

Prospect Investigation and De-Risking Using Cognitive Interpretation Workflows, Offshore Equatorial Guinea*

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Abstract

The West African Atlantic margin is a prolific oil province, and a number of major discoveries have been made offshore Equatorial Guinea. A 3D seismic dataset was shot covering the Block W lease area, and was used to explore for prospects across a variety of geological ages. Cognitive Interpretation techniques were applied to accelerate and enhance this process, resulting in greater interpretation confidence and de-risking of the identified leads. These methods include data driven but interpreter guided approaches for revealing geology from seismic data. The prospective geology contained in the seismic coverage area consists of Late Cretaceous marine sands and shales, deposited in shelf to margin and basin floor transitional settings. Observed and modeled hydrocarbon AVO is Class II and IIp (with phase change). The environments of deposition were revealed using frequency decomposition and RGB (Red, Green, Blue) blending, and this enabled sedimentary fairways and channel complex architecture to be accurately delineated in greater detail than was possible using seismic amplitudes alone. Features not previously seen were also shown. Displaying these results using stratigraphic iso-proportional slices allowed the sedimentary systems to be described fully across the entire survey. The most significant risk element for the identified leads was trapping, and fault detection workflows were applied to investigate subtle, low relief faults that may provide a trapping mechanism. Inflections in structural dip were identified which may indicate the presence of strike-slip faults providing these traps. Other faults were revealed by the presence of low amplitude, chaotic gas filled signatures, which were imaged and shown to provide updip closure to another lead. These pathways also provide further evidence and reduced risk for hydrocarbon charge in the

area. A variety of volume combination methods were used to blend the Cognitive Interpretation volumetric products with the AVO analyses, integrating the seismic attributes with rock physics to further improve the interpretations and cumulatively reduce risk. The Cognitive Interpretation workflows revealed new information within the seismic data and enhanced existing interpretations, reducing exploration risk for the identified leads. The results were generated rapidly within the scope of a ten day project, and allowed the de-risked stratigraphic prospects to be easily communicated and understood.



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Introduction

Late-Cretaceous age prospects identified from a 3D seismic survey were interpreted and investigated, in a frontier exploration setting offshore Equatorial Guinea.

- Challenges
 - In this frontier setting, uncertainty is high for all exploration risk elements.
 - Little data exists to correlate the play concepts to known discoveries to reduce risk.
 - The deep water environment, depth to targets and remote location mean exploratory drilling is expensive (\$40-60M)

Seismic surveys, as the primary data source, must be exploited to their full potential to reduce uncertainty and reduce risk.

Objectives

The extreme cost of drilling exploratory wells in the area means that risk must be reduced as far as possible.

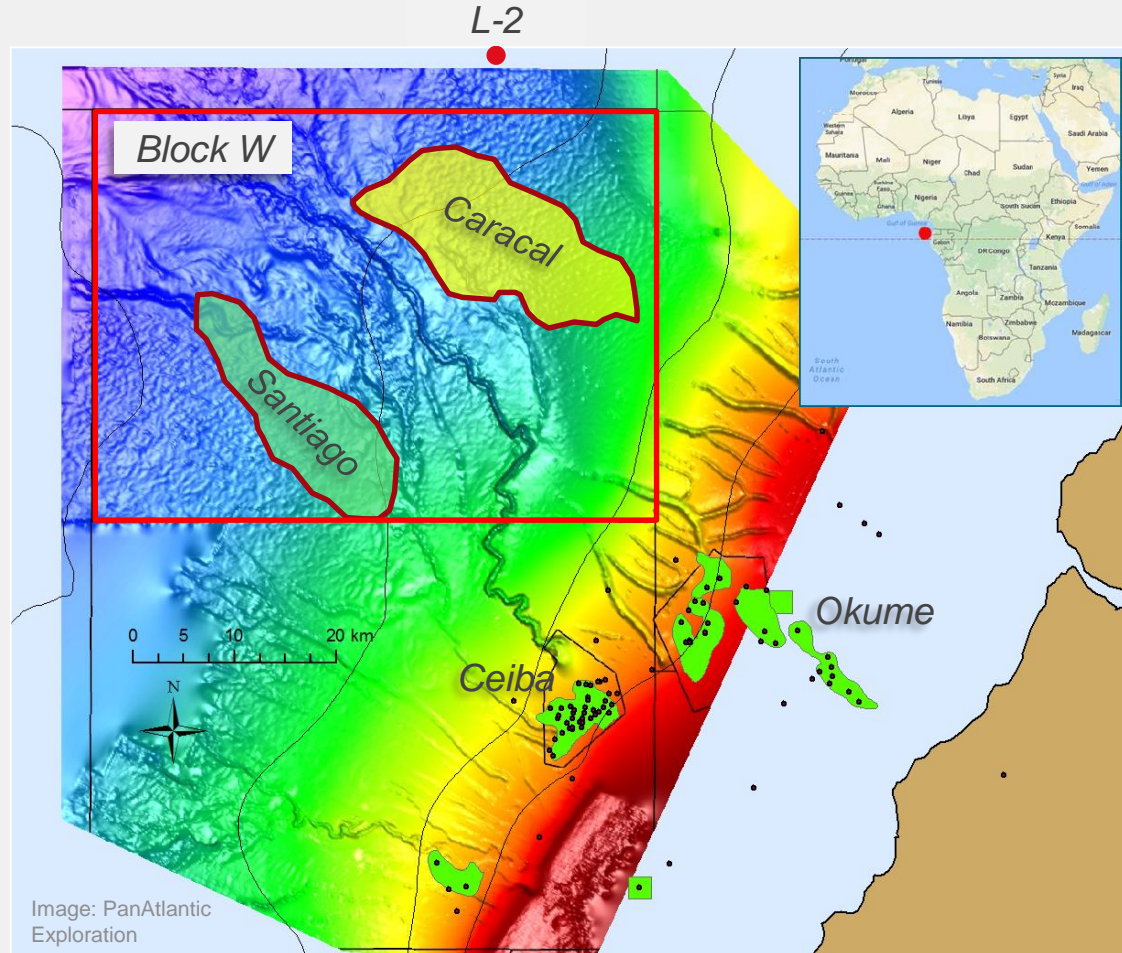
This means using the seismic data to its full value and ensuring all available information is obtained. Several prospects were identified and initially interpreted from the seismic amplitudes, but the reflectivity data did not provide the full picture alone.

The objectives for the identified prospects were to:

- Apply stratigraphic analysis to reduce the risk factor for reservoir presence
- Apply textural analysis to reduce risk for charge and migration
- Apply structural analysis to reduce risk in delineating trapping mechanisms

Geological Setting

- Offshore Equatorial Guinea
- Block Area : 2254 km² (~100 GoM blocks)
- 1150 to 2200m water column, and 1740 to 2100m target depths below mudline.
- No well control within block – the L-2 well exists just outside the survey area.
- The petroleum system in the area has been proven updip.

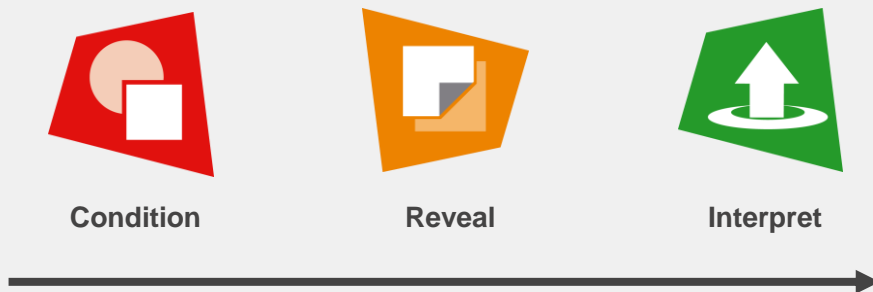


Seismic Data

- Seismic acquisition took place from November 2013 to January 2014 using slanted cable, covering 2450 km² offshore Equatorial Guinea.
- The delivered migrated cubes used Kirchhoff pre-stack time migration, interpolated at 12.5 x 12.5m.
- Additional gather conditioning and noise reduction, and AVO analysis were applied, indicating a Type II response.
- The migrated angle stacks were in the ranges:
 - Near: 4-18°
 - Mid: 16-30°
 - Far: 28-42°
 - Ultra-far: 40-48°

