Characteristics of the Frontier Northern Houtman Sub-Basin Formed on a Magma-Rich Segment of the Western Australian Margin*

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Abstract

The northern part of the Houtman Sub-Basin (Perth Basin) is adjacent to the Western Australian large igneous province of the Cuvier margin and the Wallaby Plateau. Recent studies have shown significant prospectivity for oil and gas of the southern Houtman Sub-Basin. In the north however, few 2D seismic lines have been acquired to date. These limited data indicate continuation of the structural style, major sequences and potentially key petroleum systems elements from the south to the north. The significant increase in the amount of intrusive and extrusive magmatism in the northern part of the sub-basin imaged in seismic data is related to the transition from a magma-poor to magma-rich segment of the margin.

The Houtman Sub-Basin was formed during two stages of rifting. During Early Permian rifting, a complex network of north-south oriented half-grabens were formed in the inboard parts of the basin. The second stage of rifting occurred in the Jurassic to Early Cretaceous and resulted in accumulation of up to 10 km of synrift section. In the Berriassian-Valanginian, an extensive system of dykes and sills formed in the seaward part of the basin. This heavily intruded area is adjacent to the Wallaby-Zenith

Transform Fault and the Wallaby Saddle. During Valanginian breakup, this area was affected by volcanism and partially buried beneath the volcaniclastic Seaward Dipping Reflector Sequences of the Wallaby Saddle. The geometries of the outer Houtman Sub-Basin are remarkably similar to those described off the Parana-Etendeka region on the Namibian margin. The geodynamic setting of both the Namibian and Western Australian volcanic margins are governed by large transform faults and complex rift propagation history. Data from the northern Houtman Sub-Basin are consistent with results from recent numerical modeling of melt generation on rifted margins. The modeling suggests that crustal-scale transfer faults continuing as large transform faults on the oceanic crust act as rift propagation barriers and lead to excessive magmatism typical for volcanic margins. Due to the complex rift propagation history and volcanism continuing up to Early Aptian, the northern Houtman Sub-Basin is likely to have experienced higher rates of heat flow affecting maturation of its source rocks. A new 2D seismic dataset over the northern Houtman Sub-Basin acquired the Geoscience Australia in 2014-2015 offers an opportunity to re-examine the petroleum prospectivity of this frontier basin.

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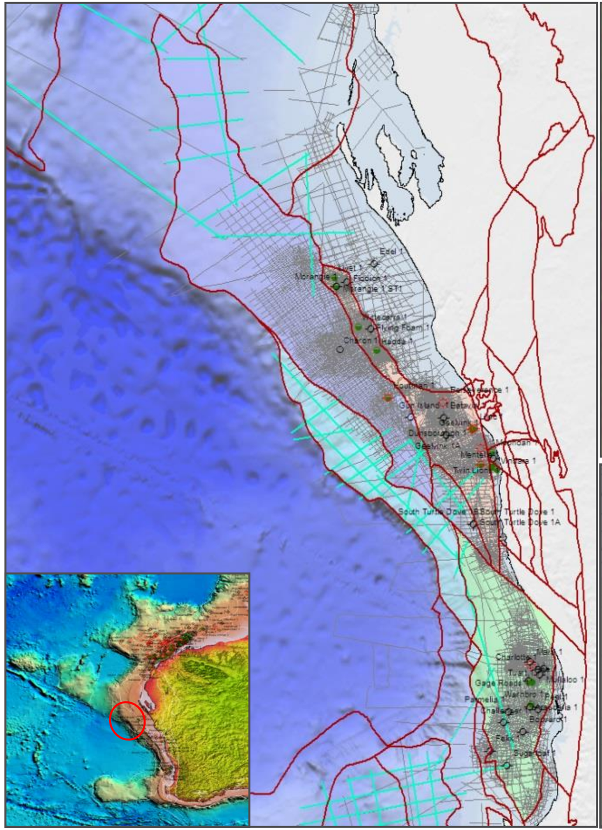
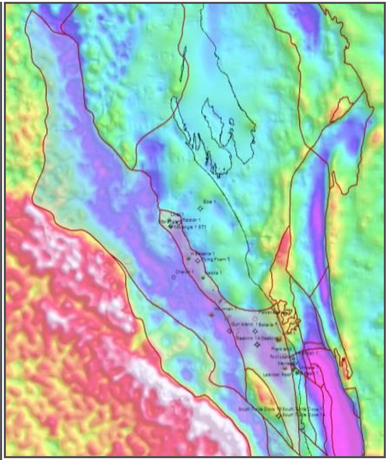
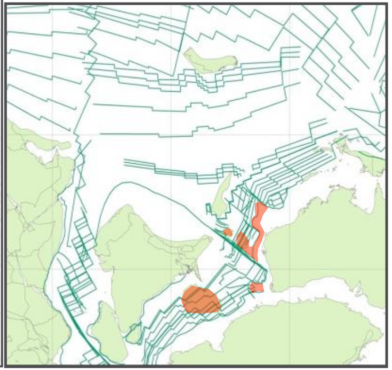
Why Houtman Sub-basin? Data and knowledge gaps







