PS Seismic Facies Classification and Characterization of Deep Water Architectural Elements: A Case Study in North Carnarvon Basin Australia*

Jerson J. Tellez[1] and Roger Slatt[1]

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Please see closely related article "Seismic Geomorphology and Characterization of Deep Water Architectural Elements and its Applications in 3D Modeling: A Case Study in North Carnarvon Basin Australia", Search and Discovery article #42097.

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Abstract

The North Carnarvon Basin in Australia is one of the most prolific basins developed for oil and gas potential in Australia in the last 10 years. This is a premier basin where important hydrocarbon fields have been found. While the 10 most significant oil and gas fields fall within the Triassic Brigadier Formation in the Rankin Platform Sub-Basin, there is significant oil and gas potential in the deep water Cenozoic deposits. Our goal is to characterize the dimensions and composition of the depositional element that provide a better estimation of the potential of those reservoirs.

Analysis of a high resolution 3D seismic volume from the Cenozoic Trealla Formation in the offshore of North Carnarvon Basin, Australia has revealed fine details of deep water architectural elements. A model-based inversion combined with the use of self-organized maps (SOM) allows the characterization of the architectural elements including seismic facies dimensions and position on slope. Four main groups of architectural elements were identified in the studied area: (1) erosive channel-fills, (2) channel-levee complexes, (3) mass transport deposits, and (4) sand fan lobes or sheets. Each depositional element exhibits a characteristic morphology and seismic response according to the lithology predominant in each architectural element. Seven attributes including acoustic impedance, dip magnitude, peak frequency, energy ratio coherence, peak magnitude and curvature are used as input for the classification. This classification technique preserves the distance information from input space into the SOM latent space. The result is a better defined clusters that when plotted against a 2D color bar clearly allow the identification of geomorphologies and facies.

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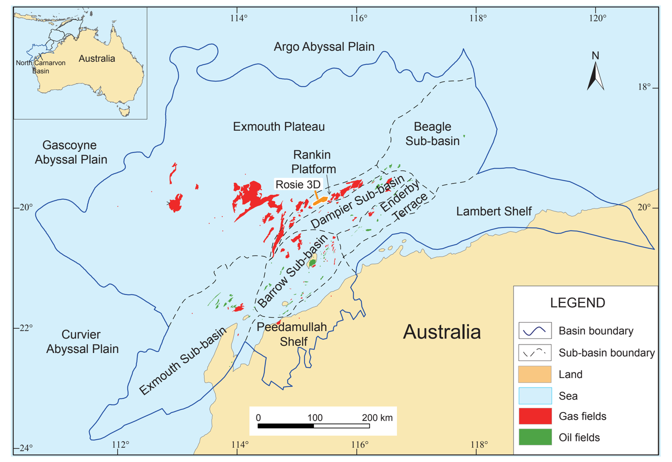
Abstract

The North Carnarvon Basin in Australia is one of the most prolific basins developed for oil and gas potential in Australia in the last 10 years. This is a premier basin where important hydrocarbon fields have been found. While the 10 most significant oil and gas fields fall within the Triassic Brigadier formation in the Rankin Platform subbasin, there is significant oil and gas potential in the deep water Cenozoic deposits. Our goal is to characterize the dimensions and composition of the depositional element that provide a better estimation of the potential of those reservoirs.

Analysis of a high resolution 3D seismic volume from the Cenozoic Trealla formation in the offshore of North Carnarvon basin, Australia has revealed fine details of deep water architectural elements. A model-based inversion combined with the use of self-organized maps (SOM) allows the characterization of the architectural elements including seismic facies dimensions and position on slope. Four main groups of architectural elements were identified in the studied area: (1) erosive channel-fills, (2) channel-levee complexes, (3) mass transport deposits, and (4) sand fan lobes or sheets. Each depositional element exhibits a characteristic morphology and seismic response according to the lithology predominant in each architectural element. Seven attributes including acoustic impedance, dip magnitude, peak frequency, energy ratio coherence, peak magnitude and curvature are used as input for the classification. This classification technique preserves the distance information from input space into the SOM latent space. The result is a better defined clusters that when plotted against a 2D color bar clearly allow the identification of geomorphologies and facies.

Study Area and Tectonic and Stratigraphic Setting



To the left, the map shows the North Carnarvon Basin. It is located in the Northwest of Australia and it is composed by several sub-basins. This is the most prolific basin for gas production in Australia and one of the most prolific basins around the world. In red color are highlighted the gas fields found and exploited at 2015.

The area of study lies on the Ranking Platform sub-basin. The most prospective reservoirs are found in the Triassic Brigadier formation, in 10 significant oil and gas fields. Furthermore, significant oil and gas fields also have been found in late Cretaceous (Toolonga Fm) and late Paleocene (Dockerell Fm) strata. Remaining potential for Cenozoic units is still present. Most of the larger fields in the area are large accumulations of gas hydrocarbons (Janz-1). Therefore, the possibility of finding oil fields in the basin, considering a shallower target, could be explored if overburden, temperature and pressure were lower. In addition, deep water deposits formed during the Cenozoic provide petroleum systems large enough to accumulate significant amounts of hydrocarbons.

The North Carnarvon Basin extends about 535,000 square kilometers (Offshore Petroleum Exploration Acreage Release, 2014). The basin covers the continental plate boundary and is bounded to the north by the Argo Abyssal plain, to the west by the Gascoyne and the Cuvier Abyssal Plains, to the east by the Roebuck Basin and to the south by the southern Carnavon Basin and the Pilbara Craton. The landward area is composed of the Peedamullah shelf and the Lambert shelf. The outside of this basin involves the Ranking Platform and the Exmouth Plateau. The major structural elements identified offshore on the Exmouth Plateau are northeast-trending graben structures parallel to the coast line of the Northwest shelf (Chongzhi et al, 2012).