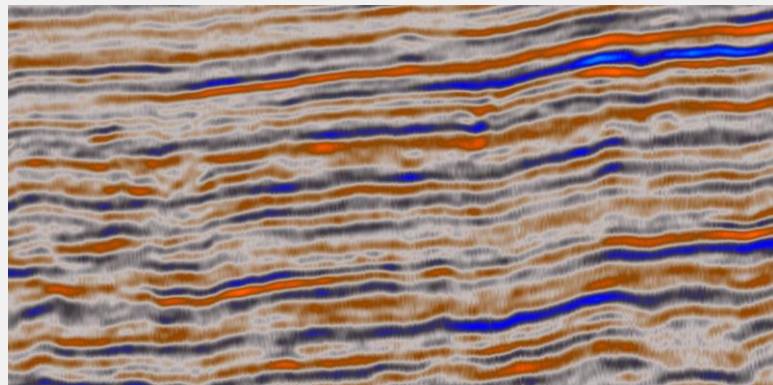
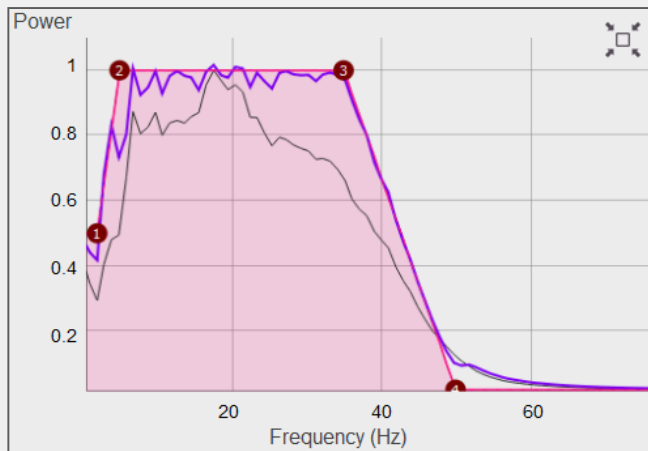
Cognitive Interpretation Workflow

- A Cognitive Interpretation workflow was applied to achieve the objectives and exploit the full information complement of the seismic data.
 - Data Conditioning reduced the level of noise and increased the vertical resolution.
 - Frequency Decomposition and attribute analysis revealed the nature of the geology present.
 - Stratigraphic and structural features were then interpreted from the data using the generated results.



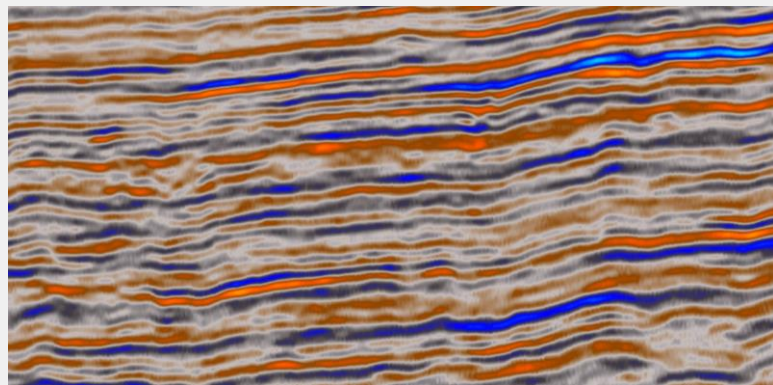
Data Conditioning

- Structurally oriented filtering was lightly applied to increase the signal to noise ratio.
- Spectral whitening improved the vertical resolution.



Original

12.4km



Conditioned

4300ms

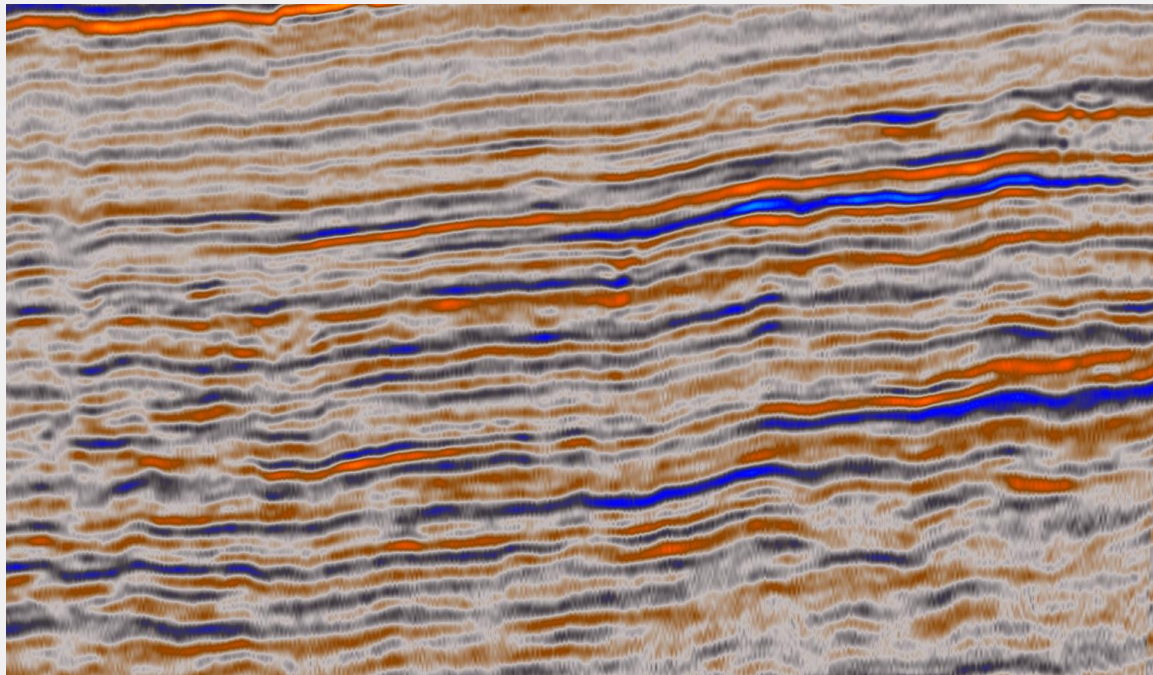
5500ms

Data Conditioning

- Original

The input seismic cube was of good quality, however some latent processing artifacts remained.

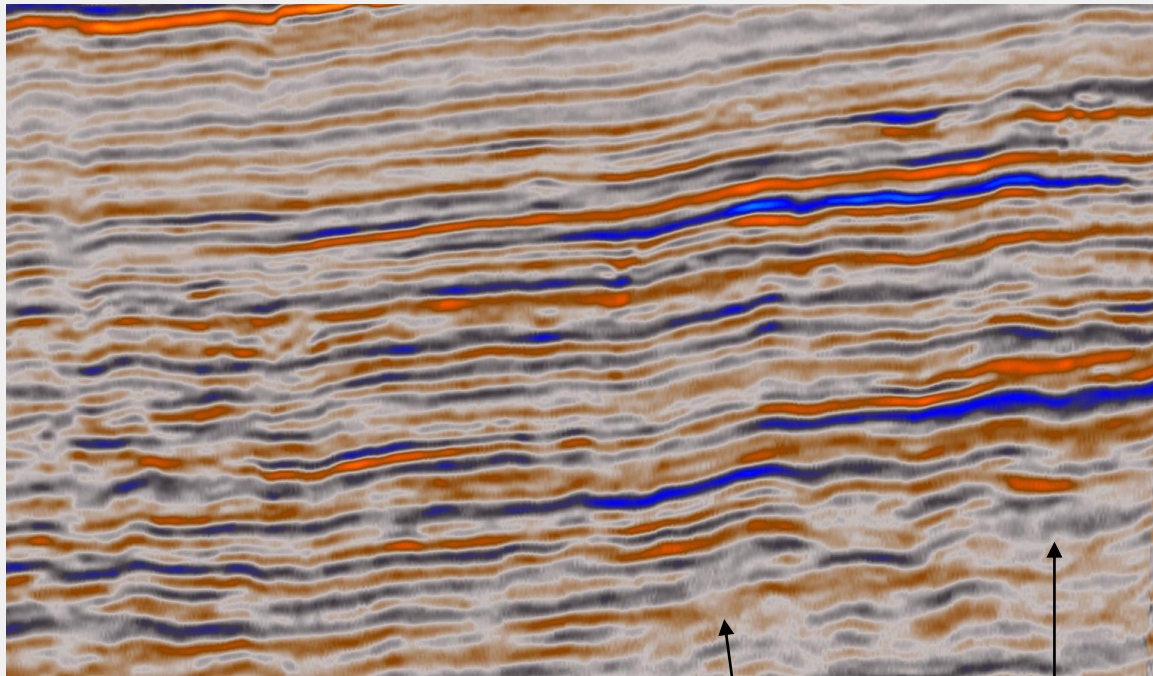
Amplitude jitter and minor migration noise were observed, reducing the effectiveness of any seismic analysis applied directly.



Data Conditioning

- Noise Cancellation

The application of structurally oriented, edge preserving noise cancellation filters removed the light migration noise, but preserved the detail of structural and stratigraphic edges.



