

# Extracting geological features from fine chronostratigraphic surfaces of the Late Jurassic-Cretaceous post-rift strata in the Dampier Sub-basin, NW Shelf of Australia

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## Abstract

The Dampier Sub-basin is an important hydrocarbon basin with significant oil and gas of the Northern Carnarvon Basin (NCB) in the North West Shelf of Australia. Late Jurassic syn-rift strata represent important reservoirs in several fields in the Dampier Sub-basin of the NCB. Understanding the depositional and structural systems is important in the hydrocarbon exploration to reduce risk. Commonly, petroleum-related geological features (e.g., paleochannels, faults) are extracted by performing seismic attributes at or near top formation surfaces. However, most surfaces are not always possible to present those features. This study applied geo-model grid method to create two hundred fine chronostratigraphic surfaces between key formation surfaces within the Late Jurassic-Cretaceous post-rift strata in the Dampier Sub-basin. The technique used in this study is to understand depositional environment and structural interpretation. Three seismic attributes (RMS amplitude, spectral decomposition, and variance) and RGB blending were applied to the chronostratigraphic surfaces. The results show that there are channels in the Cretaceous strata with flow direction running towards SW and NW. In Late Jurassic strata, there are normal faults that oriented NNE direction which consistent to Late Triassic – Last Jurassic rifting (Syn-rift) localized extension in the Dampier Sub-basin in WNW-ESE direction.

**Keywords:** Dampier Sub-basin, Northern Carnarvon Basin, Passive margin, Seismic attribute, Spatial decomposition

## 1. Introduction

The Northern Carnarvon Basin (NCB) is the southernmost basin of the Australia's North West Shelf (NWS, Fig.1) which includes a group of basins formed during the late Paleozoic to Mesozoic breakup of East Gondwana.

The NCB is the most productive hydrocarbon-producing basin of the NWS from the Mesozoic petroleum system in the basin. The Late Jurassic syn-rift strata represent important reservoirs in a number of fields in the Dampier Sub-basin of the NCB (Longley et al. 2002) and represent a primary exploration target in the basin. The Dampier Sub-basin is an important hydrocarbon basin with significant oil (>633 MMbbls) and gas (>34 Tcf) discoveries

(Barber 2013). Understanding the depositional system is important in the hydrocarbon exploration.

Commonly, petroleum element related geological features (e.g., paleochannels, faults) are extracted by performing seismic attributes.

Seismic attributes can be important predictors, either qualitative or quantitative, of reservoir geometries when they are correctly used in reservoir characterization studies. However, most surfaces are not always possible to present those features. Conventional seismic interpretation involves manually-picking, auto-tracking, and attribute mapping mainly on selective surfaces at or near top formation.

However, most surfaces are not always possible to present geological features.

Horizon stack technique can be mapped on every event that relates geological time with unlimited number of chronostratigraphic surfaces and apply with various attributes. Then interpreter can quickly scan the attribute seismic volume to understanding the detail of the geological evolution and clearly observed depositional feature. This technique is better in term of saving time and can get more detail.

This study generates fine chronostratigraphic surfaces (Horizon Stack) between key horizons within the Late Jurassic to Cretaceous strata in the Dampier Sub-basin. Seismic attributes are applied to all horizons in order to identify geological features for depositional environment and to improve structural interpretations in area where seismic quality is poor.

