techniques can give better results in the estimation of geometries, architectures, scale, etc. Some of these attributes are briefly described in order to know the impact on the methodology applied in this study.

Seismic Attributes and their visualization technique

The 3D volume rendering is an option to visualize seismic data contained in the volume using opacity control to highlight the events or anomalies of interest. The combination of some techniques like Combo Mambo® and Opacity throughout volume rendering really helps on the display of the anomalies; dismissing the noisy features and highlighting the body of interest such fault planes or fault networks.

The data set used in this study was from Heidrun Field in the Norwegian Sea. It has been producing more than 660 million barrels of oil, in 2004 with a daily production of 150,000 barrels and 65 billion m^3 of gas. The crude oil is characterized as being naphthenic with 25.0°API. (Oljedirektoratet, 2009). The reservoir of interest is compartmentalized in blocks by faults from the east to the west side. The mains faults are pretty easy to identify especially because of the contrast between the amplitude gas cap and the oil in place.

Methodology

Phase 1 and 2: Quality control & Horizon attributes calculation

First at all, a quality control was applied on the initial seismic volume. A phase analysis of amplitude distribution and vertical resolution was developed over a Post Stack Time Migration

(PSTM) volume without filter applied. The seismic interpretation of the Top and Bottom of the reservoir was made before in order to identify with precision the volume of interest. Then, an algorithm of the second derivative developed by Al-Dossary and Marfurt (2006) known as *Curvature* were applied over those horizons interpreted on the reservoir, getting in particular a significance result the Maximum Absolute Attribute shown in the Figure 1.; Chopra and Marfurt, (2007a and b, 2008) promises this attribute helps in fracture characterization.

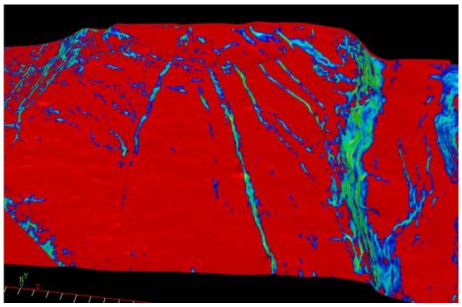


Figure 1: Maximum Absolute Curvature Attribute.

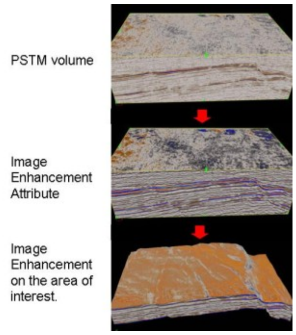


Figure 2: Initial sequence of improvement display

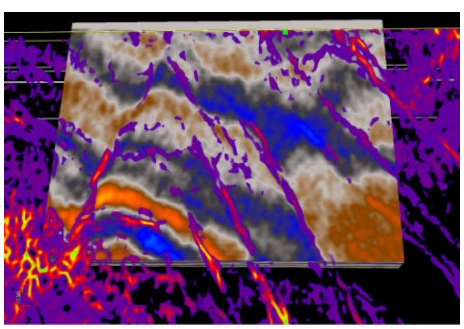
It is clear how the faults and fractures are shown bold in color blue over the rest of the surface (red background color), after just compressing the color bar range.

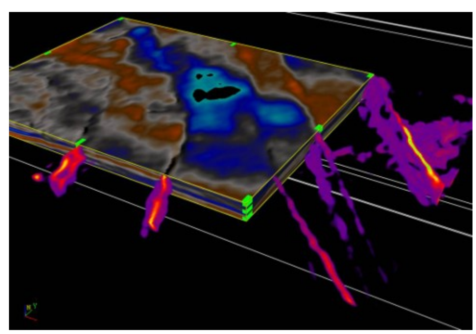
Phase 3: Display improvement

Image Enhance Attribute is calculated in the entire volume and displayed only on the reservoir. The main purpose of this attribute is to improve the seismic display, reducing the ratio noise – signal. (Figure 2).

Phase 4: Volume attributes calculation and their visualization technique

Two volumes were calculated from the *Image Enhancement* volume. The first one is a *Semblance* volume which highlights the main faults on the reservoir. The second volume is a *Structure* Volume, which represents the abrupt lateral changes in seismic data character caused by faults and fractures. Throughout the visualization technique of Combo Mambo®, it is possible to combine both volumes highlighting faults and fracture more easy, especially after adjusting the light source and shadows. However, after apply the volume render option is definitely the best option to dismiss the noise and gross rock leaving only the fault network of the reservoir as is shown in the Figures 3 and 4.