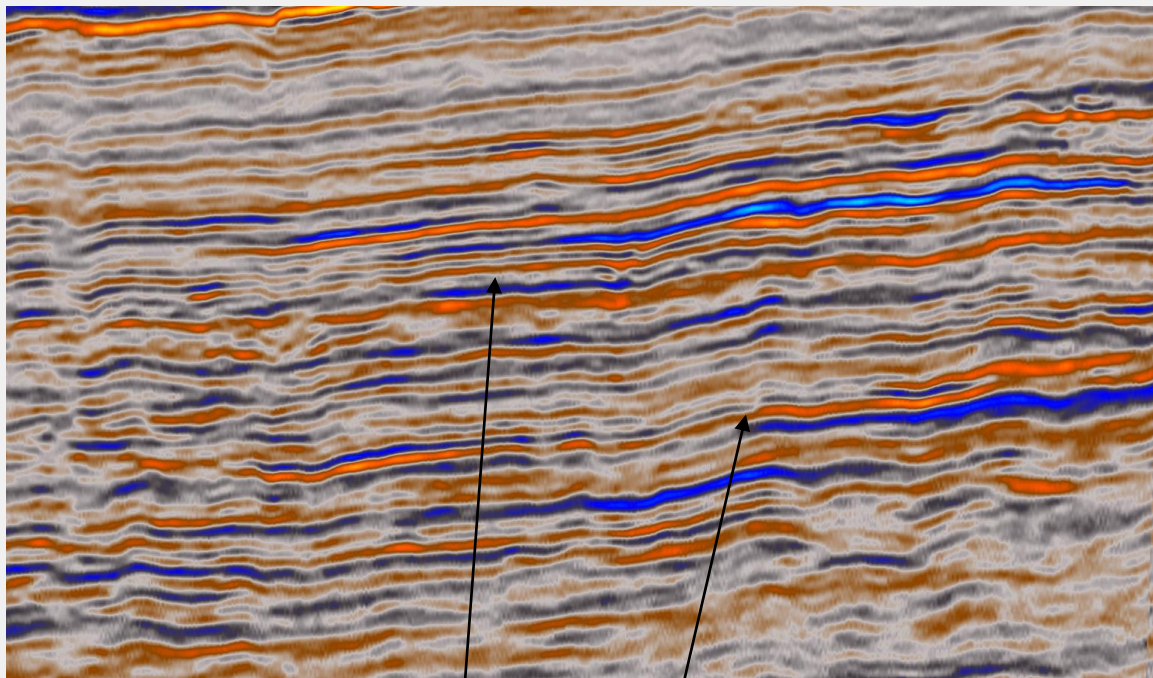
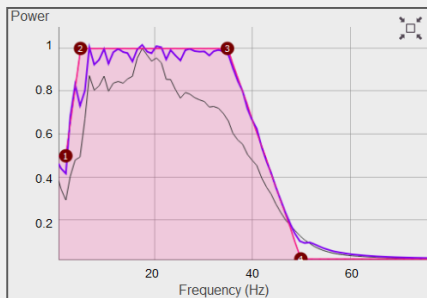
Increased continuity and reduced noise

Data Conditioning

- Spectral Enhancement

Extending the bandwidth at target depth increased the vertical resolution and mappability of thin events.

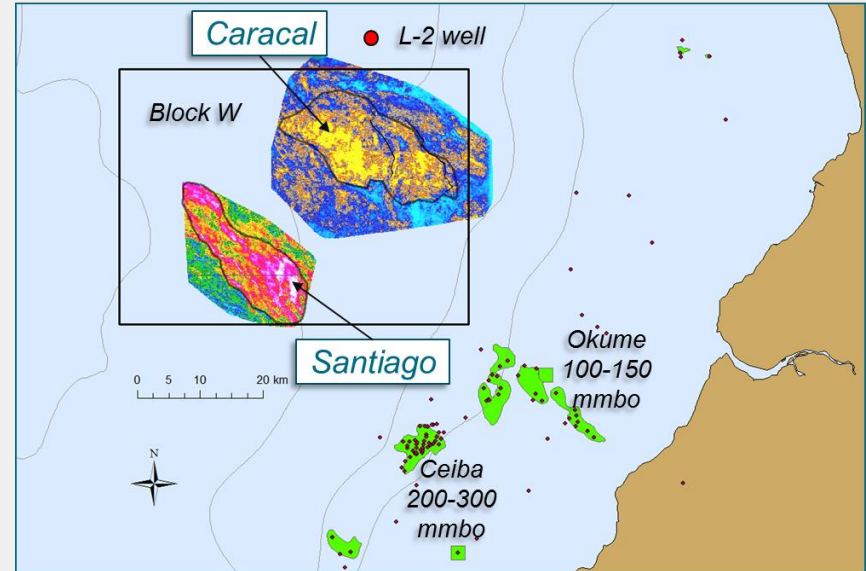
Preserving the low frequencies maintained correct event position.



Better delineation of thin events, and sharpening of structural and stratigraphic edges.

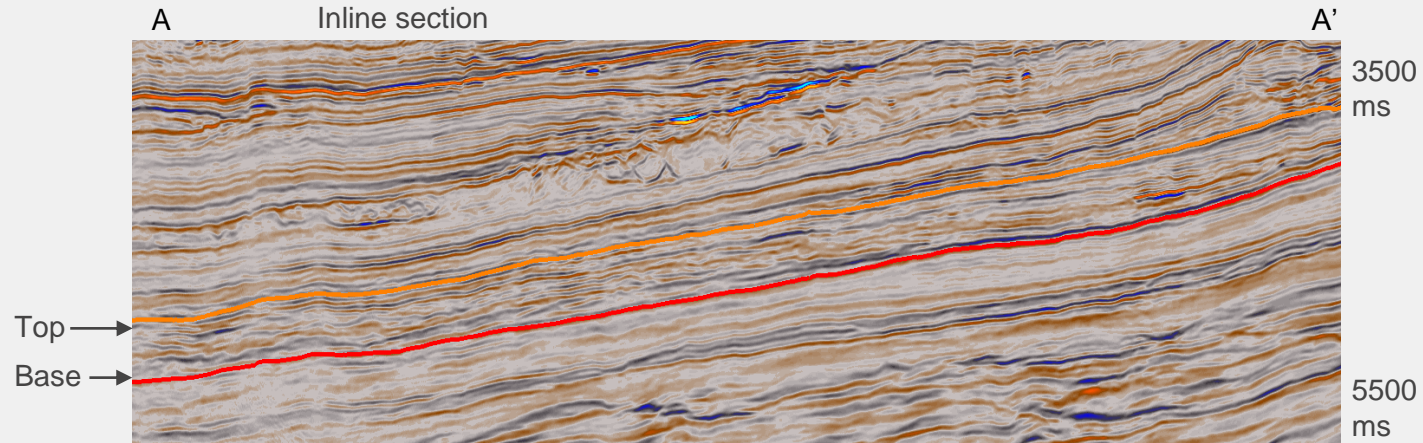
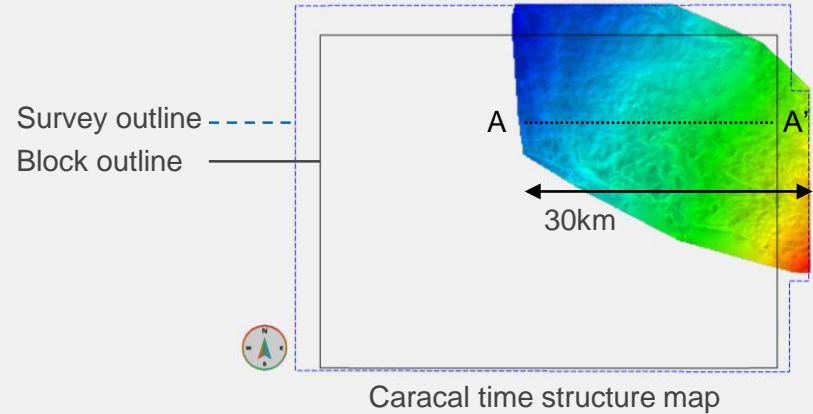
Prospects

- Two main prospects were investigated in this work: Caracal and Santiago.
- Both are of Campanian age, but have slightly different characteristics.
- These were investigated to respectively de-risk:
 - Reservoir presence
 - Migration and charge
 - Trap mechanism and probability