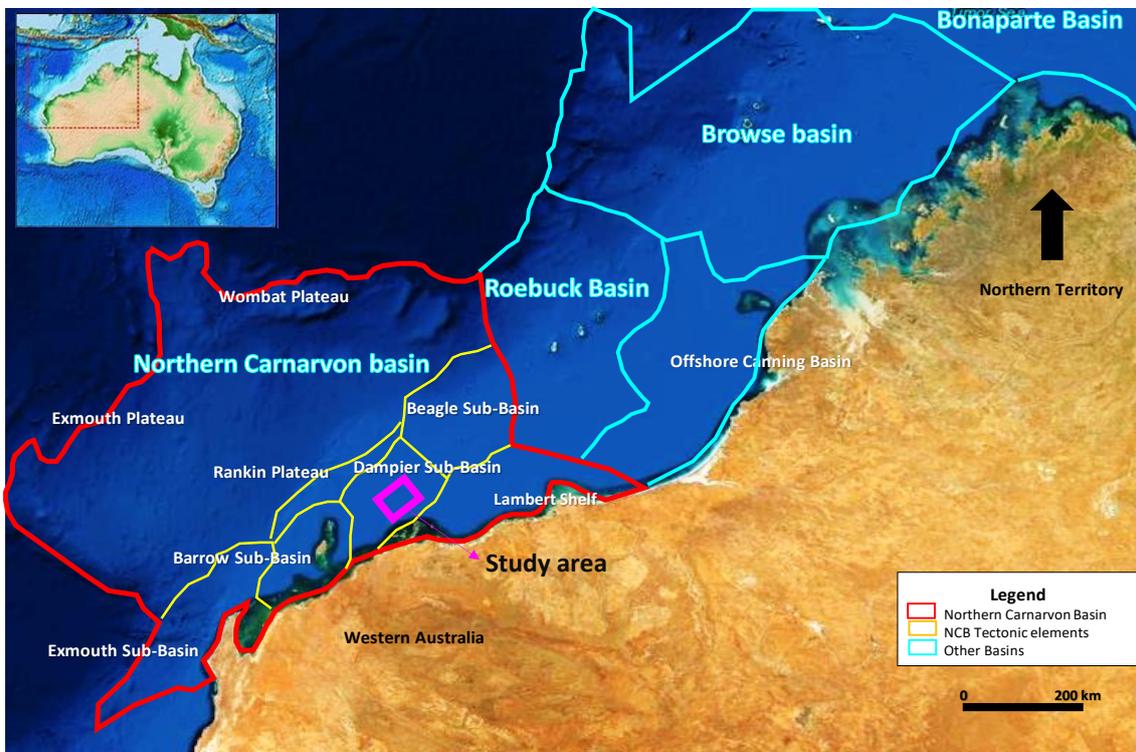
## 2. Geological Setting

### 2.1 Tectonic Evolution

The tectonic evolution of the Dampier Sub-basin was primarily influenced by the formation of the NCB, and the wider NWS, during the progressive breakup of eastern Gondwana. Seven major stages punctuate the formation of the basin and its structural components commencing in the Permian-Carboniferous and continuing to the present day (Veevers, 1988; Jablonski, 1997; Jablonski and Saitta, 2004).

1. The Sibumasu Block breakup (Permian-Carboniferous) formed the dominant northeast-southwest structural grain of the basin due to northwest- southeast extension along the northwest of Gondwanan Australia (Gartrell, 2000).

2. During the Late Triassic, the transgressional Fitzroy Movement in the Canning Basin resulted in restructuring of tectonic units along the NWS causing the separation of the Beagle and Cossigny troughs in the Beagle Sub-basin from the Lewis Trough in the Dampier Sub-basin.



**Figure 1.** Satellite image showing the location of basin provinces on the North West Shelf of Australia with respect to major basin boundaries. Study area in Dampier Sub-basin is highlighted in pink area.

3. The commencement of the series of breakup events which formed the NWS margin occurred in the Early Jurassic as a result of the breakup of the West Burma block 1 from Gondwanan Australia. This breakup event resulted in rapid thermal subsidence and a rifted arch setting in the NCB that formed the Lewis Trough and Rankin Platform.

4. West Burma Block 2 separated in the Oxfordian leading to active seafloor spreading in the Argo Abyssal Plain. Extension of the block was towards the north-northwest, oblique to the structural grain of the Dampier Sub-basin, resulting in the transtensional deepening and broadening of the Dampier Sub-basin towards and across the Rankin Platform, which formed the Kendrew Terrace.

5. West Burma Block 3 broke away from a region outboard of the Bonaparte Basin during the Late Jurassic (Longley et al., 2002; Jablonski and Saitta, 2004). As a result of the changing extension direction from northwest (the Argo spreading ridge) to west-northwest (the Gascoyne spreading ridge), fault reorientation and block rotation occurred in the Dampier Sub-basin resulting in uplift and erosion of the Rankin Platform. Tilting of fault blocks northward in the Early Cretaceous reactivated Jurassic transfer structures and caused inversion of footwalls, resulting in the anticlinal Madeline and Legendre trends (Baillie and Jacobson, 1995; Pryer et al., 2002).

6. The major Greater India breakaway event commenced in the Early Cretaceous (Valanginian) and resulted in west-northwest extension and the formation of the Gascoyne and Cuvier abyssal plains signifying the final breakup of the northwest margin of Australia (Hill, 1994; Gartrell, 2000). Cessation of active continental breakup in the Late Cretaceous led to the formation of the passive continental margin that exists at present day.

7. Collision of the Indo-Australian plate with the Banda Arc and the Eurasian Plate in the late Oligocene to early Miocene caused minor inversion along the Rosemary-Legendre Trend occurred in the Dampier Sub-basin (Cathro and Karner, 2006; Keep et al., 2007).

## 2.2 Tectono-stratigraphy and Depositional Environment

The Dampier Sub-basin contains a dominantly Early Jurassic to Early Cretaceous fill up to 10,000 m (Fig.2.1). Dang and McClay (2019) devised a multi-phase framework for the deposition of sediments into the NCB, divided into six major megasequences; a pre-rift megasequence prior to the Triassic to a passive margin from the Santonian to present. The megasequences are defined by significant changes in sedimentary deposition and dispersal patterns marked by active rifting processes and subsequent changes in subsidence.