The geology of the Northwest Shelf is a consequence of multiple stages of extension, subsidence and later minor inversion, associated to the fragmentation of eastern Gondwana and followed by compression due to the collision of the Band arc and Australia during the late Miocene (Baillie et al., 1994)

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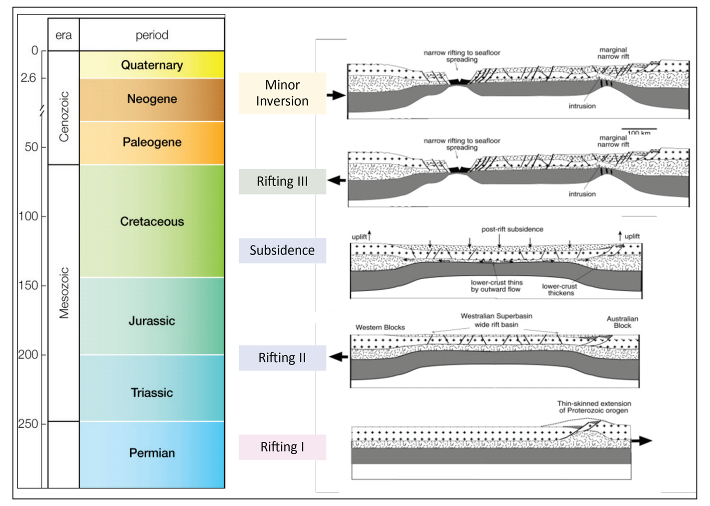
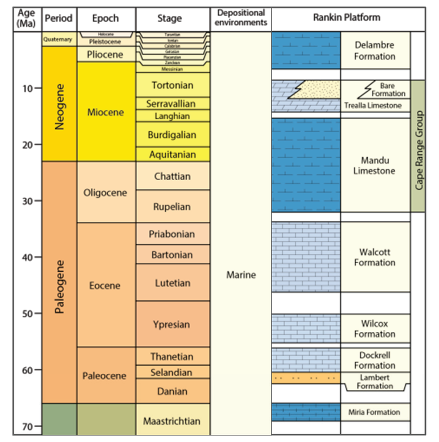
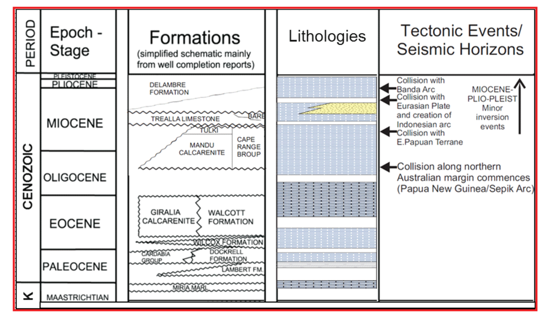


