[PS]Carbonate Reservoir Characterisation: A Middle East Case Study Using 3-D Seismic Analysis Workflows*

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Abstract

Poststack seismic analysis techniques are very effective at highlighting subtle features in carbonate zones when conventional techniques give ambiguous or inconclusive results. In this study, we used seismic analysis workflows to address two problems encountered in neighbouring fields in the Persian Gulf, one structural and one stratigraphic.

The data used in this study were dominated by steeply dipping coherent noise. This not only made interpretation difficult but also introduced artefacts into the subsequent processing. Structurally oriented noise attenuation was therefore an essential first step in the processing workflow.

The stratigraphic challenges occur in the Middle Cretaceous Mishrif reef build-ups. These carbonate build-ups were controlled by localised salt diapirism and associated bathymetric variations. Directly below the Mishrif horizon, clinoforms and pinch-outs are known to exist but are difficult to identify on the seismic data. The Bedform workflow was used to identify individual events, and when combined with instantaneous frequency was used to extract the pinch-outs as 3-D geobodies.

The structural issues occur in the massive aggrading Thamama complex of Lower Cretaceous age, where there are two potential fault scenarios. The objective of the structural workflow was to identify the subtle faulting around a key well location to clarify which of the faulting scenarios was present. A combination of structurally oriented attributes identifying both discontinuities and curvature were used to highlight the faults and confirm one of the scenarios.

A good understanding of the geomorphological evolution, as well as the structural and stratigraphic properties of these formations is crucial in defining reservoir properties. Attribute analysis and object extraction has proved to be a valuable tool for detailed

investigation into the carbonate features within these UAE fields. It has provided a level of detail that is hard to achieve with manual interpretation and has given new insights into the geology and reservoir properties of both fields.

Reference

Alsharhan, A.S., and A.E.M. Nairn, 1993, Carbonate platform models of Arabian Cretaceous Reservoirs, *in* J.A. Simo, R.W. Scott, and J-P. Masse (eds.) Cretaceous Carbonate Platforms: AAPG Memoir 56, p. 173-184.

Carbonate Reservoir Characterisation

A Middle East Case Study Using 3D Seismic Analysis Workflows

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Introduction

Carbonate reservoirs in the Persian Gulf are complex integrated systems which are often hard to interpret. The identification of subtle fracturing as well as build-ups is further complicated by poor data quality. This case study presents the use of advanced 3D seismic analysis techniques applied to post stack seismic creating attribute and object volumes which have provided an insight into the faulting and stratigraphy of the reservoir sections of two producing fields offshore UAE (Figure 1).

Investigation focused on:

1. Fault analysis within Lower Cretaceous aggrading Thamama complex in Field 1 and
2. Stratigraphic analysis within Middle Cretaceous Mishrif reef build-ups in Field 2.

The workflow applied to the data was split into 3 sections: Data Conditioning applied to both fields, Fault Analysis applied to Field 1, and Stratigraphic Analysis applied to Field 2.

Fig. 1 Study area

Data Conditioning

Presence of steeply dipping coherent noise in both data sets made interpretation difficult.

Noise attenuation was achieved by using a sequence of FMH filters that are both structurally oriented and edge preserving, thus maintaining reflector terminations and the characteristics of the data.

Spectral enhancement was applied to Field 2 data. This broadened the frequency spectrum and improved the vertical resolution of the data, making it easier to map the lateral extents of previously unresolved subtle pinch out events below the Mishrif (Figure 2).

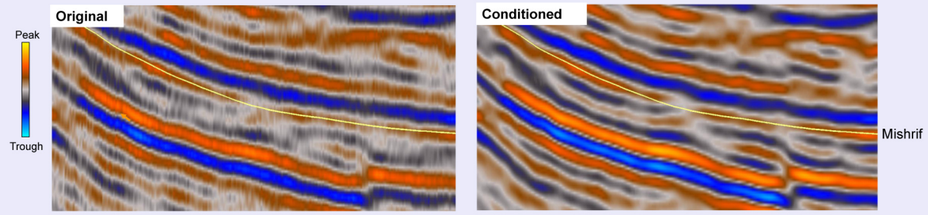


Fig. 2 Vertical section showing effect of noise attenuation and spectral enhancement on the clinoform features below the Mishrif. Note the increase in vertical resolution.