The pre-rift 1 megasequence (Pre-Late Carboniferous) and syn-rift 1 megasequence (Late carboniferous to latest Permian Syn-rift) are not well understood due to its great depth (>5 km but consists of primarily fluvio-deltaic clastic sediments (Jablonski, 1997). The sediments were derived from the land mass of the Australia Plate, with some from the microplates that were attached to be Australia Plate. Sediments were transported via transcontinental channel system.

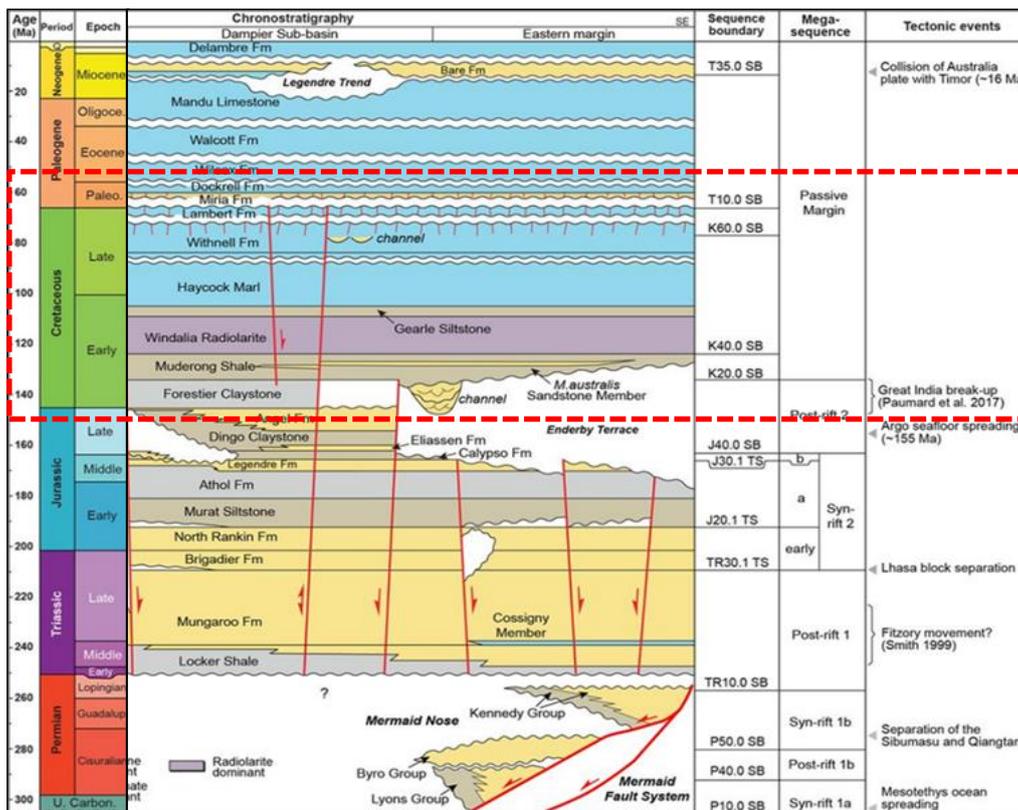
The post-rift 1 megasequence (Early – Latest Triassic) is active margin related to the Fitzroy Movement is composed of the transgressive Locker Shale deposited during a period of thermal subsidence, and the Mungaroo Formation atop, which was deposited in a fluvio-deltaic nearshore environment.

The syn-rift 2 megasequence (Latest Triassic -Late Jurassic) has been subdivided into three units: the early rift 2; syn-rift 2a and syn-rift 2b. Increased transgression and marine flooding during this time also lead to the deposition of the Murat Siltstone. The early syn-rift 2a phase (Toarcian to Callovian) resulted in the deposition of the fine-grained Athol Formation in a low-energy restricted offshore marine setting followed by the Legendre Formation deposited as a prograding delta over the basin. During this period, the main tectonic features of the Dampier Sub-basin were formed (Rankin Trend, Lewis Trough and Rosemary Fault System) marked by active rifting processes and subsequent changes in subsidence. The Legendre Delta was drowned,

depositing shales and minor sandstones of the Calypso Formation. As tectonism and displacement along bounding faults continued during the syn-rift 2 megasequence (Oxfordian to Tithonian), an open deep-marine environment existed which resulted in the deposition of the Dingo Claystone.