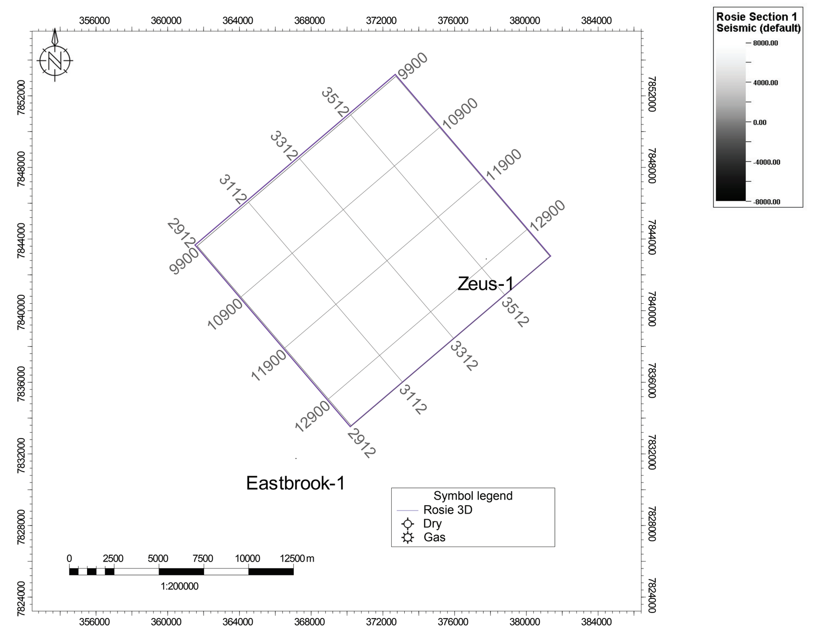


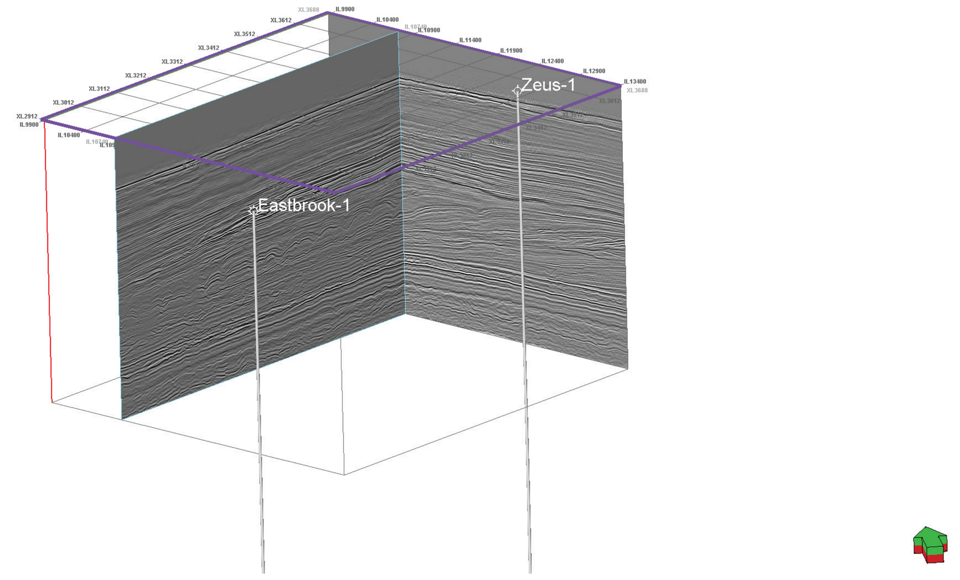


Modified from Cathro, 2002

The section studied corresponds to formations deposited during the Miocene. These sedimentary rocks were deposited after a major change from siliciclastic to carbonate sedimentation during late Cenozoic time in the North Carvarvon basin. In addition, driftting of the Australian Plate northward to lower latitudes from 36° and 40° South to its current position in 18° and 22° South, in tropical and more arid zones, facilitated carbonate sedimentation (Lawyer et al., 1999). This Oligocene carbonate sedimentation is described as a shallowing-upward, prograding carbonate shelf sequence (Arthorpe, 1998). These carbonate successions are named the Mandu limestone. After carbonate sedimentation, a large pulse of siliciclastic progradation occurred through the middle to late Miocene. This siliciclastic unit formed the Bare formation which is characterized by low angle cross bedding and it is considered a major progradational system that was deposited as a consequence of this increase of sediment into the basin. It is exhibit in several progradational wedges that were deposited on a calcareous ramp.

Data Available



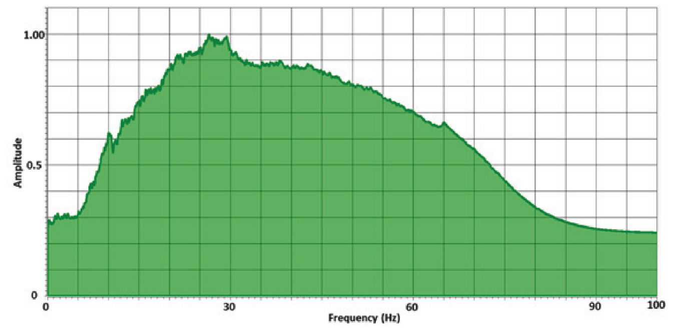


The study is based on seismic stratigraphic interpretation performed over the a section of the Rosie 3D volume, the integration with well log data, and attribute analysis.

The 3D seismic volume is part of a larger volume and it covers an area of 182 km^2. This data was acquired in November 1996 by Geco-Praka and processed between December of 1996 and July 1997 by Western Geophysics (Richardson, 2000).

Dominant frequencies of seismic data in the interest interval are 45-55 Hz.

Data provided includes gamma ray (GR), sonic (DT), density (RHOB) and photoelectric factor (PEZ) logs. Completion reports from two hydrocarbon exploration wells (Eastbrook-1, and Zeus-1) within the seismic volume were obtained from the Department of Mines and Petroleum, Australia. Information about additional wells was also obtained from the Department of Mines and Petroleum online database.



Methodology

Data Preparation → **Generate background information** → **Generate Horizon Cube** → **Sequence stratigraphy interpretation**

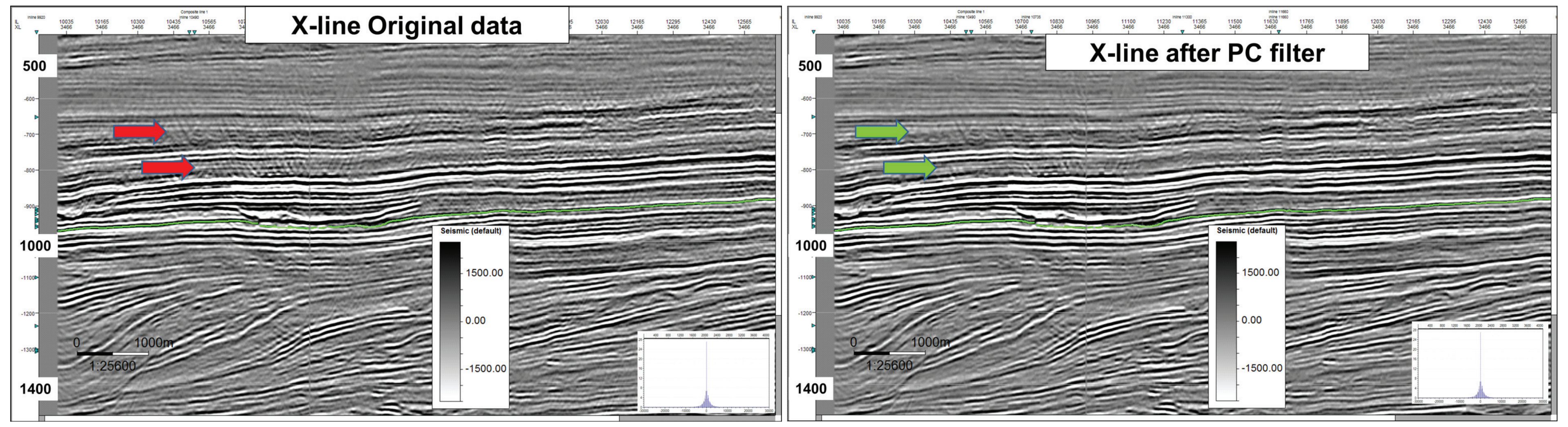
- Data Preparation:
  - Post-stack filtered seismic * (SOF)
  - Well tie
  - Hz interpretation
    - Top of the sequence
    - Middle sequence
    - Base of the sequence
- Generate background information:
  - Background Steering Cube
  - *Detailed Steering Cube
- Generate Horizon Cube:
  - 3D Horizon Cube
- Sequence stratigraphy interpretation:
  - Hight frequency system tracts identification and interpretation

