Seismic Interpretation of The Exmouth Plateau, North Carnarvon Basin, Australia: An Application of Data Conditioning, Seismic Attributes, and Self-Organizing Map on 2D Data

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Summary

In the last 15 years, 3D data have become commonplace in seismic interpretation. However, 3D seismic survey are often limited in size (at most ~100-km-long), thus insufficient for regional mapping of features that are hundreds to thousands of km in length. Such 3D surveys are often accompanied by previously acquired 2D regional lines. Yet, due to the 2D nature and older acquisition technique, these 2D lines are usually of lower quality and contain more noise than the associated 3D data. In this project, we improve seismic image quality, identify regional features and local anomalies, and analyze seismic facies that are potentially related to hydrocarbon production in the Exmouth Plateau, North Carnarvon Basin, Australia, by simultaneously applying data conditioning, seismic attribute calculation, and Self-Organizing-Map (SOM) classification to multiple vintage 2D lines.

Introduction

The North Carnarvon Basin is a major hydrocarbon reserve in Australia (Chongzhi et al, 2013). It can be divided into sub-basins (Figure 1). Among these sub-basins, the Exmouth Plateau is the largest and cover most of the major gas fields. Thanks to such a prolific amount of hydrocarbon reserve, numerous seismic surveys have been acquired over the area. Most of the 3D surveys, however, are small (<5000 km^2) and concentrate around known reservoir locations. This leaves 2D data the only feasible choice to study regional features and to explore new area that has not been covered by 3D data.

Our project involves 55 lines forming a rectangular grid, spanning an area of ~40000 km^2 in the center of the Exmouth Plateau (Figure 1). Unfortunately, those 2D lines were acquired many years before the 3D surveys and thus have lower image quality. Our goal is to improve seismic interpretation of these 2D lines via data conditioning, seismic attributes, and SOM classification in order to have a better understanding of the regional geology as well as local hydrocarbon-related facies.

Geologic Settings

In general, the North Carnarvon Basin has a geologic history of a passive margin with multiple stages of extension, subsidence, and late minor inversion that involve NE-SW trending faults (Tellez Rodriguez, 2015). The main source rocks of the Exmouth Plateau are the Locker Shale, deposited in early Triassic. The Mungaroo fluvio-deltaic formation (middle-late Triassic) and the Flag sandstone of the