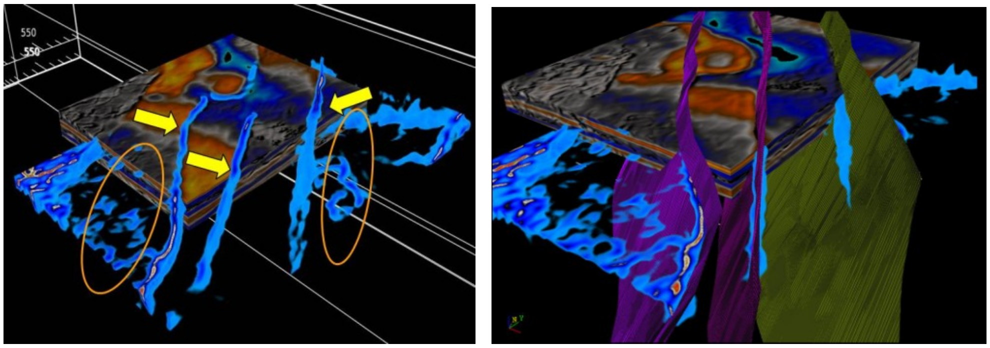




Figures 3 and 4: Volume rendering with opacity highlighting the fault planes over the Combo Mambo® volume created between the Semblance and Structure attributes.

This technique has an important impact in the entire workflow. It represents a key step in the process to highlight the fractures and faults embedded in the attributes. Once the fractures planes are displayed, they help to interpreters understand the regional and local stress applied on the area, which can be correlated with structural maps, well correlations, etc.

Phase 5: Visual correlation between the fault skeleton system and seismic data.
An overlay display for visual correlation was made between the faults and the *Image Enhancement* seismic data helping the interpreters to determine whether the vertical (blue light) planes represent faults planes or in some areas, artifacts introduced during the acquisition and processing of the data set as shown the Figures 5 and 6. (Chopra, S., 2009)



Figures 5 and 6: View from the top of the reservoir showing the fault planes highlighted by a volume rendering and the Combo Mambo® volume composes by Image enhancement and Structure volume.

Notice in the correlation exercise, how easy is to identify the main faults (some of them indicated by with yellow arrows) which stand out clearly. However, there are some areas (some of them indicated with orange circles) that were filled in a disorderly manner.

Phase 6: 3D Fault interpretation

Now, with the main faults bolded the 3D view interpretation technique is applied over the amplitude volume in vertical sections as well as in horizontal display (time slices). Through the combination of volume attributes and visualization techniques is more reliable, accurate and easy do the 3D interpretation faults and fractures probably in areas where it was no possible from the original amplitude volume. Here is where lays down the importance and the object of this entire methodology: 3D fault and fracture interpretation. The path of attributes combination and visualization technique helps directly to reach the final goal.

In a single way, this methodology can be explained as a flowchart, showing the simplicity but the powerful of the entire process. (Figure 7).

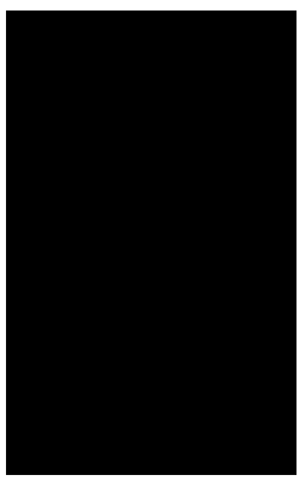


Figure 7: Methodology of fault interpretation in 3D view.

Conclusions

The methodology described above shows how faults can be highlight from an amplitude attribute volume in order to identify the shape, geometry, orientation and relative density. The attributes of *Image Enhancement*, *Semblance* and *Structure* for seismic volume and *Curvature* for horizons seismic interpretation are very useful for fracture characterization. Individually, each attribute can help to the interpreters to identify and interpret faults from a seismic volume, but the right sequence and combination of them and an appropriate visualization technique, reduce considerable time and effort achieving better and accurate results in the interpretation of subsurface features like faults and fractures.

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