Caracal Prospect

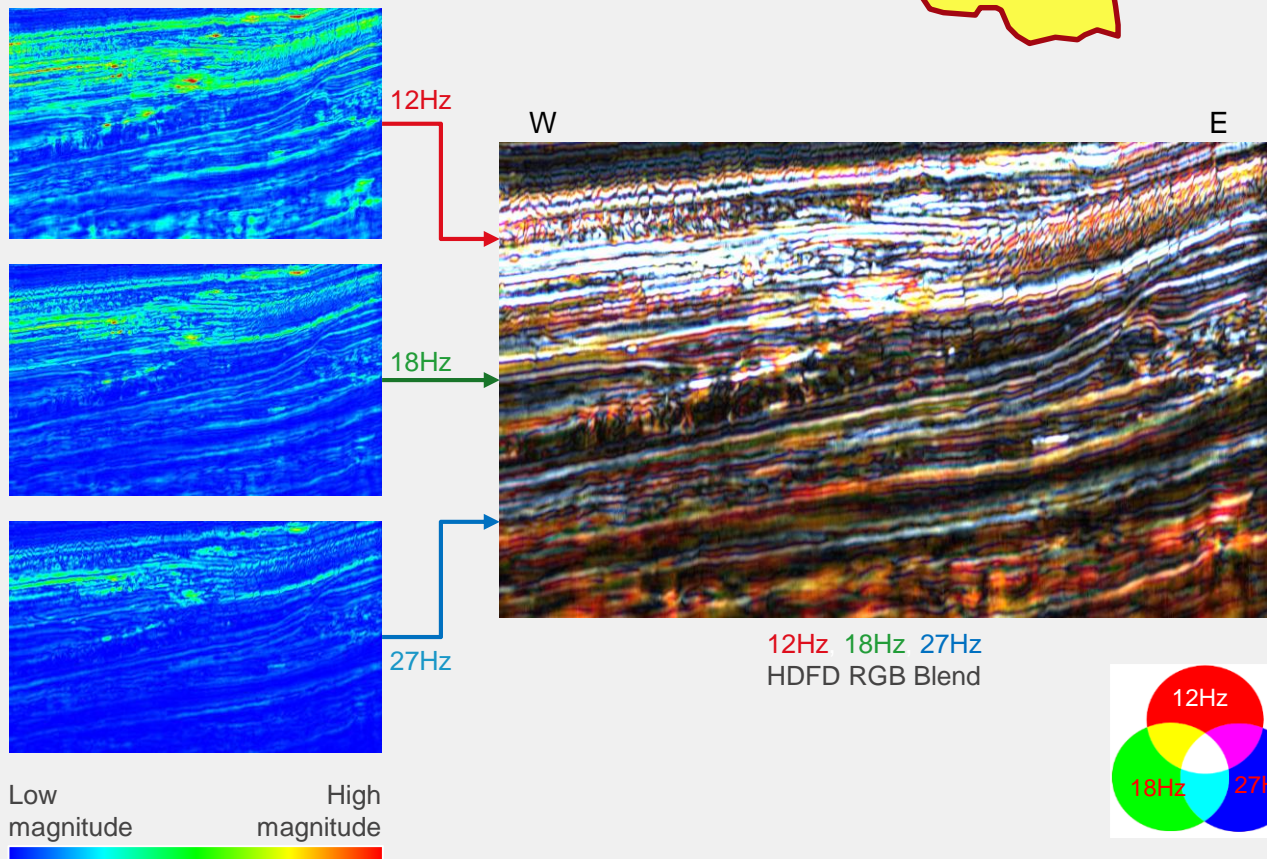
- AVO supported
- 4400ms mean time
- Average thickness 233m
- Overbank or crevasse splay with cross-cutting channel input
- Critical risk: Trap



Reservoir Risk Reduction

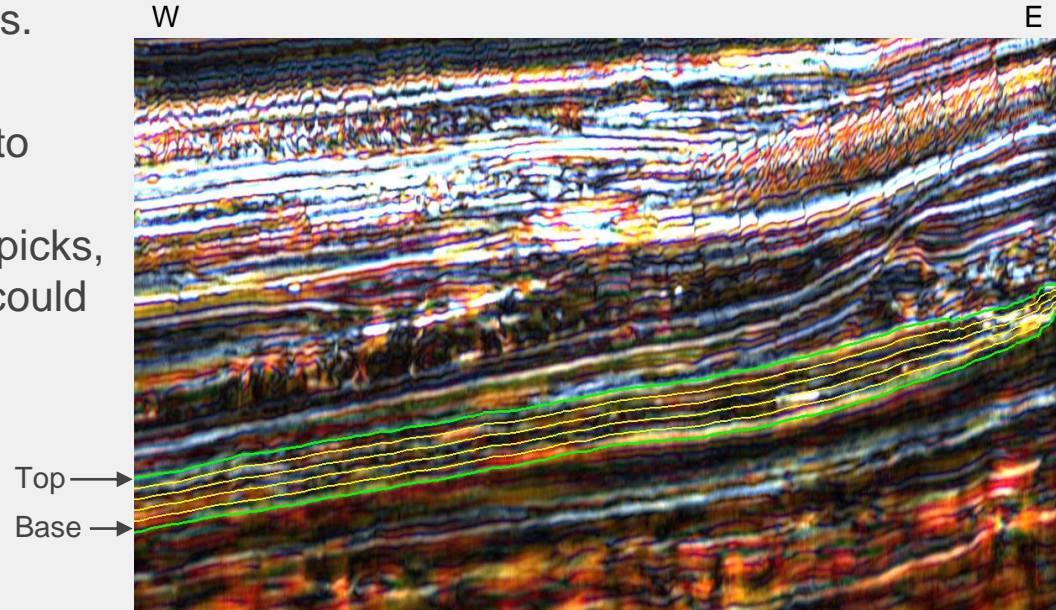
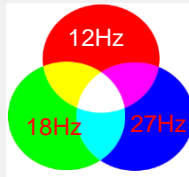
Frequency decomposition was applied to better image the prospect stratigraphy and reduce risk when interpreting the depositional system.

The frequency content responds to changes in thickness, lithology, and porefill.



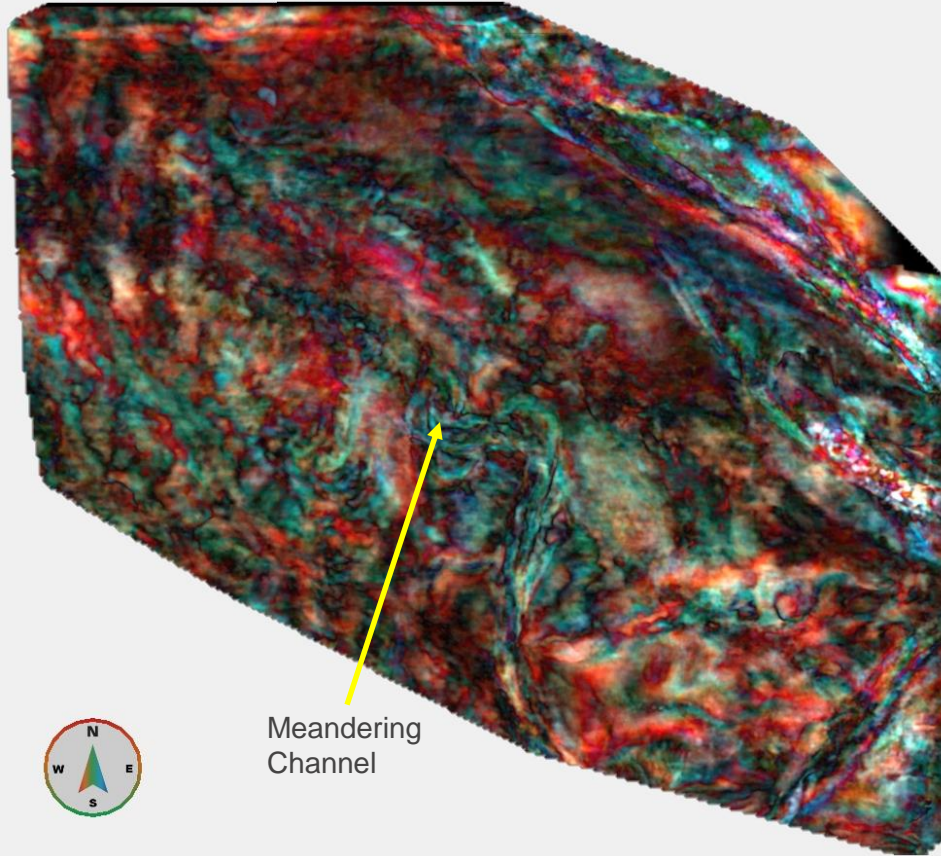
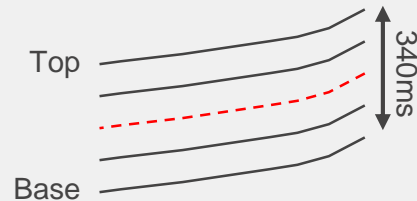
Reservoir Risk Reduction

- Interpreting stratigraphy within the Caracal prospect was difficult due to the structure and low continuity of events.
- Iso-proportional slicing was applied to create stratigraphically conformant surfaces between the top and base picks, from which the depositional setting could be interpreted.

