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Multi Attribute Analysis - An effective visualization & interpretation technique

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Summary

Multi-attribute analysis (MAA) enables geoscientists to work on several attributes simultaneously allowing integration of varied but vital information in an intuitive fashion. It aids interpretation by offering ease in identification & delineation of subsurface features & anomalies. In this paper, methods used for multi-attribute analysis and their efficacy in better definition of subsurface features are discussed & presented with illustrative examples.

Introduction

In recent years, advances in geophysical techniques have consistently been complemented by visualization tools and techniques for data analysis & interpretation. These advances have lead to a paradigm shift in the G&G workflows and paved new paths for the industry. Among them is the transformation from single attribute analysis to multi-attribute analysis.

MAA is employed to aid seismic interpretation by making features of interest more easily visible or by identifying anomalies. The key methods used for MAA include blending, multi-attribute voxbody detection, cross-plotting and automatic pattern recognition (James et al., 2002).

Some of these techniques are quite popular while others are known but not being exploited to their potential. MAA in most cases doesn't require a specific or special input, since attributes or interpretation performed for any generic interpretation workflow can serve as an input for MAA.

An interpretation workflow using MAA helps geoscientists to make unbiased observation and robust interpretations of structures, facies, and hydrocarbon systems in an interactive & intuitive manner.

Method

The primary methods of MAA are discussed below:

Blending:

Blending combines the information of two or more seismic attributes volume or horizon attributes through opacity or other methods. Of the various methods of MAA, blending is the most visual approach and therefore the easiest.

It is most effective if one or more attributes are displayed in grayscale and another attribute is displayed in color (Figure1). Attributes that are most effectively displayed in grayscale tend to be structural attributes, and attributes that are most effectively displayed in color tend to be stratigraphic attributes (Table 1).

Grayscale Attributes	Color Attributes
Discontinuity, dip, azimuth, shaded relief, Curvature, amplitude change (vertical or lateral)	Original seismic, reflection strength, average frequency, response phase, response frequency, acoustic impedance, parallelism, AVO attributes

Table 1: Typical attributes to use in volume blending. Blending is most effective when one attribute is displayed with grayscale and another is displayed in color.

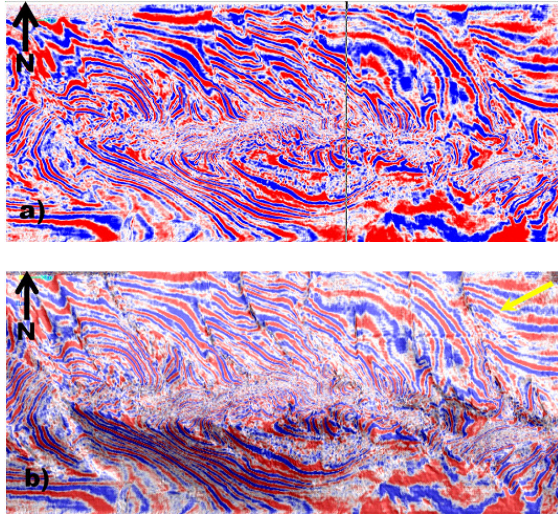


Figure 1 An example of blending to aid structural interpretation a) Original seismic b) Original seismic data blended with lightscape attribute to enhance faults and give an indication of their relative displacement. The yellow arrow shows the effective direction of illumination. The lightscape attribute in this example was filtered through vertical median filtering to produce a cleaner and more interpretable image. While such filtering can remove small scale features, it often produces superior images in blending.

Another popular way of blending volumes or horizons is RGB blending, most commonly applied to co-render spectrally decomposed volumes (Figure 2), which allows extraction of substantial amounts of information from 3D seismic data.

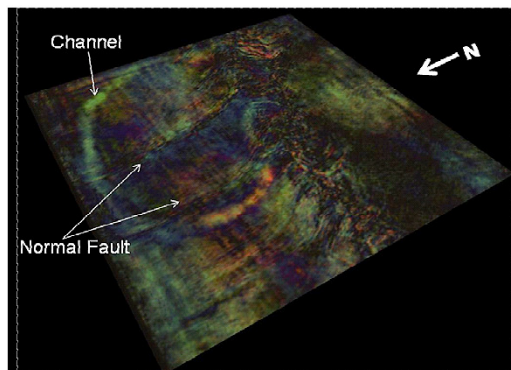


Figure 2 Example of a time slice from RGB blend. The richness of structure and ease by which channel can be visually separated is very compelling.

Blending volumes along with visualization techniques like formation sculpting can be very useful for discriminating feature of interest in structurally complex regimes. In general blending is followed up by geobody detection workflows discussed below.