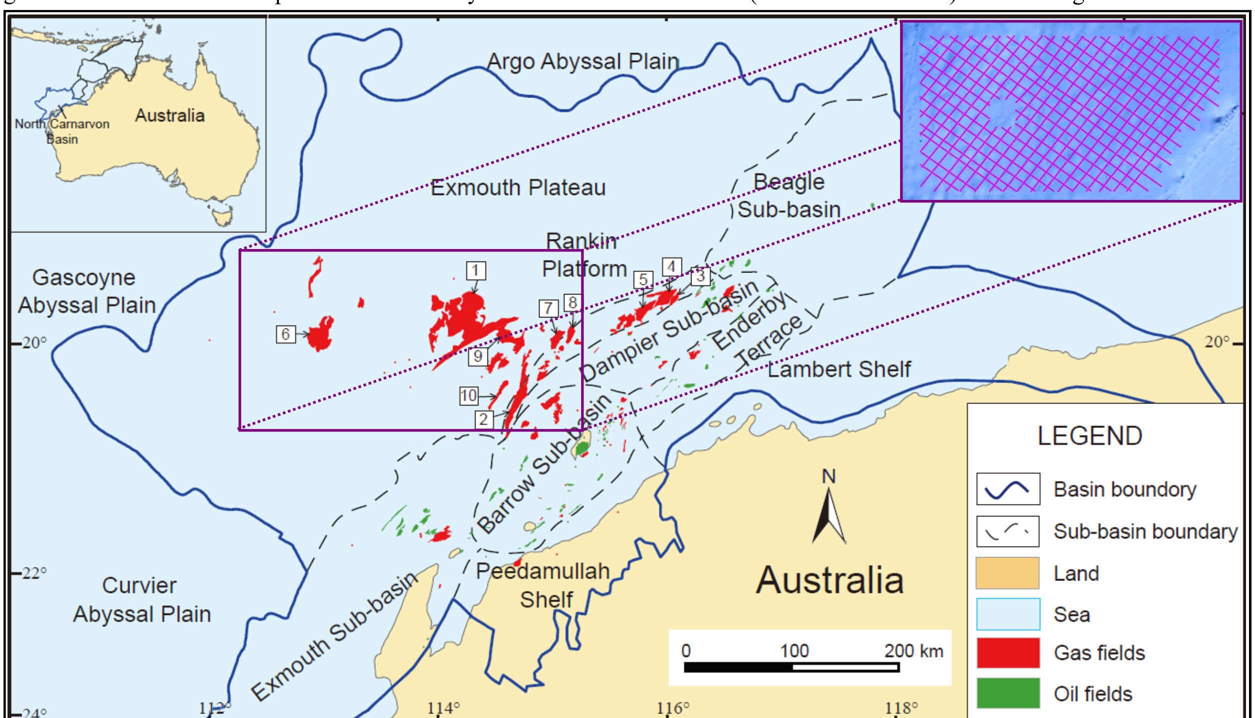

Figure 1. North Carnarvon Basin, Australia (Modified from Chongzhi et al). The study area consists of 55 2D seismic lines forming a rectangular grid at the center of the Exmouth Plateau, where most of the major gas fields are located.

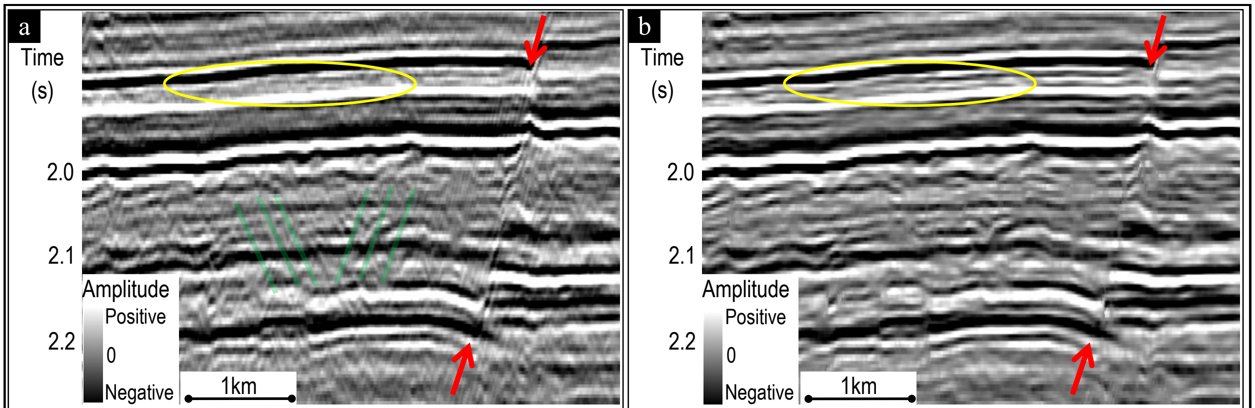

Figure 2. Seismic image (a) before and (b) after data conditioning. Reflectors are clearer and better resolved (yellow ellipse), faults are sharper (red arrows), and cross-cutting migration artifacts (green lines) are suppressed in the seismic image after spectral balancing and structure-oriented filtering.