The post-rift 2 megasequence (Late Jurassic – Early Cretaceous) is base section of stratigraphic interval of this study. It is defined by Oxfordian SB sequence boundary. During

directly supplied basin-floor fans in the north and central Dampier Sub-basin and grade laterally into basinal facies towards the Barrow Sub-basin to the south. A gradual decline in rifting and a gradual increase in thermal subsidence during Berriasian to Valanginian resulted in the submergence of the Rankin Platform and the shutting off of sediment supply that sourced the Angel Formation, resulting in the deposition of the Forestier Claystone, and subsequently, the Muderong Shale during the



**Figure 2** Tectono-stratigraphic chart of the Dampier Sub-basin (Deng and McClay, 2019) studied interval is highlighted as red line.

the Oxfordian, basin-floor fan systems sourced from the basin margins led to the deposition of the Eliassen Formation. Increasingly sand-rich basin-floor fan systems supplied from the southeast Beagle Sub-basin and the Legendre Trend were deposited towards the southwest in the northern and central parts of the Dampier Sub-basin. These thick, widespread sandstones constitute the Angel Formation and represent major petroleum reservoirs in the Dampier Sub-basin. The Angel Delta supplied sediment that

post breakup megasequence.

The passive margin megasequence (Early Cretaceous to Holocene) was strongly affected by the opening of the Indian Ocean and progradation of carbonate-dominated systems across the NWS to the present day, reflecting the passive continental margin setting (Longley et al., 2002).

### 3. Data and Methodology

#### 3.1 3D Seismic Data

West Panaeus 3D seismic volume is used in this project. The survey is aligned NE-SW, covering an area of 1,040 sq.km along the eastern margin of the Dampier Sub-basin and extends down to 5.5 second TWT. The seismic volume was realized (16 bit to 8 bit) in order to optimize seismic processing during interpretation with bin size 12.5 X 12.5 m. The water depth ranged from 45-75 m. The data quality is fair to poor in complex structure and deeper section particularly below the Cretaceous post-rift strata, where the discontinuity of the seismic reflectors is enhanced in most areas by local erosion and faulting.

The visibility of weak seismic reflectors was improved using PaleoScan™'s auto gain control and structural smoothing volume processing. The Trace AGC attribute enhances low amplitude sections for improve horizon interpretation. The structural smoothing attribute increases signal or noise ratio for structural interpretation.

### 3.2 Seismic Interpretation

Marker horizons were firstly identified. Based on the interpreted marker horizons (see Fig. 2), study interval was divided into five seismic horizons. The base horizon is J40.0 (Oxfordian) Horizon, next horizon is K20.0 (Valanginian) Horizon, K40.0 (Abtian) Horizon, K60.0 (Campanian) Horizon, T10.0 (Danian) Horizon, and near seabed, were mapped because of their significant stratigraphic features. Seismic horizons were manually interpreted every 10 in-lines and 10 crosslines (a 125 m spacing) across the seismic survey. The key erosional surface in this study is the J40.0 horizon

### 3.3 Model-Grid Model

Building a Relative Geological Time (RGT) model directly from the seismic is an innovation in the interpretation workflow. This method is composed of two main steps. The first step consists in computing a geological Model-Grid using a cost function minimization algorithm, which merges seismic points according to the similarity of the wavelets and

their relative distance. This process automatically tracks every horizon within the seismic volume to constrain a grid, where a relative geological time is computed for every point. The task of the seismic interpreter will consist in refining the model by modifying relationships between auto-tracked horizons. The second step will be the generation of the RGT model from the Model-Grid, where a relative geological age is assigned to each pixel of this volume.

### 3.4 Geo-Model Method

The Geo-Model method corresponds to the vertical interpolation of the interpreted Model-Grid. It also takes every links between patches into account. It is a RGT model which can be managed as any other attribute volumes. A relative geological age is assigned to each pixel of this volume. This method has the betted advantage of allowing the interpreter control of the Geo-Model geometry by marked horizon which is most consistent reflectors (corresponding to consistent series of connected patches).

### 3.5 Chronostratigraphic Horizons

Once computed, an unlimited number of horizons can be derived from the 3D seismic volume. This set of horizons is called chronostratigraphic horizons (also called Horizon Stack in PaleoScan™). This horizon set enables an interactive strata-slicing through the seismic volume where geological feature as well as structural features can be highlighted. In this study, two hundred sub-horizons were created with various seismic attributes to identify geological feature such as structural orientation, facies of deposition environment.

### 3.6 RMS Attributes

Amplitude maps were generated by using RMS (root mean square) amplitude attributes along the interpreted horizons to map the sand distributions. Variable 10 ms window intervals were selected along each horizon depending upon the thickness of the sands encountered at wells.