*This processes are not mandatory and they can be simplified depending on quality of the information

Acoustic Impedance Inversion → **Seismic Attributes Calculation** → **Facies Classification** → **Facies and Architectural Elements Interpretation**

- Acoustic Impedance Inversion:
  - Chronostratigraphic generated horizons
  - Well log information
- Seismic Attributes Calculation:
  - Coherence
  - Dip Magnitude
  - Peak Frequency
  - Curvature K1
  - Energy Ratio
  - Amplitude
- Facies Classification:
  - Not linear related attributes
  - Principal Component
  - K-Means
  - Self Organizing Maps
- Facies and Architectural Elements Interpretation:
  - Facies identification and interpretation

Principal Component Filter

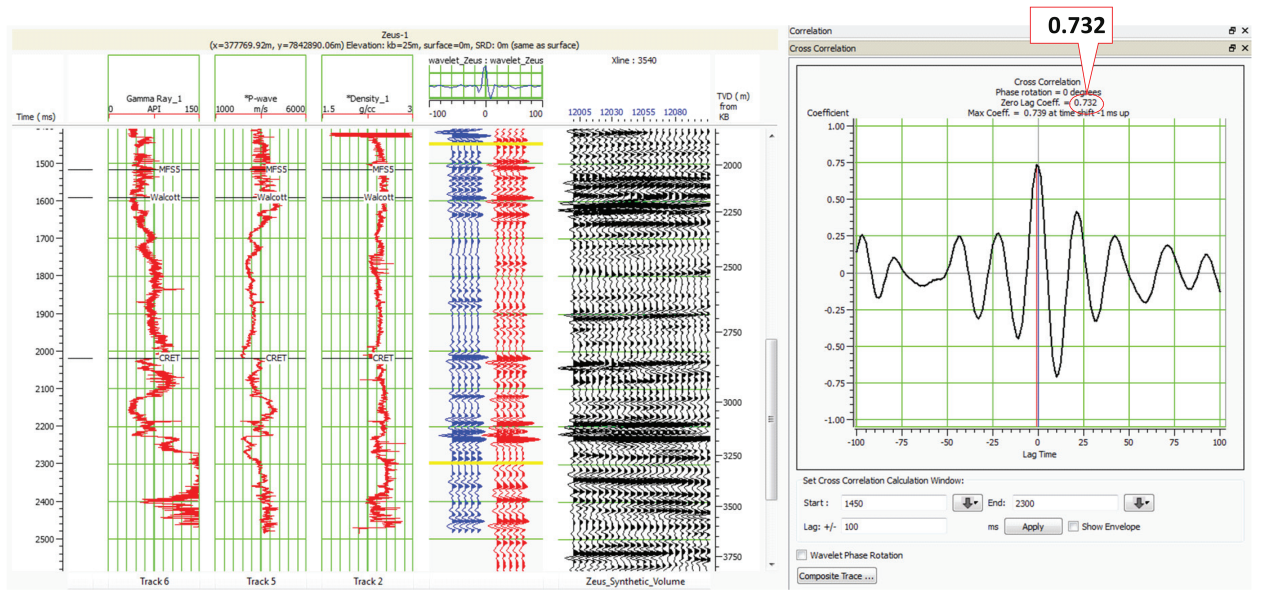


Eliminates migration artifacts

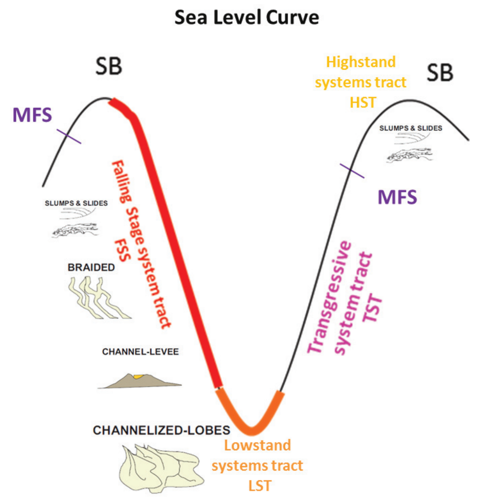
Improved image

Well Tie

- T-D well tied was performed in Hampson-Russel™ Software for three wells within the seismic volume
- Wavelet extracted from each well for improving correlation
- Correlation factor varies from 0.73 to 0.5



Depth Water Architectural Elements



PRINCIPAL ARCHITECTURAL ELEMENTS

SYSTEM TYPE	WEDGES	CHANNELS	LOBES	SHEETS	CHAOTIC MOUNDS
GRAVEL-RICH SYSTEMS		CHUTES			
SAND-RICH SYSTEMS		BRAIDED	CHANNELIZED-LOBES		
MUD/SAND-RICH SYSTEMS		CHANNEL-LEVEE	DEPOSITIONAL LOBES		SLUMPS & SLIDES
MUD-RICH SYSTEMS		CHANNEL-LEVEE	DEPOSITIONAL LOBES		SLUMPS & SLIDES

Interpretation was based not only on the Vail (1987) model but also on later systems considerations by Loucks (1993). The model proposed by Loucks (1993) considers mass transport deposits present within all systems tracts. .