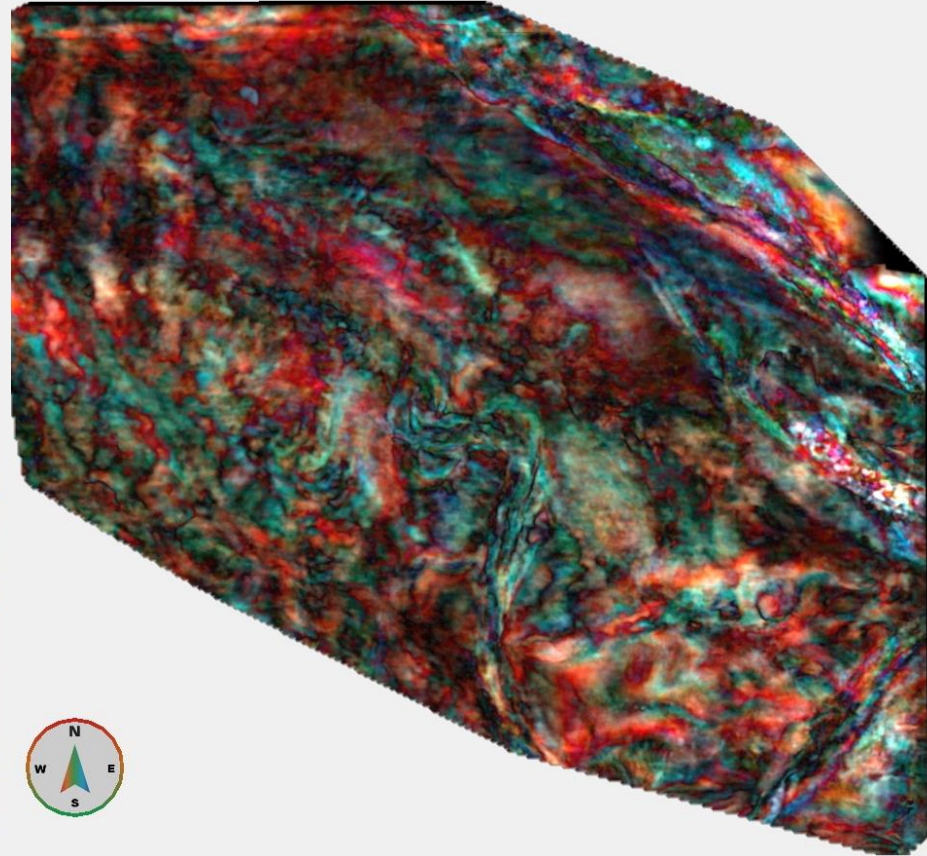
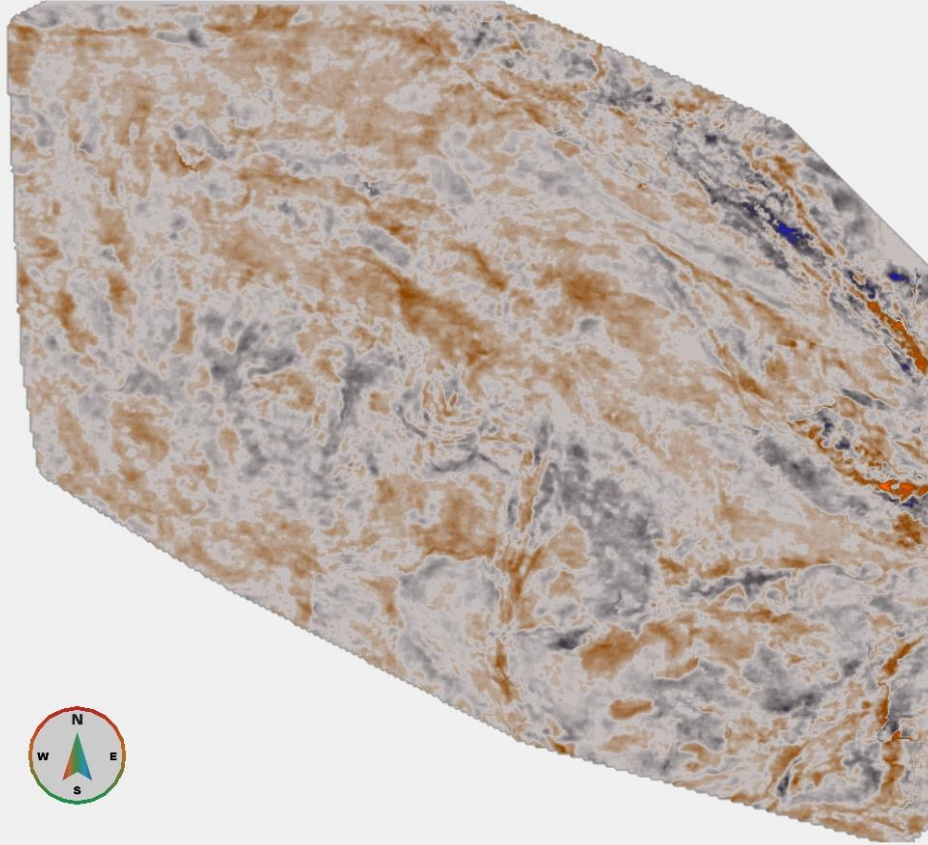


Reservoir Risk Reduction

- The internal stratigraphy and facies variations were more readily interpreted from the HD Frequency Decomposition and Iso-proportional Slicing, compared to amplitude interpretation alone.

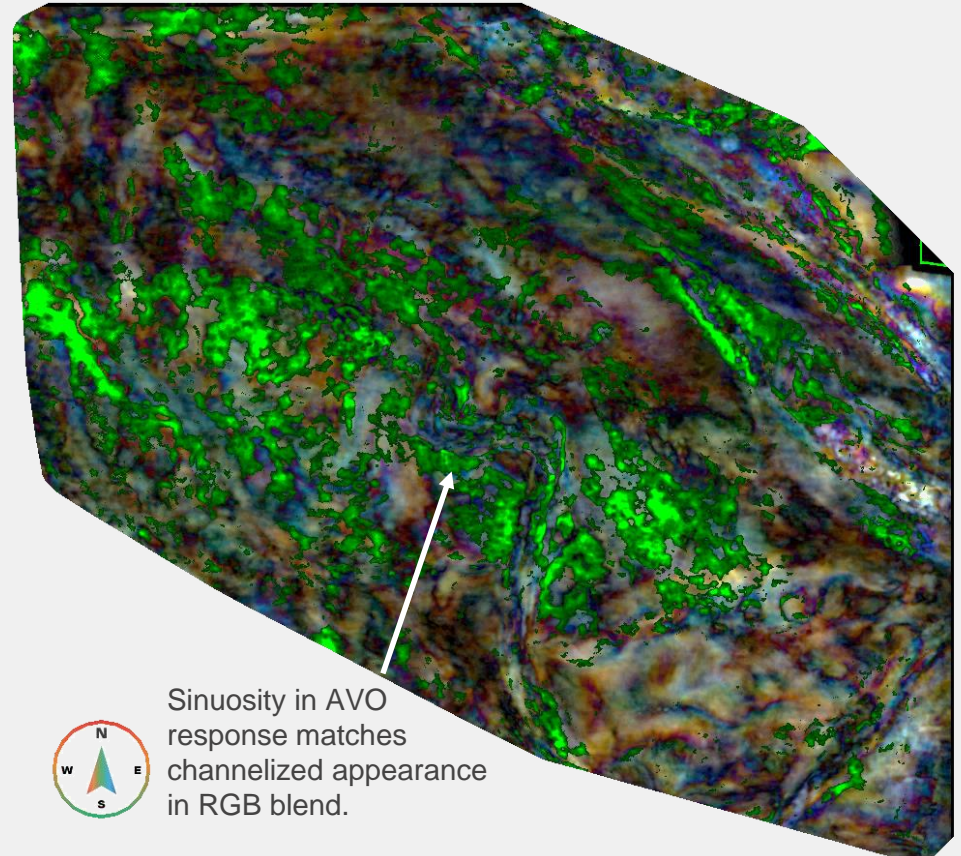
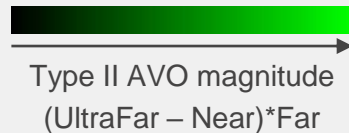