### 3.7 Spectral decomposition and RGB Blending

Spectral decomposition or time–frequency decomposition is an effective method for seismic interpretation that gives better definition to determine stratigraphic and structural features. The converted amplitude spectrum (frequency domain) can be used to identify the lateral discontinuity of geologic bodies that can help locating prospect areas and delineating facies such as channel sands which cannot be resolved in the time domain due to the low seismic resolution. The RGB (Red - Green - Blue) color display is the addition of the R, G and B components. These components are based on frequency filtered seismic data to highlight depositional features using the primary colors. With this method, a better visualization of geologically events is possible by adjusting the contrast between the three different colors.

## 4. Results

This section presents some of the key chronostratigraphic surfaces that provide geological feature for depositional environment and structural deformation based on their seismic characters in map view and 3D perspective view with cross section. Three attribute filters applied on these horizons include variance, RMS and spectral decomposition. Two geological features were observed on the chronostratigraphic surfaces as described below.

### 4.1 Structural features

In the Late Jurassic strata, a series of normal faults is well illustrated on the attribute surfaces. Fault strike is mainly in NNE direction with dip direction to the west. They form NE-trending en-echelon fault pattern in map view, which is parallel to the Rosemary fault system to the northeast. These normal faults have displacement between 20-150 m in seismic cross section (Fig. 4). The faults are terminated at an erosional surface (Early Cretaceous, K20.0) and it is mostly observed in southern part of study area.

In Late Cretaceous strata, Structural feature observed at this level includes ENE-trending normal faults. They form ENE-trending en-echelon fault pattern in map view, which is oblique to the previous fault pattern on the Late Jurassic horizons. These faults are planar east-dipping normal faults with low in displacement. Most of the faults cut the progradation of carbonate-dominated systems above the channel indicating postdate fault development.

### 4.2 Channelize features

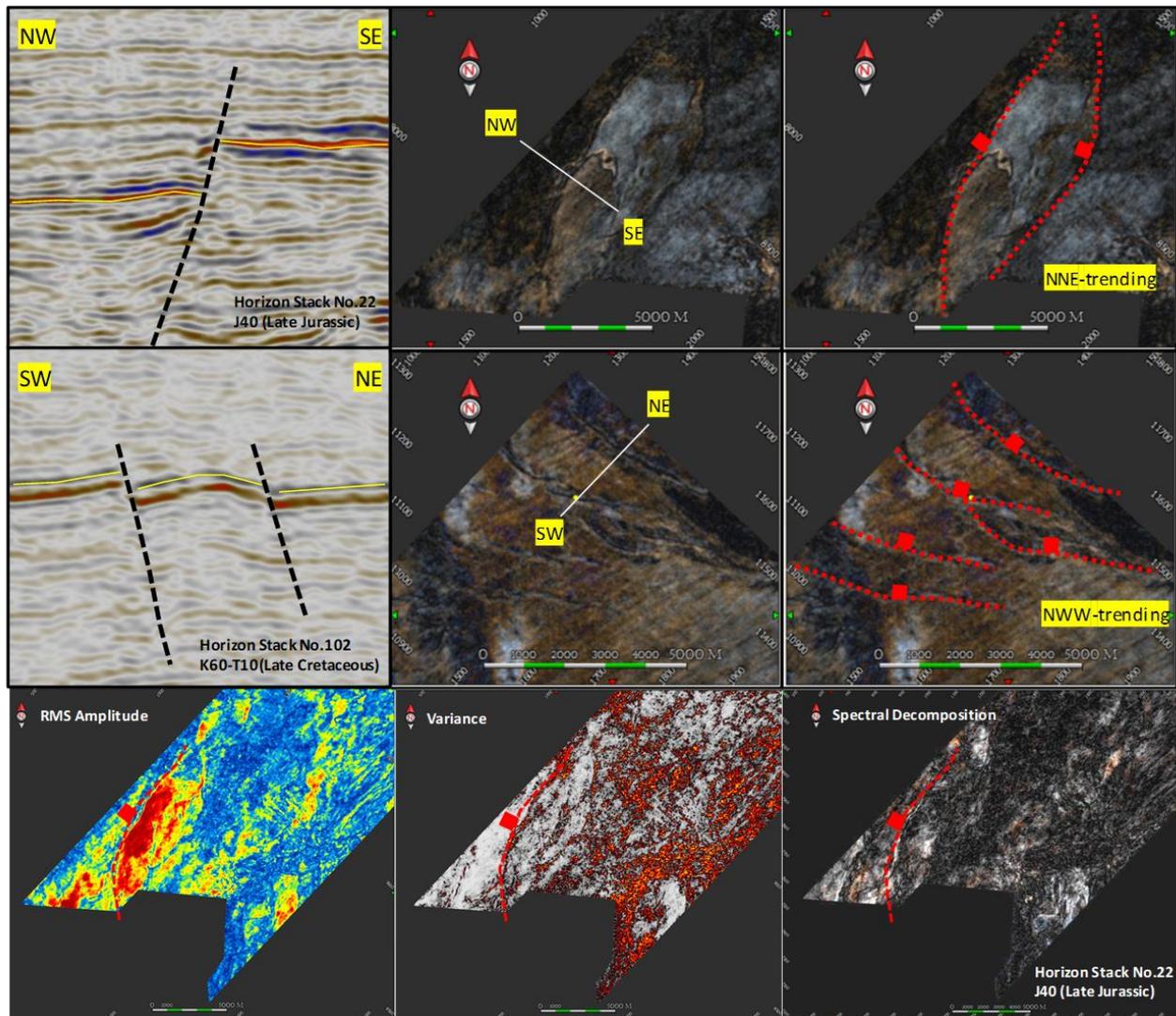
In the Late Jurassic strata, Seismic attributes on these surfaces did not illustrate a clear depositional feature or pattern that can be explained by depositional environment. Although, in cross section, it seems that there is channel-like feature which is cut by normal fault, erosion base or migration was noticed on seismic section (Fig.5).