Multi-attribute geobody detection:

Geobody detection refers to automatic detection of features like channels sand overbank, levee, slumps, reefs, wedge, Direct Hydrocarbon Indicators (DHI) etc. and is carried out by picking single or multiple seed samples within an event of interest and searching other samples that are spatially connected or disconnected (in multi-geobody detection) having similar specified range of attribute values to the seed sample. The idea which drives Geobody detection is the distinguishing characteristics of the feature to be mapped followed by processing the data to enhance those characteristics for visualization and geobody mapping. Geobody detection enables an interpreter to quickly isolate prospective areas of large volumes for further investigation. Multi-attribute geobody detection involves combination of attribute to isolate the geobody. Initially the technique was popular for tracking an event based on seismic amplitude and instantaneous phase (as phase may aid in autopicking weak, discontinuous amplitude events). Multi-geobody mapping is effective with a combination of geometric and instantaneous/AVO attributes and may help in delineating the geometry/architecture of the feature and anomalous point within it (Figure 3).

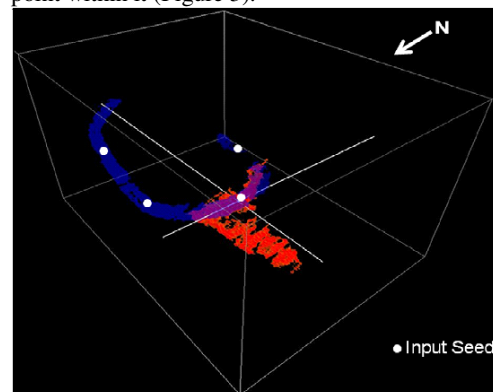


Figure 3 Example shows channel (blue color) mapped based on multi seed input, connectivity and attribute value range on the time slice shown on Figure 2. The red highlighted part is a geobody detected on additional criteria of low values of Lambda-Rho which may be probable gas sand.



Crossplot:

Crossplotting seismic attributes, well log data, and horizon slices is a key tool for quantitative interpretation.

Introduced initially to display the relationship between attributes, today crossplotting is the most widely used MAA tool for isolating anomalies. Vern & Hiltebrand (1994) and later Castagna and Smith (1997) ushered the era of crossplotting AVO attributes. Since then, crossplot techniques are widely used to discriminate the anomalous (probable hydrocarbon) zone from the background trend.

With the advent of 3D visualization, two dimensional cross plotting (Figure 4 & Figure 5) can be extended directly to three dimensional visualization of the anomalies. This has additional benefits since data points in 3D space are more readily investigated and it also results in a quick & reliable interpretation of the lateral extent of the anomaly. Sub volume detection followed by crossplotting based on the other attribute (not included in crossplotting) can further constrain or refine the detected geobody (Figure 6).

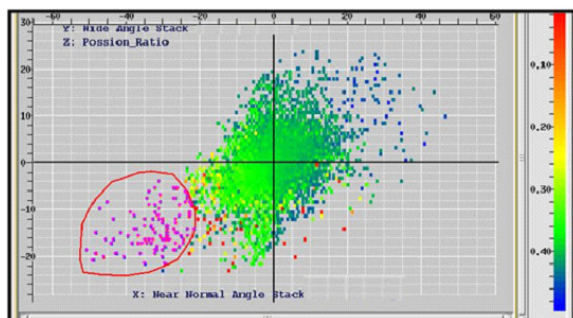


Figure 4 Example shows a 2D cross plot X-axis: Near angle stack Y-axis: Far angle stack and Z: Poisson ratio (color). The polygons isolate points away from the background trend.

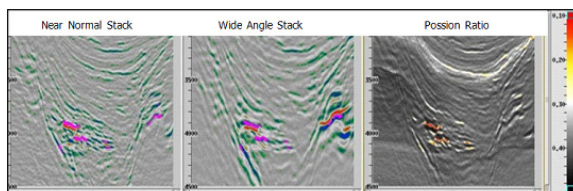


Figure 5 Example show the points marked on the near and wide angle stack from the crossplot window. Pink color marked section may be a probable AVO anomaly.