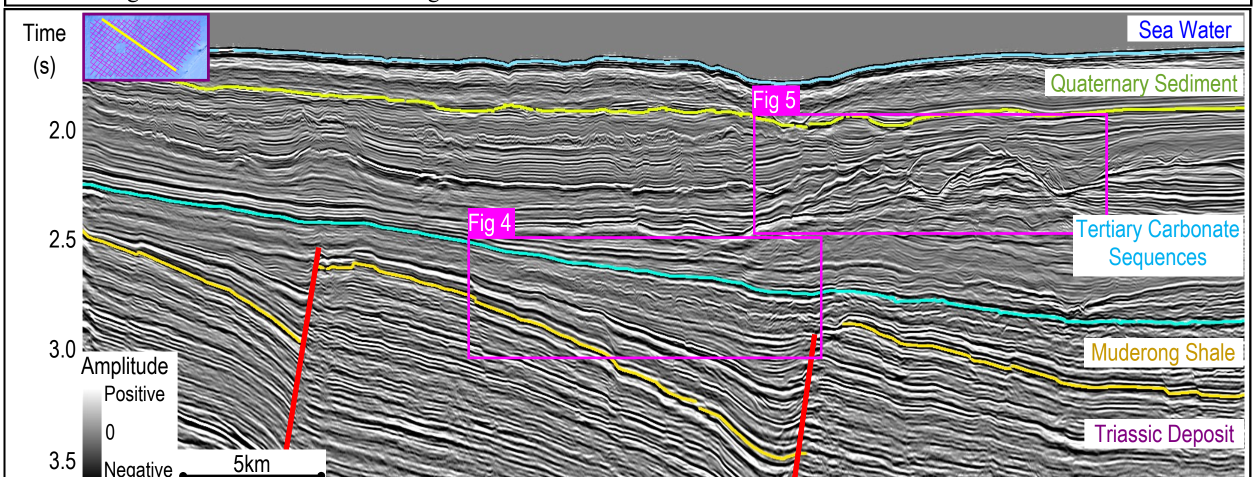

Figure 3. A representative portion of a 2D seismic profile in our project, with interpreted events. Major faults (red lines) terminate against the top of the Muderong shale, consistent with post-rifting subsidence configuration of the area in middle Cretaceous. MTCs within the Muderong shale and Tertiary carbonate are chaotic, exhibiting low coherency (Figure 4). Within the carbonate sequences, wavy pattern of turbidite channels can be observed, exhibiting strong negative curvature (Figure 5).

Barrow delta (early Cretaceous) are the main reservoir rocks. During middle Cretaceous, post-rifting subsidence enables a thick deposition of the transgressive Muderong shale throughout the entire basin, which act as a regional seal (Chongzhi et al, 2013). During the Tertiary, the Australian Plate drifted northward to warmer tropical zones, facilitating development of carbonate sequences, including the Mandu Limestone formation (Smith, 2014).

Methods

To improve seismic image quality, we follow Hutchinson et al's data conditioning workflow (2016) and apply spectral balancing to the data, followed by an edge-preserving structure-oriented filtering (Zhang et al, 2016). Figure 2 compares seismic vertical profiles before and after data conditioning. Thin layers are more resolved, cross-cutting migration artifacts are suppressed, while faults are sharper, enabling us to have an over-all better interpretation. To perform seismic facies analysis, we compute seismic attributes, including coherence, envelope, and structural curvature, and then input those attributes into SOM automatic classification (described in detail by Zhao et al, 2016).

Results

A representative portion of 2D seismic data with interpreted events is shown in Figure 3. Most of the deeper faults (below 2.5s time-depth) terminates within the Muderong shale, consistent with the post-rifting tectonic setting during the Cretaceous. Within the Muderong shale and upper sequences, mass transport complexes (MTCs) that exhibit

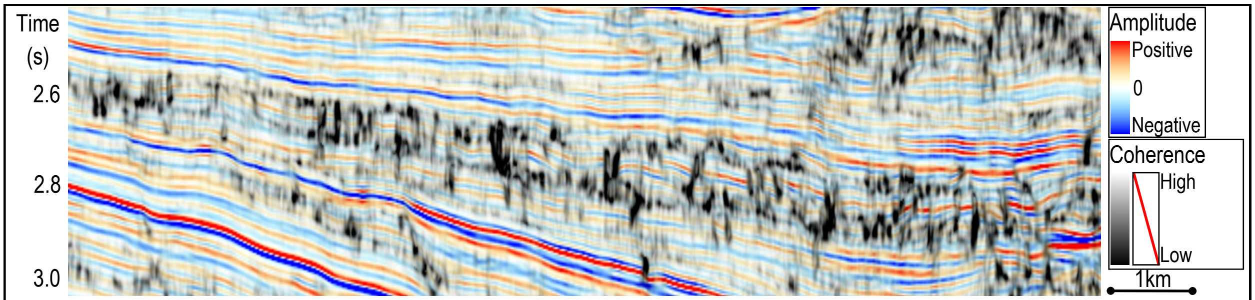

Figure 4. Co-rendered coherence and seismic amplitude profile of the region containing Mass Transport Complexes (MTCs). Seismic amplitude is plotted in red-white-blue color scheme. These MTCs are chaotic, exhibiting low coherency, and are tens-of -kilometers wide. We found MTCs both within the Muderong shale and the upper carbonate sequences.