In Late Cretaceous strata, channel feature can be clearly observed between TWT 1,100-1,200 ms in Late Cretaceous strata interval. These channels have flow direction in NE-SW and SE-NW trends. The width of channel varies from 900-1,300 m. Seismic cross section of channel shows U-shape of channel incision and infill sediment as lateral stack (Fig.4). The lateral stacking pattern indicates a frequently lateral channel migration. Moreover, it also shows terrace and base channel feature that should be channel belt. RGB blending of strata slices result shows the geometry and spatial distribution of sand bodies.

## 5. Discussion and conclusion

### 5.1 Structural Interpretation

According to Deng and McClay (2019), the 3D seismic volume used in this study is located near the eastern margin of the Dampier Sub-basin. Their 2D seismic interpretation suggests that depositional environment in the study area and structural development particularly during the Late Jurassic are strongly affected by the deformation of the hanging wall of the west-dipping listric basin bounding fault during basin formation. These faults may have formed by an oblique extension of the NE-



**Figure 4.** (Top) Seismic section shows fault displacement and fault trending in Late Jurassic (Middle) Seismic section shows fault displacement and fault trending in Late Cretaceous (Below) RMS amplitude, Spectral Decomposition, Variance and Amplitude time slice maps of horizon No.22 respectively showing clearly faults appearance.

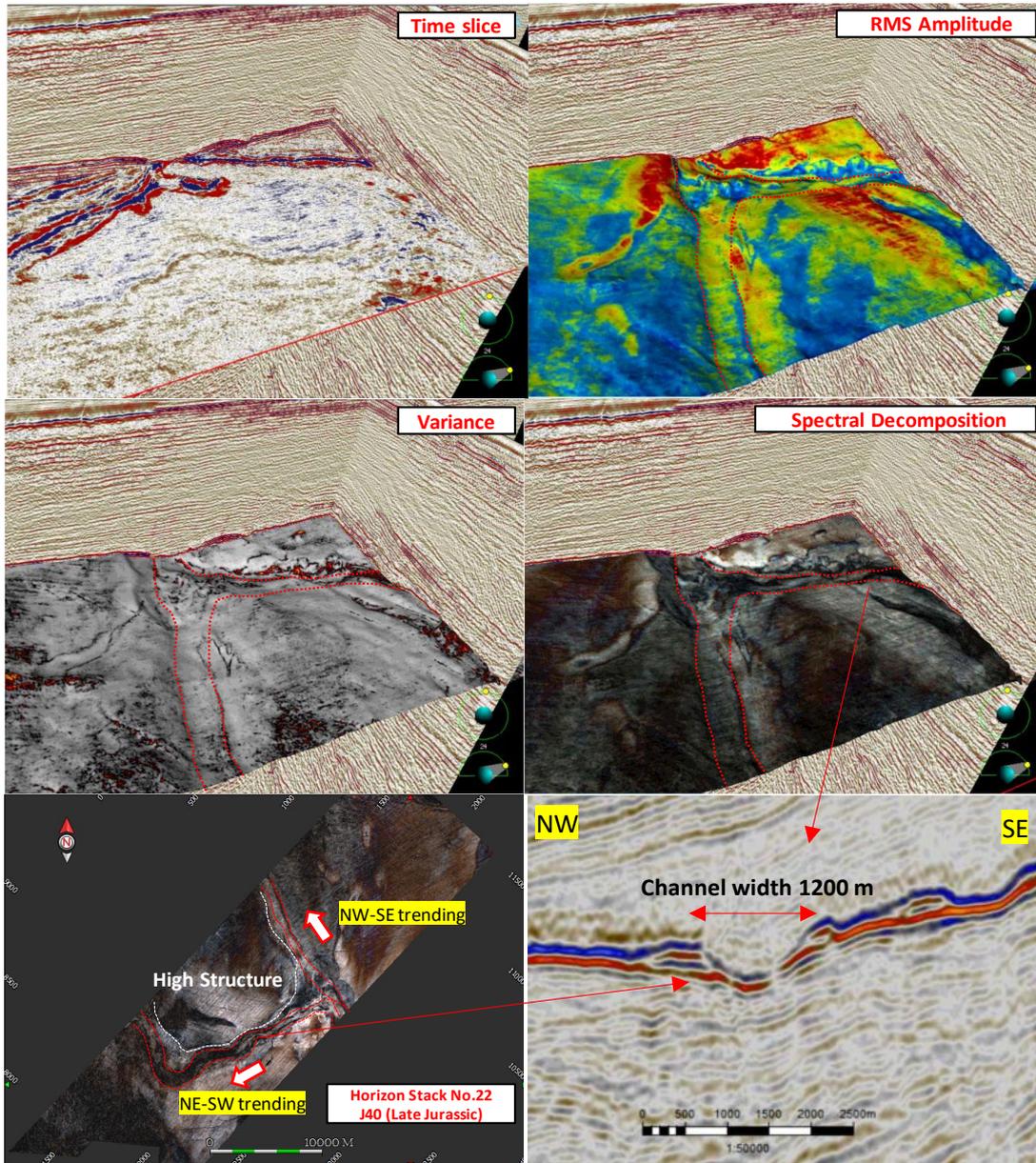
trending bounding fault on the eastern margin of the Dampier Sub-basin during separation of West Burma Block 3 from the Bonaparte Basin.

