# LINEAR TRENDS OF PALEO-POCKMARKS AND FLUID FLOW PIPES IN THE JURASSIC AND TRIASSIC SEDIMENTS OF OFFSHORE NORTHWEST AUSTRALIA

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## SUMMARY

This study records 315 paleo-pockmarks with associated focused fluid flow pipes within the Jurassic and Triassic sediments over three study areas on the Exmouth Plateau, offshore Northwest Australia. Paleo-pockmarks are identified along a surface that represents the top of Jurassic sediments, while the fluid flow pipes extend into Triassic sediments from the base of these pockmarks. The pockmarks and pipes form in linear trends that are parallel to and laterally offset from the tops of extensional faults intersecting an interval from the top of Jurassic sediments into Triassic sediments, where they are seen to terminate. Bases of the fluid flow pipes are observed to intersect and terminate along these extensional faults within the Triassic sediments. The pockmarks and associated fluid flow pipes are interpreted to have formed when extensional faults developed that intersected an overpressured unit within Triassic sediments. This caused a localized reduction of lithostatic pressure along the overpressured sequence at the intersection which then acted as a focal point for fluid escape and vertical migration. The source of the fluid overpressure could not be confirmed in this study. The Triassic sequence is a known hydrocarbon source and 1D modelling shows that at the time of fluid flow and pockmark formation, these Triassic sediments were entering the hydrocarbon generation window. However, no evidence of hydrocarbons associated with the pockmarks has been observed. Our findings identify fluid migration pathways that are seal risks for hydrocarbon reservoirs, but could also potentially be fluid migration pathways that were previously untested.

**Key words:** Paleo-pockmarks, fluid flow, feeder pipe, Exmouth Plateau

## INTRODUCTION

Pockmarks are circular or elliptical crater-like depressions that are surficial expressions of focused fluid flow events (Judd and Hovland, 2009; King and MacLean, 1970). They are underlain by feeder pipes and can provide insight into subsurface fluid migration dynamics, pressure regimes or even petroleum systems (Hovland and Judd, 1988). The fluids expelled by focused fluid flow events are typically escaping from overpressured zones and they may be hydrocarbons, biogenic gasses or even brine (Andresen et al., 2008). Focused fluid flows commonly occur in random spatial distributions; however, underlying geological features could act as controls or focusing mechanisms for fluid migration, resulting in an organized spatial distribution of indicators (Pilcher and Argent, 2007).

The Northern Carnarvon basin is one of Australia’s premier hydrocarbon exploration regions where evidence of focused fluid flow events has been documented (O'Brien and Woods, 1995). The region is known to have overpressured Jurassic and Triassic sediments as well as having a working petroleum system; however, the cause of focused fluid flow in the basin has not been investigated. In this paper, we present linear trends of indicators of ancient focussed fluid flow events in the Exmouth Plateau of the Northern Carnarvon Basin, primarily buried pockmarks (paleo-pockmarks) with underlying feeder pipes. We identify the mechanism that caused the focused fluid flows as well as the controls that led to their organized spatial distribution. We assess the source and type of fluids that were involved and discuss the implications of these findings on fluid migration dynamics in the study area.

## METHOD

Focused fluid flows are identified in three time processed seismic data sets from the Exmouth Plateau; Io-Jansz 3D, Thebe 3D and Claudius 3D surveys. Wireline and lithology logs from wells in each survey area (Io-1, Io-2, Thebe-1, Zagreus-1, Jansz-1, Alaric-1, Tiberius-1) were used to identify key seismic reflections for interpretation (Figure 1). Reflectors that represent the top of the Jurassic and Triassic sequences were interpreted in each seismic dataset. Sonic logs from the wells, where available, were also used in converting two-way time values and measurements to depth. Seismic attributes that emphasize lateral changes in seismic reflections (variance, inline dip, cross line dip) were used to highlight features indicating palaeo-fluid flow.

## RESULTS

Along the top of the Jurassic sequence within each survey area, a total of 315 paleo-pockmarks with underlying feeder was identified; 17 in Thebe 3D, 23 in Io-Jansz 3D and 275 in Claudius 3D (Figure 1). Underlying the paleo-pockmarks are feeder pipes that extend into the Triassic sequence. The paleo-pockmarks in each survey have linear trends to their spatial distributions; NNW-SSE in Claudius 3D, N-S in Thebe 3D and NE-SW in Io-Jansz 3D. Seismic cross-sections, inline dip and crossline dip attributes revealed a series of low-throw normal faults (30-70 m) parallel to the linear trends of the paleo-pockmarks in each survey area with the fluid flow features occurring solely in the hanging wall of these faults. The faults terminate at the top of the Jurassic sediments and extend down into the Triassic sequence where they terminate or fall below the detection due to limitations on seismic resolution. Seismic interpretation reveals the bases of 52 feeder pipes intersecting minor fault planes within the Triassic sequence.