Increased understanding in deposition



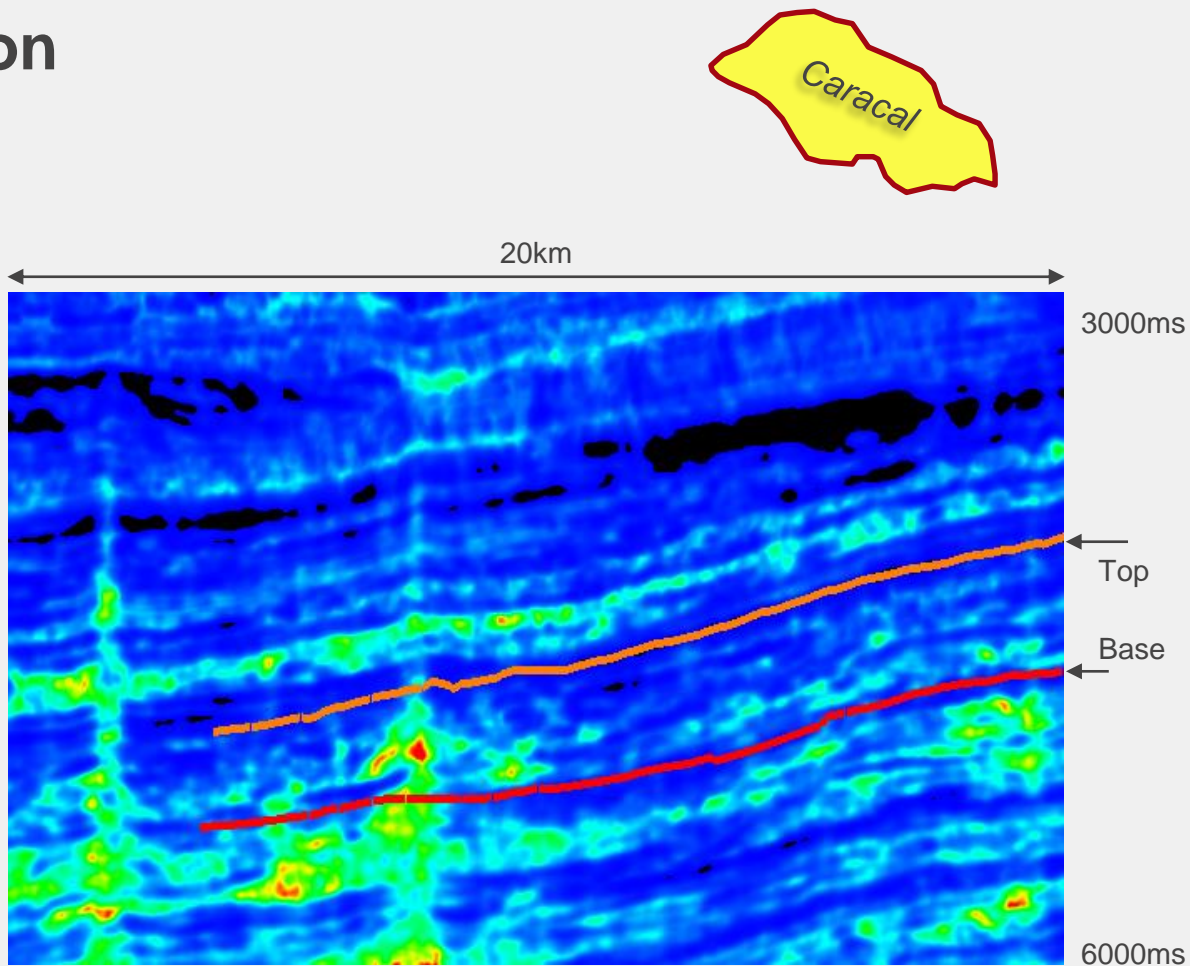
Reservoir Risk Reduction

- Geobodies highlighting the AVO response were opacity blended with the frequency decomposition results, to allow the relationship between fluid effect and stratigraphy to be interpreted.
- The integration of the data types allowed for more confident interpretation of the depositional setting and estimation of the presence of reservoir facies.



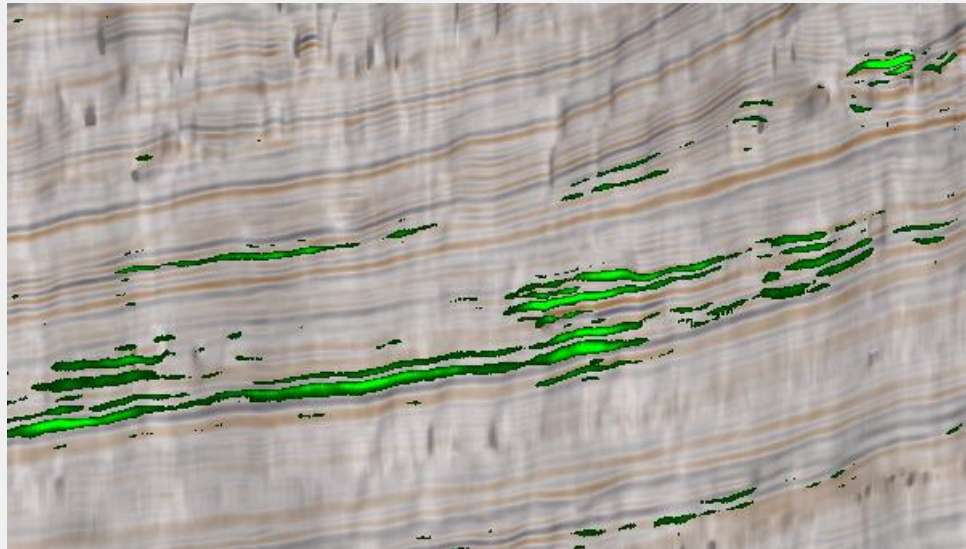
Charge Risk Reduction

- Proven petroleum system in the area
- Chaotic, vertical or sub-vertical chimneys are interpreted to be faults facilitating fluid movement.
- The Diapir attribute highlights the low amplitude, chaotic signatures allowing them to be interpreted with relationship to the prospect.

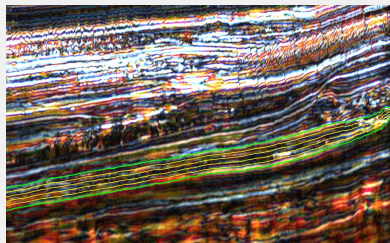


Trap Risk Reduction

- Trap is the critical risk for the Caracal prospect.
- Subtle, low relief inflections of structure are interpreted as small-displacement strike-slip faults that can act to trap accumulations.
- A detailed Dip attribute was calculated to highlight these trends, which are difficult to interpret from seismic.
- The interpretation confidence was aided by combination with AVO and the seismic data, using opacity blending.

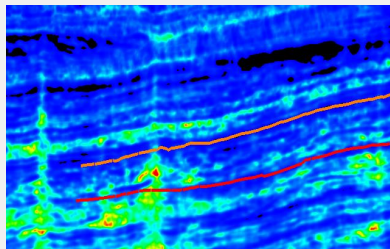


Caracal Risk Reduction



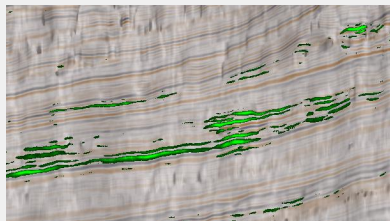
Reservoir risk:

- Reduced 10%



Charge risk:

- Reduced 15%



Trap risk:

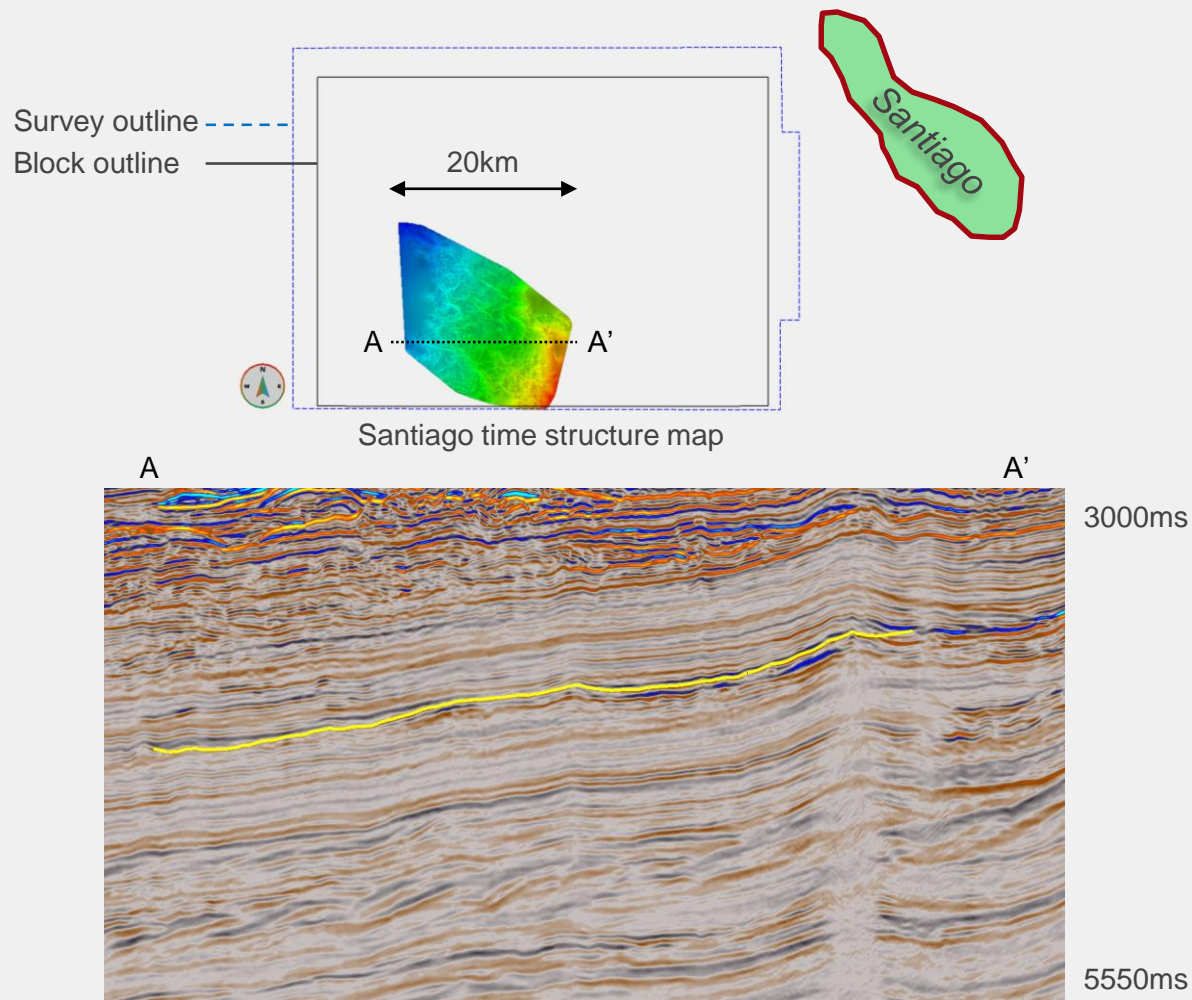
- Reduced 15%

Cumulative Risk Reduction:

- 12% increase to geological probability of success
- The improved interpretation allowed the prospect to be subdivided into 'A' and 'B' sections

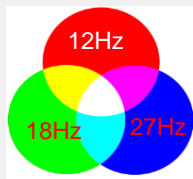
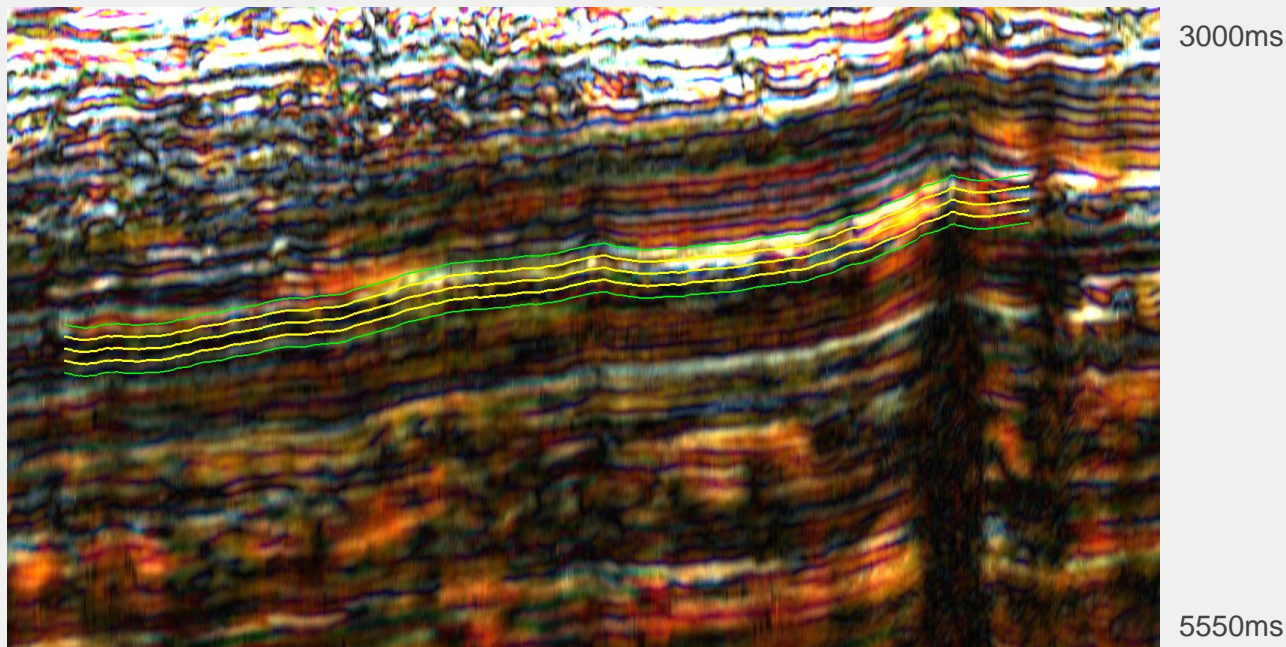
Santiago Prospect

- No AVO support
- 4230ms mean time
- Average thickness 55m
- Channel or crevasse splay



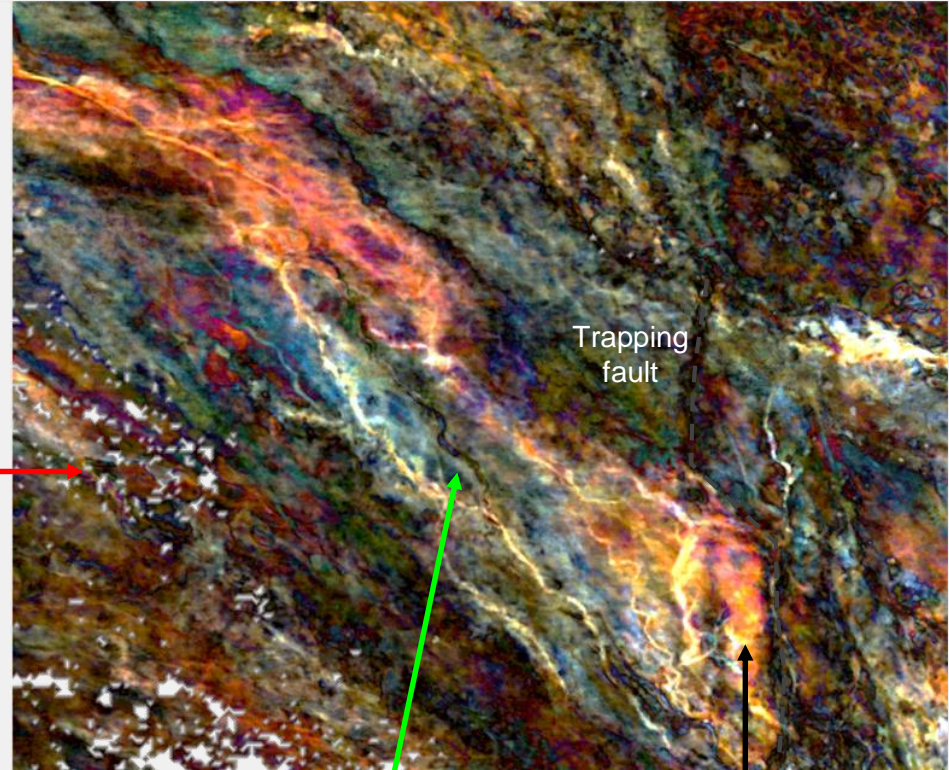
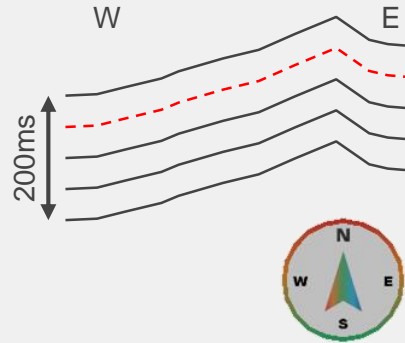
Reservoir Risk Reduction

- High Definition Frequency Decomposition and Iso-proportional slicing were applied again to better delineate the prospect stratigraphy.