Architectural elements were related to system tracts. Note MTD's are developed in FSST and HST considering a carbonate-siliciclastic system. Modified from Slatt, (2007)

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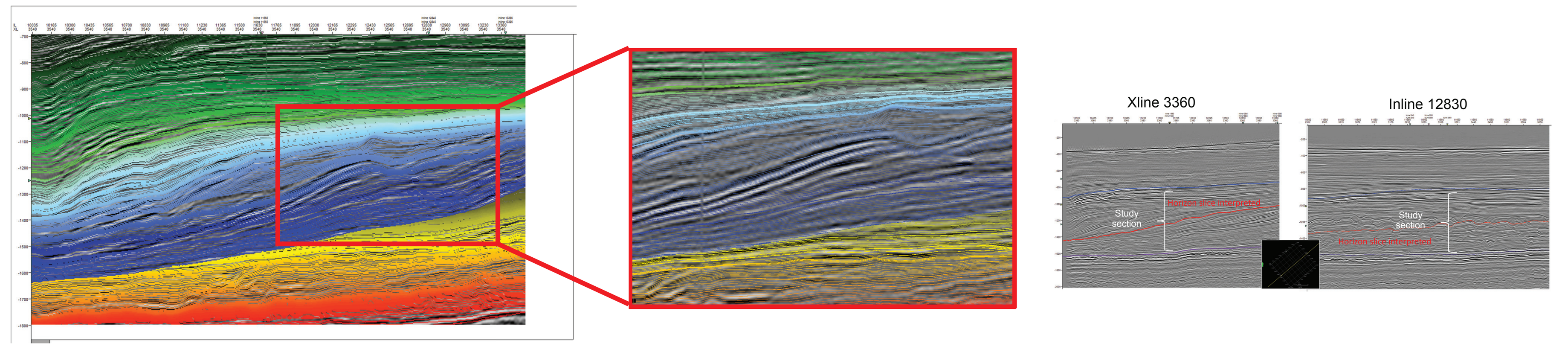
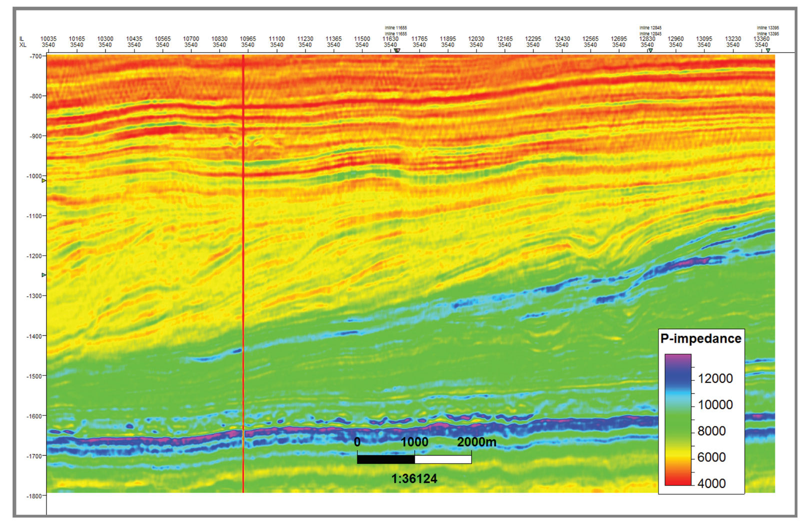
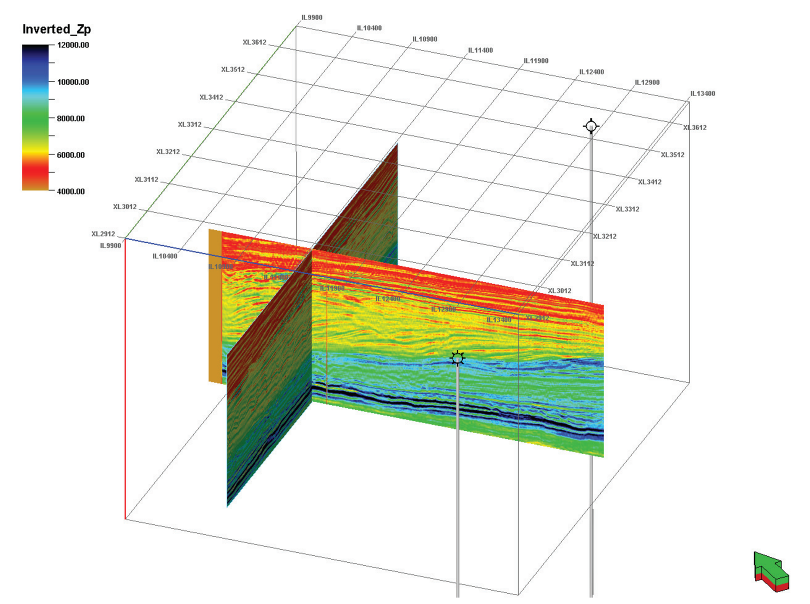
Horizon Cube Generation