Timing of the paleo-fluid flow events is constrained by the observation that all paleo-pockmarks developed along the top Jurassic surface only and that none of the feeder pipes extend into the overlying Cretaceous sequence. We thus constrain the timing of fluid flow events to be during the Late Jurassic, after Jurassic sediments were deposited but prior to deposition of Cretaceous sediments. Isochron mapping of Jurassic and Cretaceous sequences indicate that the low throw faults formed during the Late Jurassic, similar in timing to that of fluid flow occurrence.

## CONCLUSIONS

Observations of interaction between the bases of feeder pipes with minor faults as well as constraints on the timing of pockmark and fault formation led us to propose that the faults formed at the end of the Jurassic, prior to deposition of Cretaceous sediments, and had intersected an overpressured unit in the Triassic sequence. The point of intersection experienced a localized decrease in lithostatic pressure, acting as a focus point for the overpressured fluids to migrate vertically through the overburden. The source of overpressure and nature of the migrated fluids could not be established owing to constraints of the dataset available. The findings of this study have implications for hydrocarbon exploration in the region as the focussed fluid flow features could potentially act as subsequent fluid migration pathways.

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**FIGURES**

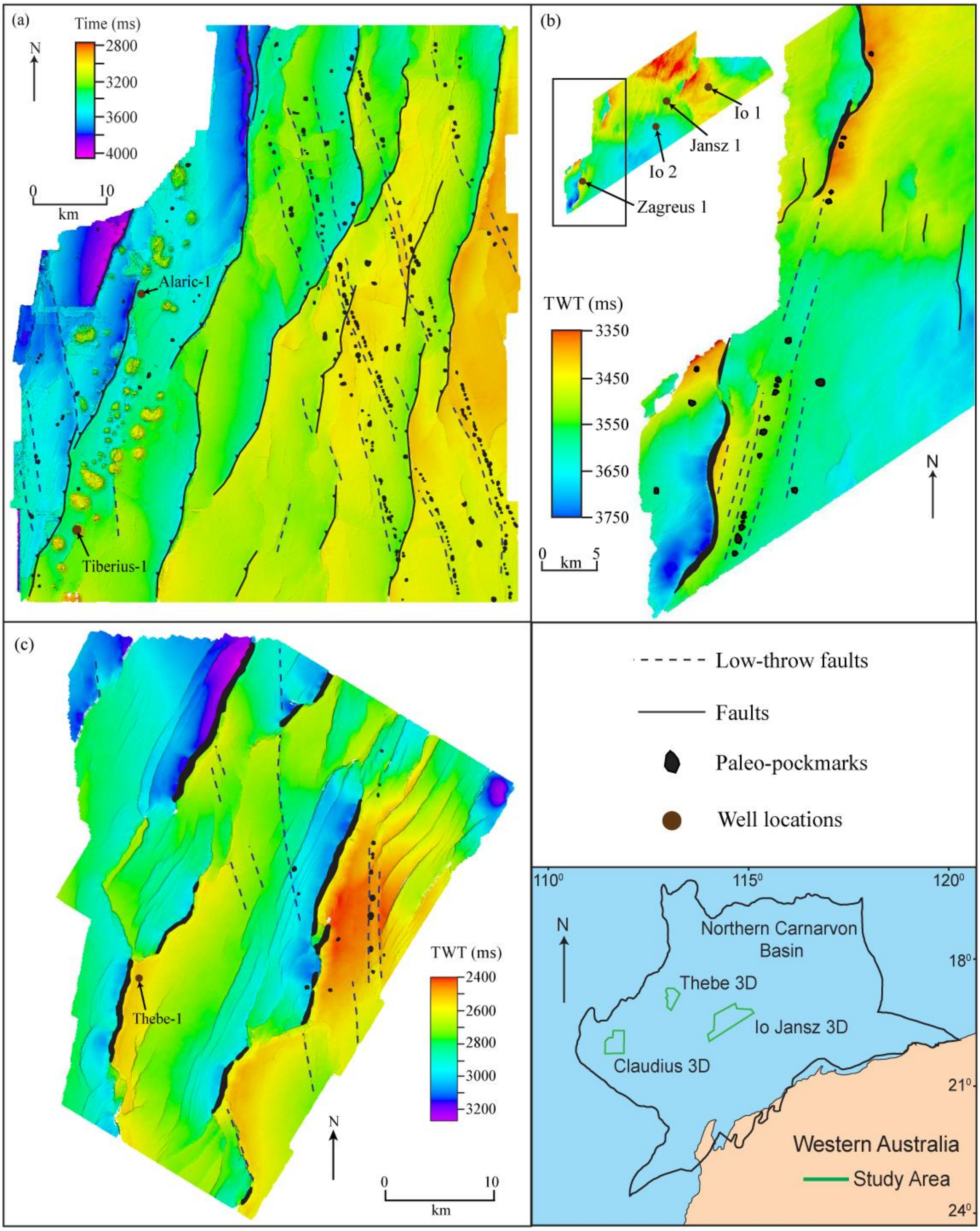


**Figure 1: Interpreted Top Jurassic horizons of the (a) Claudius 3D, (b) Io-Jansz 3D and (c) Thebe 3D seismic surveys. Paleo-pockmarks interpreted within each survey area are marked, along with low throw extensional faults that strike parallel to the linear trends of paleo-pockmarks.**