The Cretaceous fault set differs from the Jurassic fault set according to its ENE-trending and east-dipping normal fault. This fault set developed during passive margin period. This fault set developed during passive margin period. Their formation could be related to the opening of the Indian Ocean that has affected across the NWS to the present day (Longley et al., 2002). Fine chronostratigraphic surface combines attribute horizon stack technique can better enhance structural feature and more

understanding basin evolution.

### 5.2 Deposition Environment

Channel is one more geological feature that was detected by attribute horizon stack. There are two main flow directions which are NE-SW and SW-NE trend and erosional base cut the underlying sediment. The main channel belt NE-SW trend migrate laterally to SE-NW trend. This channel flow oblique high structure in western part. These channel trends were flow from continental shelf source and flow to depocenter of the Dampier Sub-basin that is western part of study area. Channel width



**Figure 5.** (Top) Amplitude time slice, RMS amplitude, Variance and Spectral Decomposition maps of horizon No.102 respectively showing clearly channelize with highlighted interpreted channels. (Below) RGB blending of 20 Hz, 30Hz and 40 Hz showing the presence of channelize channels which were not visible in other horizon slices and seismic cross section

is about 900 – 1,300 m with thickness 35-40 meters. These channels deposited as confined channel on lower slope (<1°). Altogether depositional environment should be sub-marine channel system that is middle between canyon and lobe.

Fine Chronostratigraphic or Horizon Stack technique reduces interpretation time and manual picking error that suitable for quickly screen entire volumes and analyze targeted

reservoir intervals in 3D such as bidding process in dataroom.

Understanding the depositional environment and fault system is important in the hydrocarbon exploration. Fault can trap hydrocarbon such as 3-way closure and tilted fault block. Furthermore, fault can conduit hydrocarbon even depositional environment controls the architecture, heterogeneity, and ultimately the quality of

reservoirs and is therefore one of the most important considerations in the development of any enhanced oil recovery. Fine Stratigraphic surface combine with attribute horizon stack technique is more accurate for seismic interpretation that not only reduce risk exploration but also sustain development plan.