Reservoir Risk Reduction

- The Iso-proportional Slicing reveals the channelization pattern in the interval immediately below top prospect.

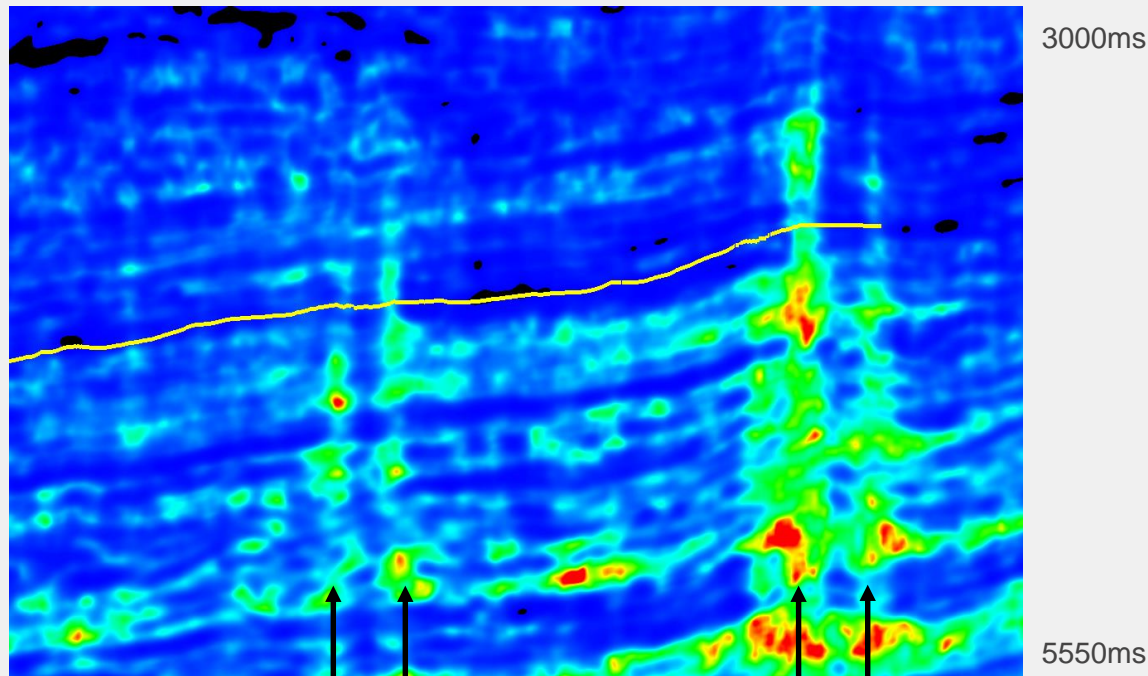
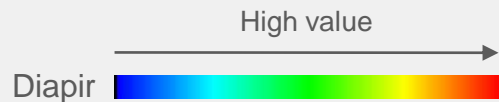


Abandoned
channel

Amplitude
anomaly

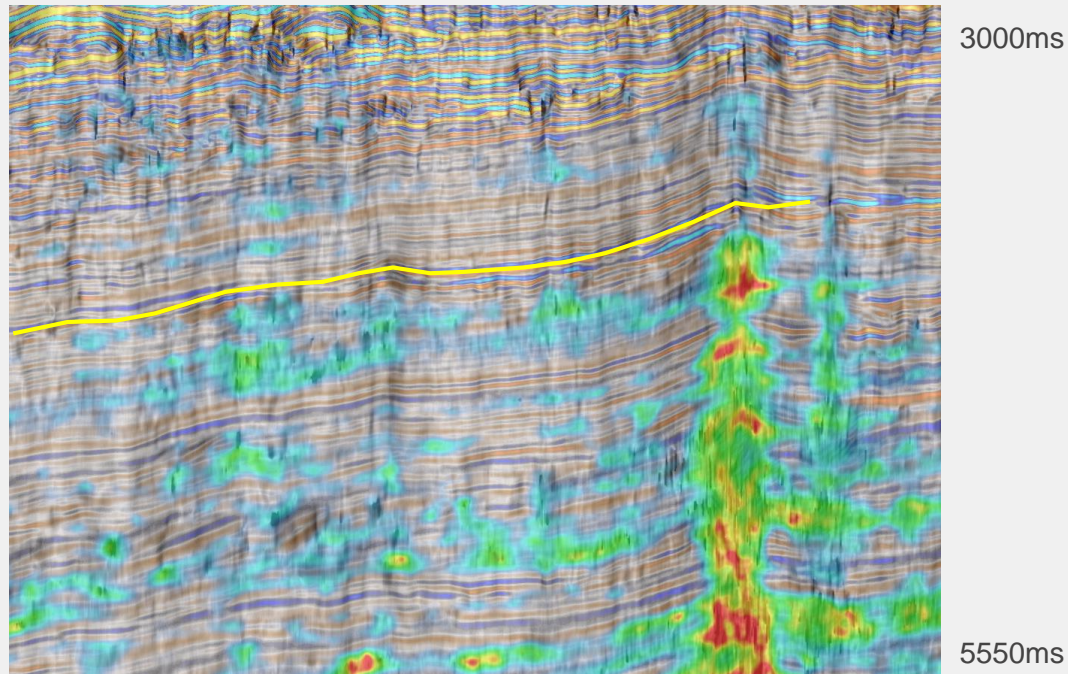
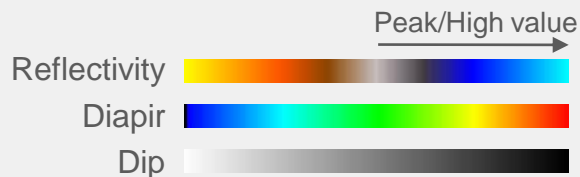
Charge Risk Reduction

- The Diapir attribute was used to identify the locations and extents of vertical columns of seismic incoherency, indicating potential migration.
- One column is interpreted to exploit a fault that controls the crest of the structure, but others can be interpreted to charge the prospect.

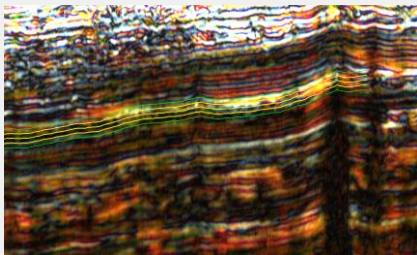


Trap Risk Reduction

- The trap at Santiago is interpreted to be a subtle, low relief strike-slip fault manifesting in a shallow anticline.
- The interpreted migration column appears to baffle at top prospect, suggesting it may trap vertically. The localized amplitude anomaly indicates the fault may trap laterally.

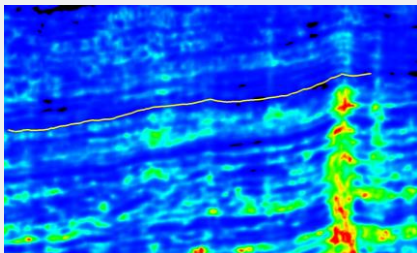


Santiago Risk Reduction



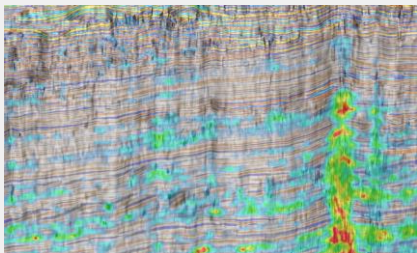
Reservoir risk:

- Reduced 10%



Charge risk:

- Unchanged



Trap risk:

- Reduced 10%

Cumulative Risk Reduction:

- 9% increase to geological probability of success

Conclusions

- The Cognitive Interpretation workflow provided results that significantly improved confidence in the interpretation of risk elements for the Caracal and Santiago prospects.
 - High Definition Frequency Decomposition and Iso-proportional slicing revealed the stratigraphy in greater detail than seismic amplitudes, increasing the confidence of encountering reservoir.
 - Charge for each of the prospects was interpreted from the Diapir attribute, which captured the morphology of the migration columns towards prospect level.
 - Structural attribute analysis highlighted pervasive, subtle inflections of structure that were interpreted as low-relief strike slip faults with little displacement, and ambiguous or invisible to see from the original seismic data.
 - A key element of the success of this project was to integrate several different types of information, AVO analysis, depositional and structural volumes.
- The end result was a reduction of cumulative risk for both Caracal and Santiago prospects, an increase to the risked reserve estimates, and an overall better understanding of the subsurface and play elements in this frontier exploration area.

Thank you.

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PanAtlantic Exploration

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