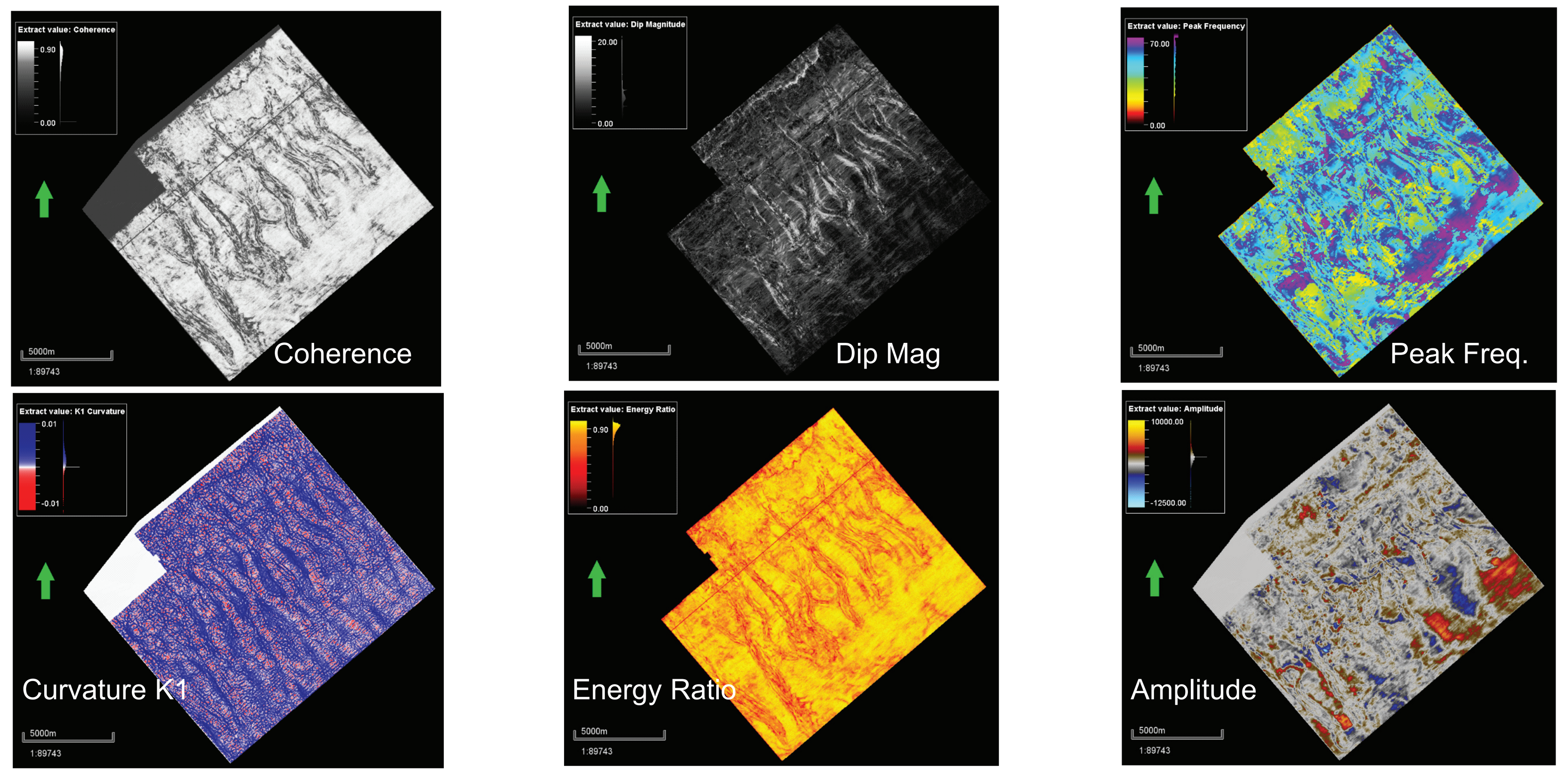
Horizon cube built to constrain the generated inversion model. Chronostratigraphic surfaces were generated using dip steering volume as source of the calculation. The resulting horizon surfaces follow pretty close the reflectors on the seismic information. These stratigraphic surfaces were used to build the low frequency model for the seismic inversion.