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## 8. References

- AGSO (Australian Geological Survey Organization), North West Shelf Study Group, 1994. Deep reflection on the North West Shelf: Changing perceptions of basin formation. In: Purcell, P. G., Purcell, R. R., (eds). The Sedimentary Basins of Western Australia: Proceedings of Petroleum Exploration Society of Australia Symposium. Perth: WA, p. 63-76.
- Barber, P., 1994a. Late Jurassic – Early Cretaceous depositional systems of the Dampier Sub-basin – Quo Vadis APEA Journal 32, p. 566-585.
- Barber, P., 1994b. Sequence stratigraphy and petroleum potential of Upper Jurassic-Lower Cretaceous depositional systems in the Dampier Sub-basin, North West Shelf, Australia. In: Purcell, P.G. and Purcell, R.R. (Eds.), The Sedimentary Basins of Western Australia 1: Petroleum Exploration Society of Australia, p. 525-542.
- Baillie, P.W., Powell, C.M., Li, Z.X., Ryan, A.M., 1994. The tectonic framework of Western Australia's Neoproterozoic to Recent sedimentary basins. In: Purcell, P.G. and Purcell, R.R. (Eds.), The Sedimentary Basins of Western Australia 1: Petroleum Exploration Society of Australia, p. 45-62.
- Blevin, J.E., Stephenson, A.E., West, B.G., 1994. Mesozoic structural development of the Beagle Sub-basin – Implications for the petroleum potential of the Northern Carnarvon Basin. In: Purcell, P.G. and Purcell, R.R. (Eds.), The Sedimentary Basins of Western Australia 1: Petroleum Exploration Society of Australia, p. 479-495.
- Cathro, D.L., Karner, G.D., 2006. Cretaceous-Tertiary inversion history of the Dampier Sub-basin, northwest Australia. insights from qualitative basin modelling. Marine and Petroleum Geology 23, p.503-526.
- Deng, H. and MCclay, K. 2019. Development of extensional fault and fold system: insights from 3D seismic interpretation of the Enderby Terrace, NW Shelf of Australia. Marine and Petroleum Geology, 104, p. 11–28.
- Deng, H. and MCclay, K. 2019. Tectono-stratigraphy of the Dampier Sub-basin, North West Shelf of Australia. <http://sp.lyellcollection.org>.
- Exon, N.F., von Rad, U., 1994. The Mesozoic and Cainozoic sequences of the northwest Australian margin, as revealed by ODP drilling and related studies. In: Purcell, P.G. and Purcell, R.R. (Eds.), The Sedimentary Basins of Western Australia 1: Petroleum Exploration Society of Australia, p. 181-199.
- Gartrell, A.P., 2000. Rheological controls on extensional styles and structural evolution in the Northern Carnarvon Basin, Northwest Shelf Australia. Australian Journal of Earth Sciences 47, p. 231-244.
- Geoscience Australia and Bureau of Resource and Energy Economics, 2014. Australian Energy Resource Assessment 2nd Ed. Geoscience Australia, p. 364.
- Geoscience Australia, 2021. Regional Geology of the Northern Carnarvon Basin Report, <https://www.ga.gov.au/scientific-topics/energy/province-sedimentary-basin-geology/petroleum/acreagerelease/northern-carnarvon>.
- Hocking, R.M., 1990. Carnarvon Basin. In: Geological Survey of Western Australia,

- Geology and Mineral Resources of Western Australia, Memoir 3, p. 457-495.
- Hocking, R.M., 1992. Jurassic deposition in the southern and central North West Shelf, Western Australia. Geological Survey of Western Australia Record 1192/7.
- Hill, G., 1994. The role of pre-rift structure in the architecture of the Dampier Sub-basin, North West Shelf, Australia. APEA journal 34, p. 602-613.
- Jablonski, D., 1997. Recent advances in the sequence stratigraphy of the Triassic to Lower Cretaceous succession in the Northern Carnarvon Basin, Australia. APPEA Journal 39, p. 429-454.
- Jablonski, D., Saitta, 2004. Permian to Lower Cretaceous plate tectonics and its impact on the tectono-stratigraphic development of the Western Australia margin. APPEA Journal 44, p.287-328.
- Keep, M., Harrowfield, M., Crowe, W., 2007. The Neogene tectonic history of the North West Shelf, Australia. Exploration Geophysics38, p.151-174.
- Longley, I.M., Buessenschuett, C., Clydsdale, L., Cubitt, C.J., Davis, R.C., Johnson, M.K., Marshall, N.M., Murray, A.P., Somerville, R., Spry, T.B., Thompson, N.B., 2002. The North West Shelf – a Woodside perspective. In: Keep, M and Moss, S.J. (Eds.), The Sedimentary Basins of Western Australia 3: Petroleum Exploration Society of Australia, p. 27-89.
- P.G. and Purcell, R.R. (Eds.), The Sedimentary Basins of Western Australia 1: Petroleum Exploration Society of Australia, p. 45-62.
- Pryer, L.L., Romine, K.K., Loutit, T.S., Barnes, R.G., 2002. Carnarvon basin architecture and structure defined by the integration of mineral and petroleum exploration tools and techniques. APPEA Journal 42, p. 287-309.
- Stephenson, A.E., Blevin, J.E., West, B.G., 1998. The paleogeography of the Beagle Sub-basin, Northern Carnarvon Basin, Australia. Journal of Sedimentary Research 68, p. 1131-1145.
- Veevers, J.J., 1988. Morphotectonics of Australia's north west margin – a review. In: Purcell, P.G. and Purcell, R.R. (Eds.), The North West Shelf of Australia 1, pp. 19-27.
- Wulff, K., Barber, P., 1995. Tectonic controls on the sequence stratigraphy of Late Jurassic fan systems in the Barrow-Dampier Basin, North West Shelf, Australia. PESA Journal 23, p. 77-89.