Fault Analysis

The Thamama complex presents two potential fault scenarios a dominant NW-SE fault trend and a subtle perpendicular NE-SW trend which may be compartmentalizing the reservoir.

Objective:

To identify the subtle faulting around a key well location and to clarify which of the faulting scenarios was present.

Workflow:

Multiple fault analysis techniques were used to image the subtle NE-SW trend in an objective manner. These include orientation attributes and edge attributes (Figure 3 mapped onto the Thamama horizon).

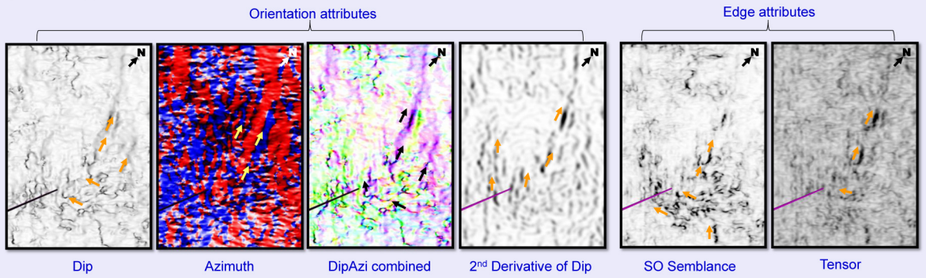
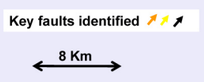


Fig. 3 Orientation and Edge attributes. Each shows a different picture of the faults around the target well mapped onto the Thamama surface.



1. Best fault image achieved by combining structurally oriented attribute together with a curvature attribute (Figure 4a).
2. Faults were extracted from the combined attribute, their orientation analysed within the fault Trends volume and plotted on a rose plot (figure 4b).
3. Rose plot revealed two dominant trends in the NW-SE and NE-SW orientation, (dark yellow and dark pink in figure 4b).
4. Computed Fault Density (Figure 4c) revealed areas that have a high number of faulted voxels with NE-SW trend, further supporting the observed NE-SW trends in the Fault Trends volume

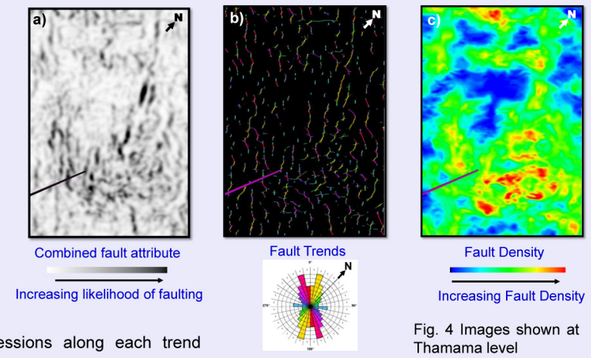


Fig. 4 Images shown at Thamama level

Result:

Two perpendicular trends were seen in the attribute data with different expressions along each trend suggesting the second scenario was more probable.

Stratigraphic Analysis

The middle Cretaceous Mishrif formation hosts major reservoirs in offshore UAE. Some of these reservoirs contain different growth stages of the prograding rudist reefs and varying porosity and permeability characteristics which in some cases have been greatly enhanced by leaching due to subaerial exposure to meteoric waters. The basinal source rocks formed during the early part of the next succeeding transgressive cycle sealed the reservoirs (Alsharhan and Nairn, 1993). These reservoirs which pinchout against the Top Mishrif sealing surface are prime exploration targets offshore UAE.

Objective:

To perform a comprehensive stratigraphic analysis that will provide an insight into the Mishrif reef pinchout morphology, their 3D geometry and extents.

Workflow:

Bedform analysis was used to identify and extract the pinchouts and clinoforms directly below the Mishrif horizon.

1. The Bedform attribute identifies individual layers by isolating constant phase events (Figure 5b)
2. The bedform peaks and troughs were combined with the instantaneous frequency to create an attribute in which pinchouts, onlaps and downlaps are easily identified (Figure 5c & d).
3. Extraction of these clinoforms and pinchouts as geobodies using voxel connectivity analysis enabled their lateral extent and shape to be easily visualised (Figure 5e & f).
4. Embedding the outer skin of the geobodies into the reflectivity helped in understanding the exact outline and extents of the pinchout zones within the reflectivity data (Figure 5g).