Acoustic Impedance Inversion



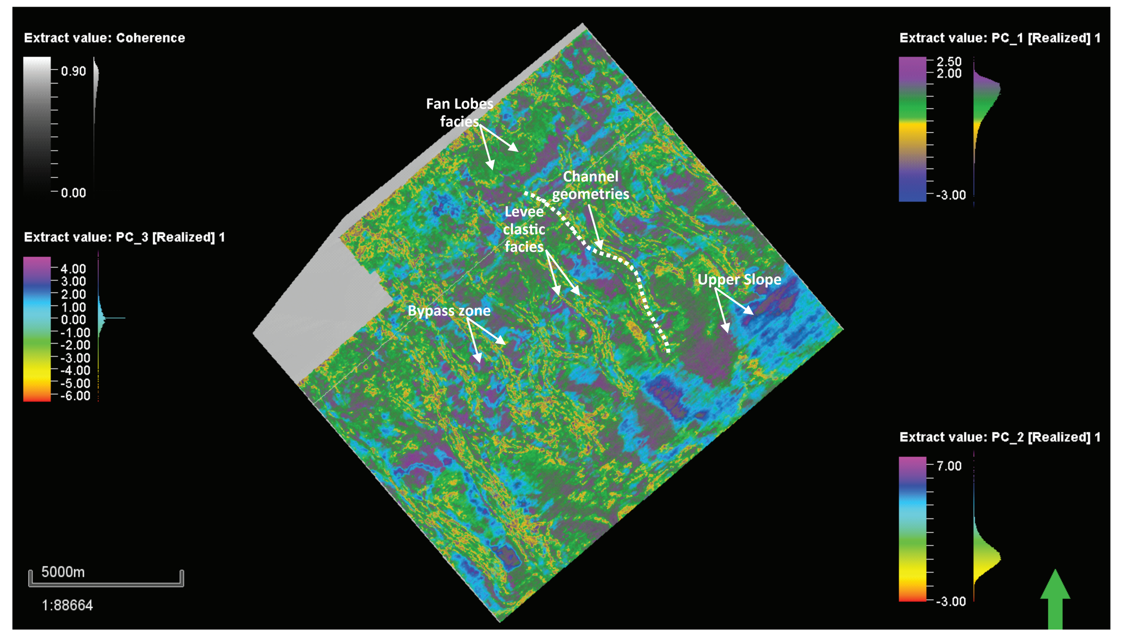


Seismic Attributes



Horizon slices though the studied section. The scope of this study is the integration of several of the characteristics exhibit from seismic attributes by using statistical aproaches in a quick seismic classification.

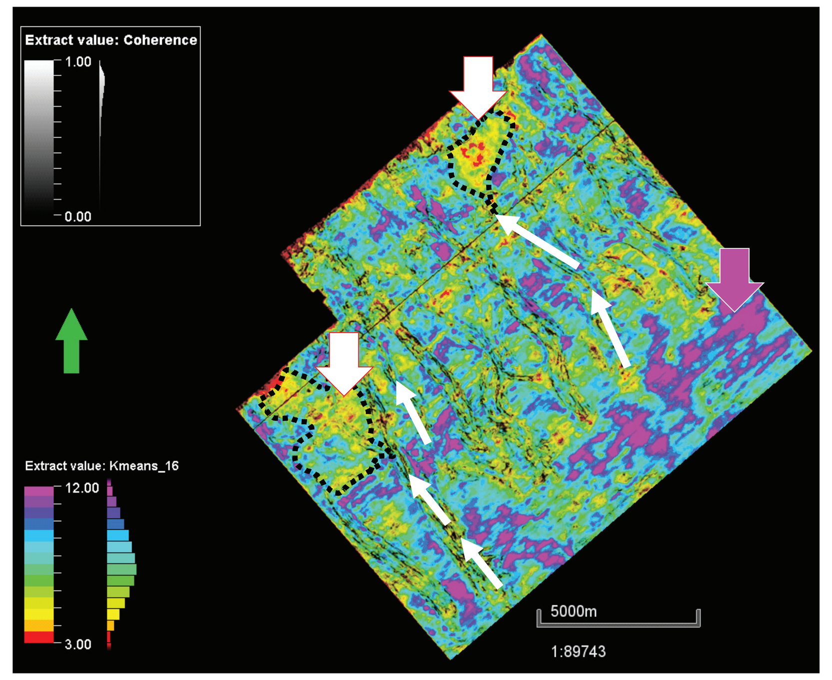
Principal Component Analysis



Combination of PC1, PC2 and PC3, allows a better interpretation of facies. The result is similar to the resulting image given for K-means technique. However, PC analysis allows a more detailed interpretation. First 3 PC's reflect the 80% of the variability of the data. That is why the remaining PC components were not used.

Eigenvalue no.	Variability percentage
PC1	43
PC2	19
PC3	17
PC4	13
PC5	7
PC6	1

K-Means



By using the combination of those attributes a K-means classification technique was used to identify facies.

Following parameters where used for classification:

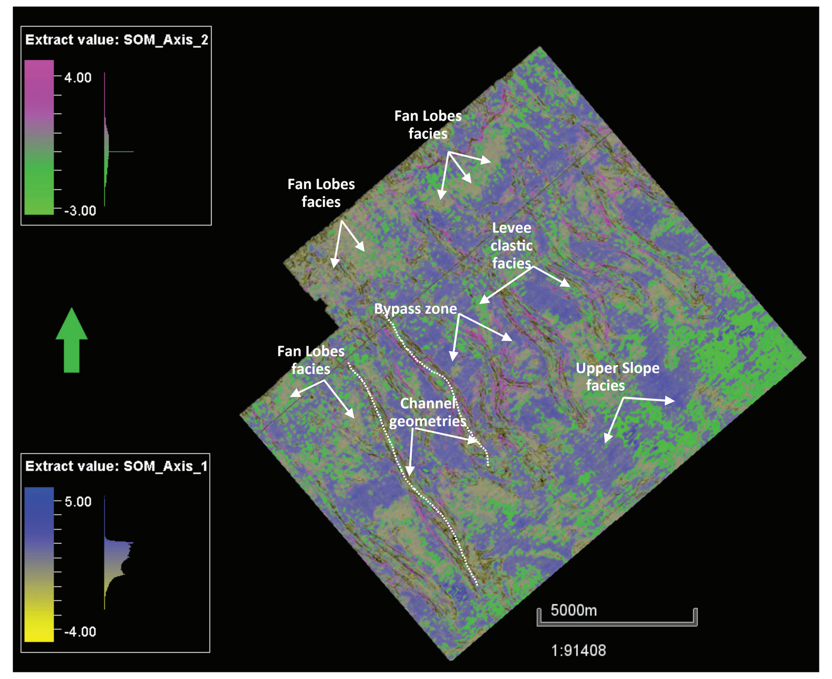
50 iterations

16 Cluster selected.

The resulting classification shows more information within clusters 3 to 12.

Purple zones are interpreted as calcareous platform. Yellow zones are interpreted as clastic deposits within the channels and forming small fan lobes.

SOM



SOM classification technique was used. The latent space was selected in a color scale of 256 colors for allowing visualization.

Parameters:

50 iterations

256 Cluster.

The resulting classification shows two main axis from the SOM analysis.