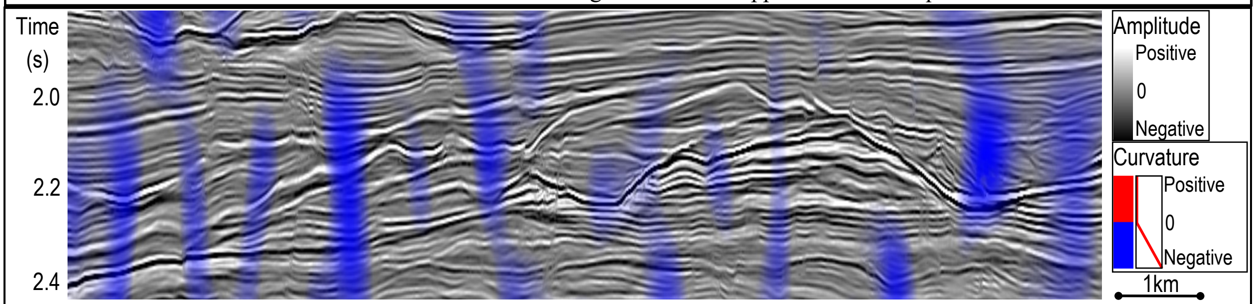

Figure 5. Co-rendered negative curvature and seismic amplitude profile of the region containing turbidite channels. Highly negative curvature values corresponds to channels' axes, similar to Wallet's observations (2016). These channels have thickness ranging from 20 to 100ms (equivalent to ~ 25-125m for v=2500m/s) and half-width ranging from 0.5 to 1.5km.

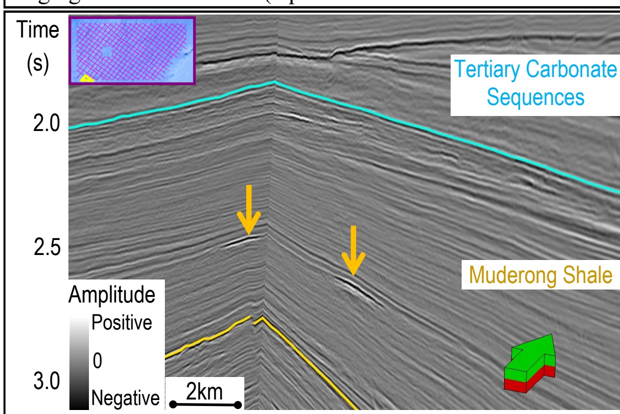

Figure 6. 3D perspective view showing perpendicular seismic amplitude profiles at the SW corner of the study area. Orange arrows point to two amplitude anomalies within the Muderong shale. These anomalies are apparently 2-km-long. We interpret these anomalies as bright spots that could be potential gas-charged reservoirs.

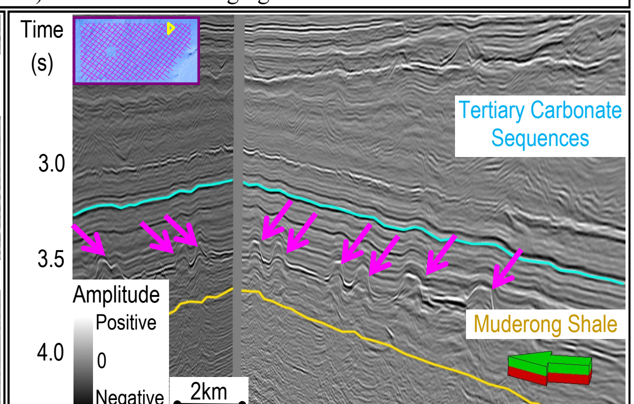

Figure 7. 3D perspective view showing perpendicular seismic amplitude profiles near the NE corner of the study area. Pink arrows point to multiple dome-shaped features (~1km apparent width) within the Muderong shale. These domes are possibly carbonate mounds developed in the middle Cretaceous that could be potential reservoirs if filled with organic material.

chaotic texture on amplitude profile can be easily seen on coherence profile (Figure 4). On top of the Muderong shale, wavy pattern of channels can be observed, which corresponds to turbidite channels within a carbonate shelf as described by Wallet (2016). These channels exhibit strong negative curvature at their axes (Figure 5). Near the SW corner of the survey, we notice two bright spots within the Muderong shale, which could be potential gas-charged reservoir (Figure 6). In the NE corner of the survey, several dome-shaped features emerge within the Muderong shale (Figure 7). We interpret these domes as carbonate mounds formed during the middle Cretaceous. If they are filled