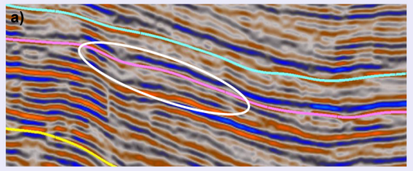


Fig. 5a Vertical section showing (circled) prograding clinoforms below Mishrif surface (in pink).

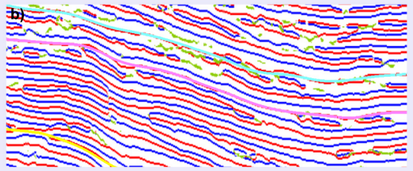


Fig. 5b Bedform attribute highlights peaks in red, troughs in blue and unresolved doublets in green. Stratigraphic terminations below Mishrif surface are clearly visible independent of amplitude.

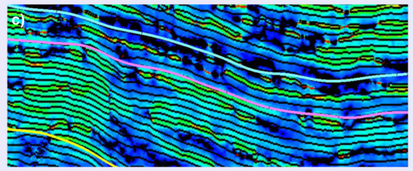


Fig. 5c Bedform Frequency attribute shows both reflector structure and frequency content highlighting pinchout zones.

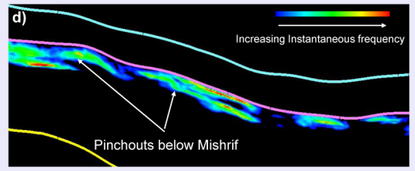


Fig. 5d Pinchout attribute provided a concentration of the high instantaneous frequency pinch outs cropped below the Mishrif surface.

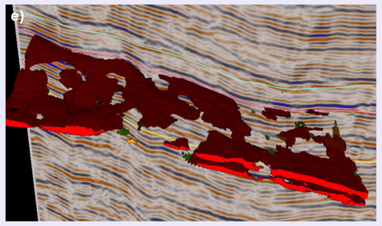


Fig. 5e Vertical section showing extracted pinchouts in 3D render mode.

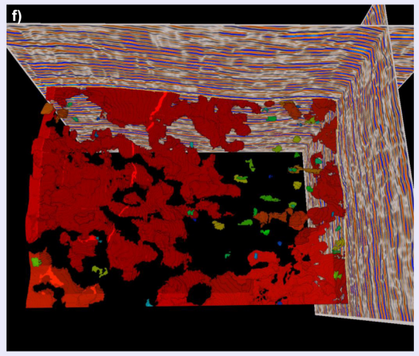


Fig. 5f Plan view of Pinchout geobodies displayed in 3D provided a good understanding of the lateral extents and connectivity of the pinch out zones.

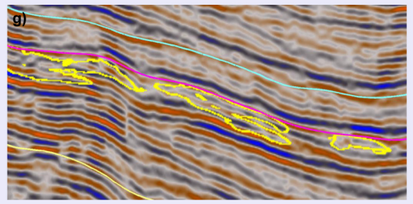


Fig. 5g SkinIn volume shown in cross section. The yellow lines mark the outline of the pinch out geobody and provided an excellent visual correlation for the extents of the pinchouts within the reflectivity data.

Result:

The Bedform and Bedform Frequency attributes highlighted the prograding clinoforms, onlaps and pinch outs, whilst providing templates for 3D geobody extraction. The pinchouts which correspond to the prograding Mishrif rudist reef carbonate reservoirs were subsequently extracted and analyzed in 3D and in combination with the reflectivity data.

Conclusions

Attribute analysis and object extraction has proved to be a valuable tool for detailed investigation into the carbonate features within these two fields. It has provided a level of detail that is hard to achieve with manual interpretation and has given new insights into the geology and reservoir properties. By analysing the individual component parts of the seismic data (amplitude, frequency, phase, and lateral variability) it has been possible to extract a high level of information out of the data which is directly relevant to the interpretation.

References

Alsharhan, A.S. and A.E.M. Nairn, 1993. Carbonate platform models of Arabian Cretaceous Reservoirs, Ch.15, pp. 173-184.

Acknowledgements

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