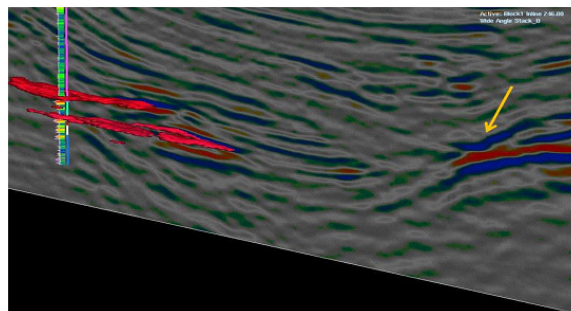


Figure 6 Example shows the spatial distributions (which is not so apparent in 2D crossplot) of the true AVO anomaly validated with the Poisson ratio log in 3D. Subvolume detection based on low Poisson ratio criteria, removes the false AVO anomaly shown by yellow arrow.

Multi-attribute Seismic facies classification

Seismic facies classification techniques have been used for years in interpretation and reservoir characterization workflows. Seismic waveform shape and character define facies with significant detail compared to time and amplitude mapping.

Traditional single seismic amplitude-based facies analysis is complemented by a multi-attribute seismic facies classification by concurrently evaluating trends in various seismic attributes such as instantaneous attributes, geometric attributes, impedance and AVO attribute for better identification and validation. Among various automatic facies classification methods, the neural network method (NNT) based on the Kohonen self-organizing map methodology and clustering are well known.

A basic challenge in multi-attribute facies classification is trend correlation from one volume to another. Statistical methods like Principal Component Analysis (PCA) are used to understand the trend of the dataset, attribute dependencies and correlation. PCA can also be used as a noise reduction technique prior to running multi-attribute classification. It also helps in addressing data redundancy inherent to multi-attribute analysis by selecting a relevant set of attributes for the classification.

Automatic seismic facies identification is greatly improved by using several key attributes rather than a single attribute (Figure 7 & Figure 8). This approach offers the further



advantage of giving more meaning to the facies (classes) that are identified.

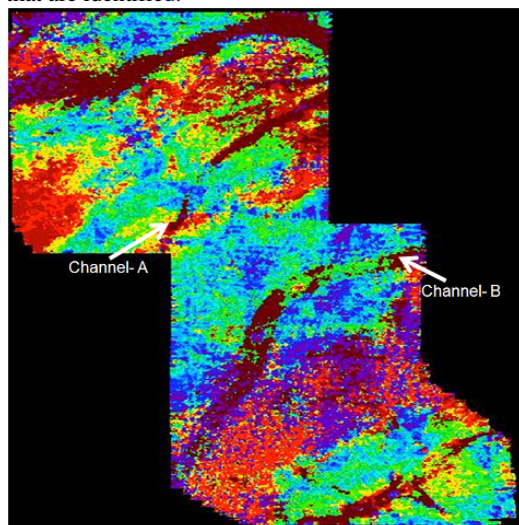


Figure 7 Example of facies map generated using NNT trace shape classification single seismic amplitude (number of classes = 10)

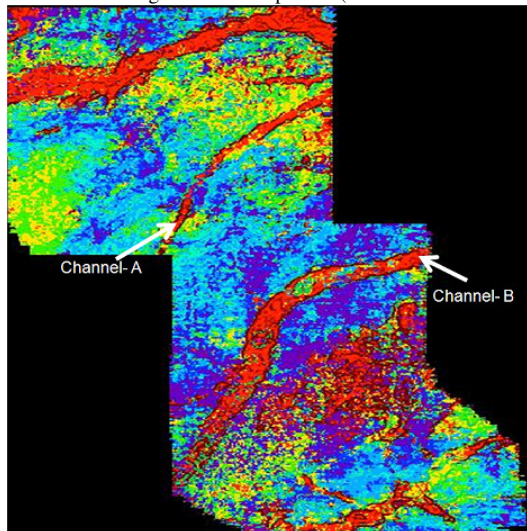


Figure 8 Example of a facies map generated using seismic amplitude, coherence & reflection strength (number of classes = 10) with PCA which better maps the geometry of the channel feature. Channel A is quite clear as compared to the same feature in Figure 7. Channel-B shows better continuity and mid-channel bars features in channel are quite prominent as well.

Conclusion

In general it is very rare that a single seismic attribute validates all the details of the reservoir interval or geologic features. Multi-attribute analysis can reveal detailed information by combining the information available on independent seismic attributes in the best possible fashion depending upon the approach used. MAA like blending or crossplotting comprehended by multi-attribute sub- volume geobody detection play an important role in prospect evaluation workflows viz. delineating volumetric extent and evaluating spatial connectivity of significant seismic features. A multi-attribute seismic facies classification approach offers a further advantage by giving more meaning to the facies that are identified.

The challenge which persists in multi-attribute analysis is the choice of the appropriate set of attributes which basically depends on the distinguishing characteristics of the features to be mapped.

Acknowledgments

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