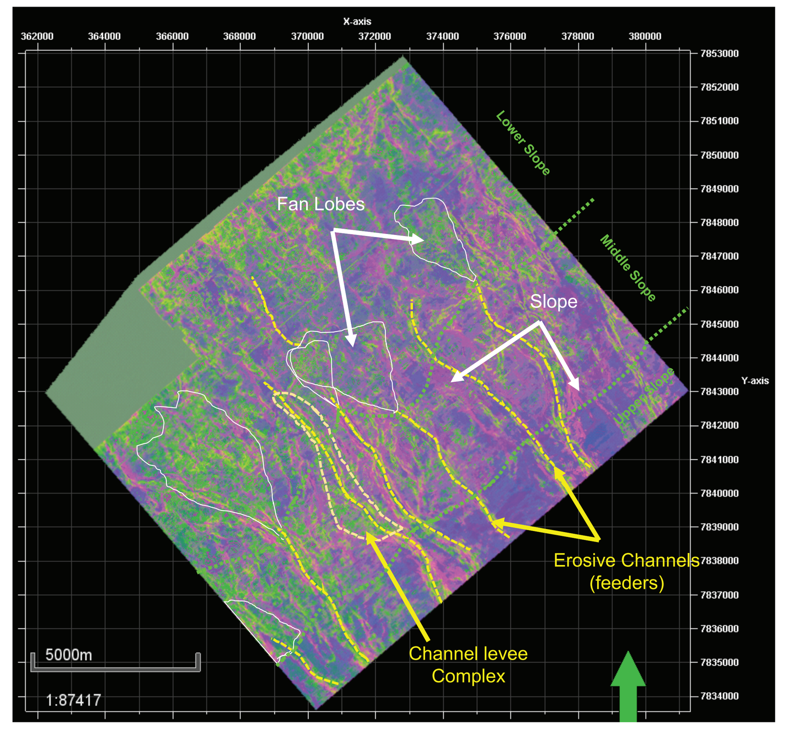
The combination of the output axis shows a detailed image of many clusters. This output offers a better understanding of the facies in this horizon.

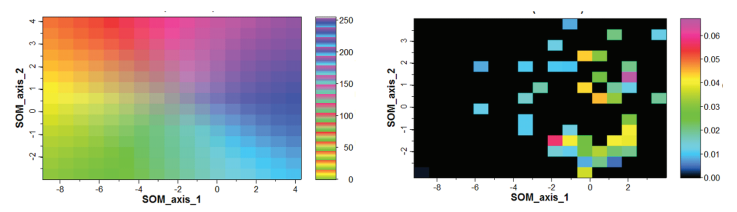
Yellowish features are interpreted as clastic related Fan lobes or levees.

Purple features are interpreted as calcareous features mainly platform.

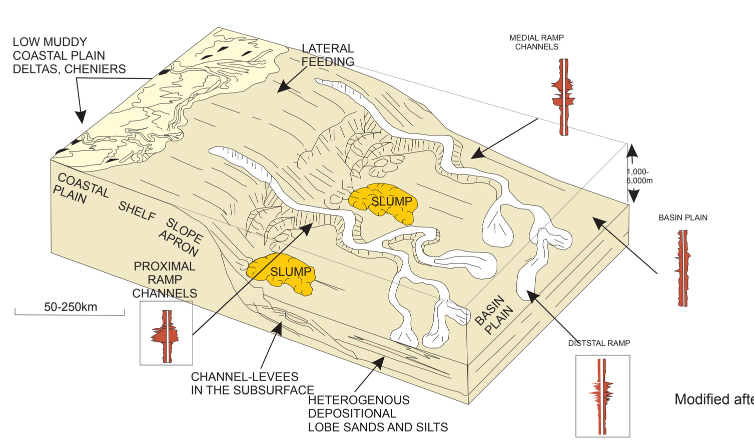
Reddish features could be related to muddy facies helping to determine limits in architectural elements.

Facies Interpretation





Submarine Ramp



Modified after Reading and Richards (1994)

Using multiple unsupervised statistical techniques different architectural elements can be identify on interpretation of horizon slices that represent chronostratigraphic surfaces.

Horizons used for interpretation were extracted from the resulting horizon cube generated using dip attribute volume. These generated horizons allow for a quick identification of key surfaces (sequence boundaries) within the volume .

The contrast in colors displayed by a two dimensional color palette allows the interpreter the identification of channelized features, lobes, and channel-levee associations.

The horizon slice shows an interpretation made on one of the extracted horizons.

Green dashed lines show divisions of the analyzed slope.

Upper slope, is characterized by erosive and straight channels .

Middle slope, exhibits more sinuous channel-levee systems. There is a contrast between the channelized feature and the associated levee possibly due to a change in lithological composition.

Lower slope, shows lobate shapes at the end of the channelized systems .Channel systems deliver the sediment basinwards and they are deposited in a more extensive area due to a gentle slope

Conclusions

Model based inversion improves the resolution of seismic adding low frequencies form information incorporated from well-logs

Horizon Cube (dGB is a powerful tool to improve the low frequency model built during the inversion model construction

Acoustic impedance extracted from inversion provides relevant information for interpretation of features not visible with standart seismic attributes.

The use of unsupervised statistical approaches like Principal Component Analysis, K-Means classification and Self Organized Maps provide a quick and reliable output for facies interpretation. This process usually takes longer time when only co-rendering of seismic attributes is used.

SOM looks to be the faster and most reliable classification technique in this case study. However, the combination of another seismic attributes can be used in order to obtain better results with the different classification techniques.

Aknowledgements

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