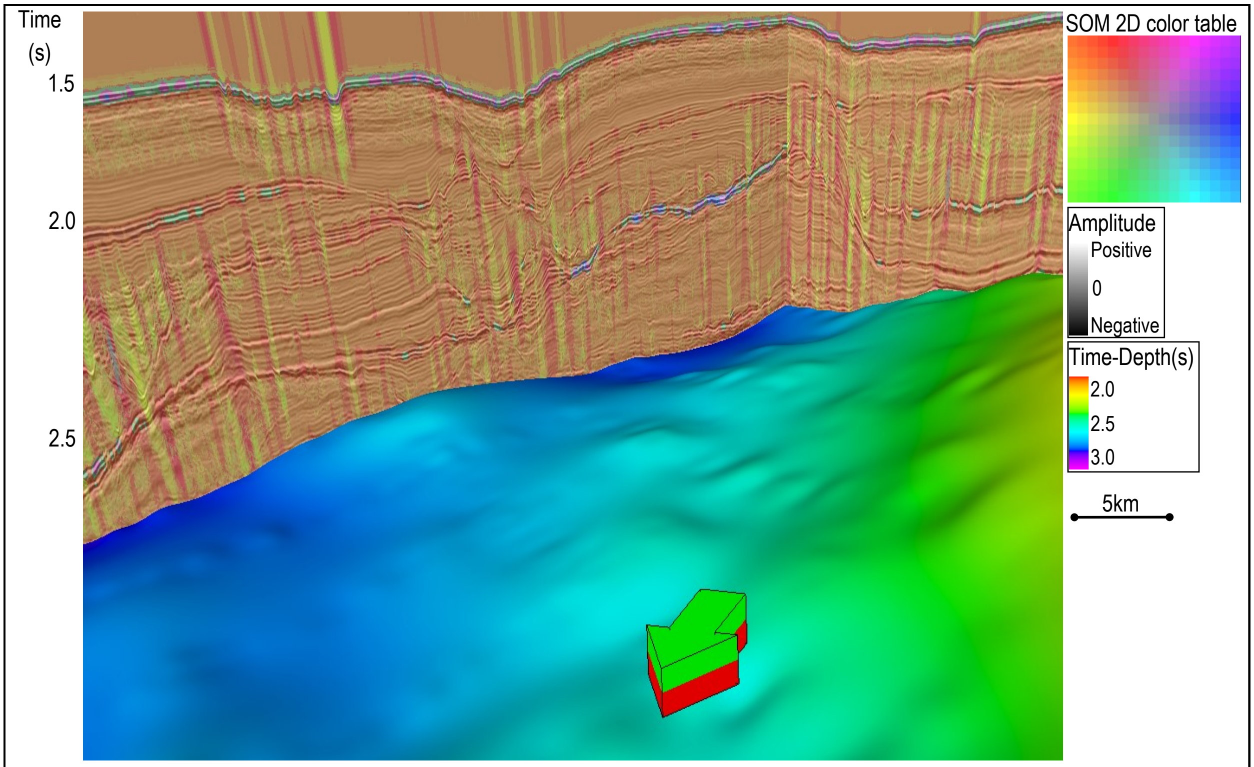

Figure 8. 3D perspective view showing two profiles of co-rendered SOM results and seismic amplitude, along with the top Muderong shale horizon. Bright yellow color corresponds to concave channels. Gold color corresponds to chaotic MTCs. Green, blue, dark red, and purple colors corresponds to bright, coherent reflectors.

with organic material, these mounds could be potential reservoirs.

Lastly, we present a 3D perspective view composed of two profiles of SOM output and a time-structure surface of the top Muderong shale in Figure 8. The top Muderong shale can be easily traced across all lines, further confirming the widespread deposition of transgressive shale during the middle Cretaceous. Each color of the SOM represents a different combination of coherency, amplitude envelope, and structural curvature. Bright yellow color corresponds to concave channels. Gold color corresponds to chaotic MTCs. Green, blue, dark red, and purple colors corresponds to bright, coherent reflectors.

Conclusions

By applying data conditioning to the 2D data, we are able to improve seismic image quality. Seismic attributes, including coherence, envelope, and structural curvature, help us interpret regional geological features (such as the widespread Muderong shale and the turbidite channels within the Mandu limestone formation), as well as local anomalies (such as bright spots and carbonate mounds). Analysis of seismic facies, including MTCs and turbidite channels, can be accelerated with the aid of SOM classification.

Acknowledgements

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