Largest offshore sub-basin in the Perth Basin - 1300km long, 70 -150 km wide

Active petroleum system and HC discoveries in the southern Houtman and Abrolhos sub-basins

Similarity in structural style between southern and northern Houtman sub-basin

Almost no seismic data – 50-70 km line spacing

Gravity and limited seismic data indicate the presence of a large depocentre (~ 7km thick)

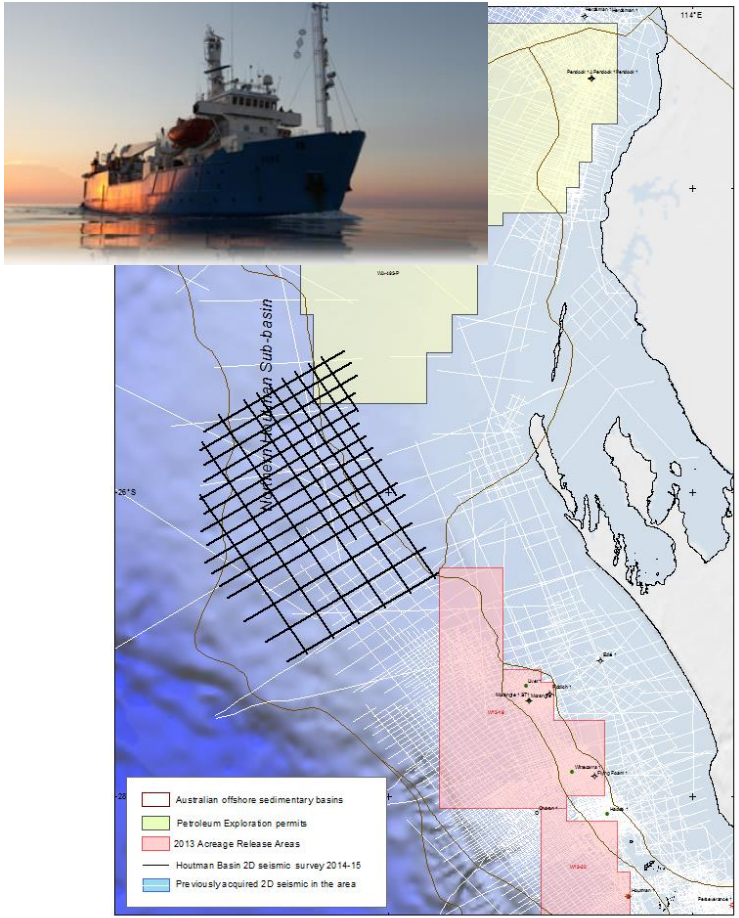
Potentially prospective depocentre

New data and GA program

SURVEY: 69 days, 15 November 2014 to 22 January 2015 on M/V Duke

DATA: Acquired 3308 line km of 2D seismic data providing adequate initial coverage of this frontier area

The data is acquired in Deep Tow configuration (8 km streamer towed at 15.6m deep). The data is being processed using broadband PSTM/PSDM.

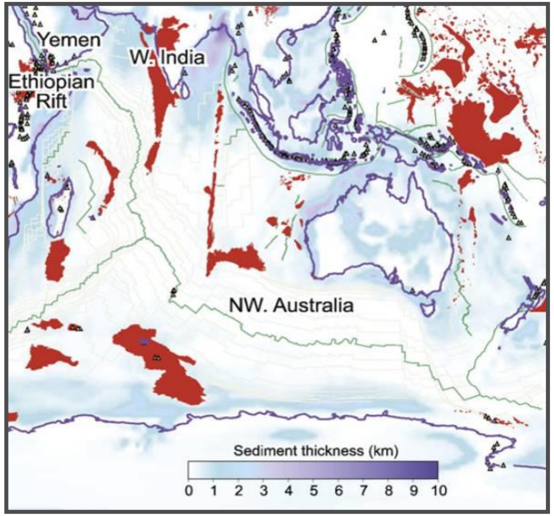


Aims of the project:

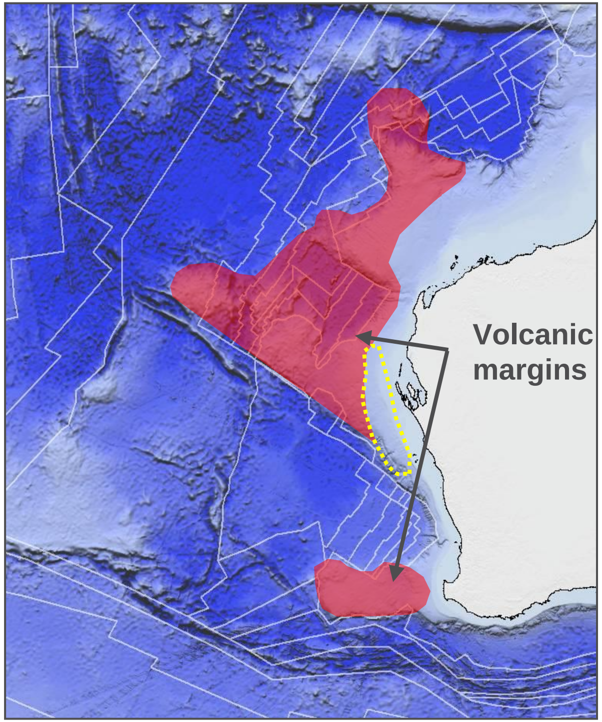
1. **Evaluate petroleum prospectivity of the northern Houtman Sub-basin**
2. **Understand architecture of the Houtman Sub-basin in relation to development of the Wallaby-Zenith sheared margin**

Unique Geological Setting

Large Igneous Provinces (LIPS)



After Yamasaki et al., 2009



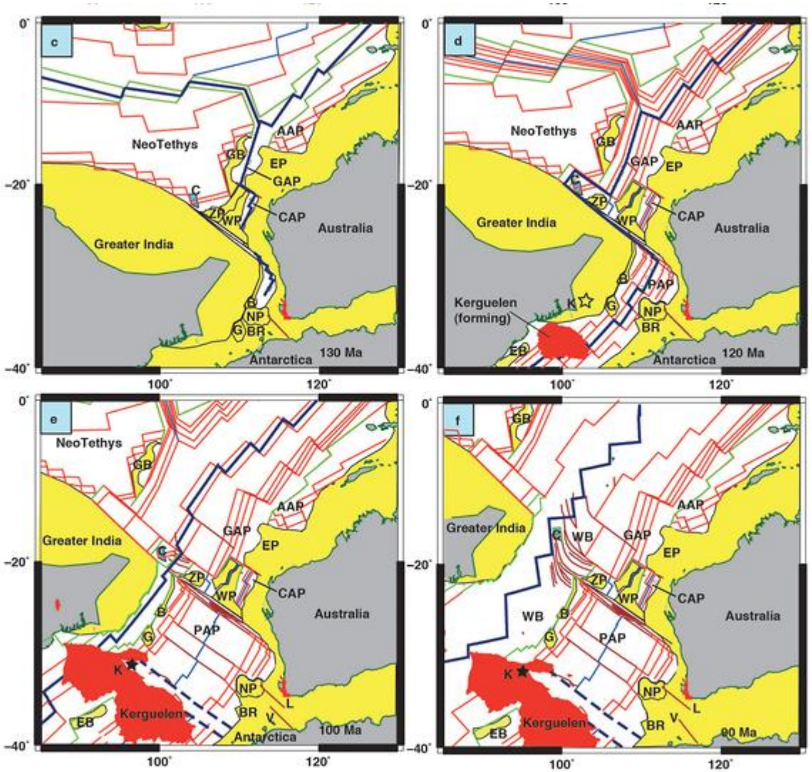
After Symonds et al., 1998

Volcanic margin – adjacent to the Large Igneous Province (LIP) of Wallaby Plateau (Symonds, Planke et al. 1998)

Transform margin – 1500 km Wallaby-Zenith FZ defining the shape and breakup history of the margin

Complex geodynamic history – several extinct ridges corresponding to ridge jumps (Robb et al, 2005; Gibbons, 2012)

Breakup history - Transform Margin



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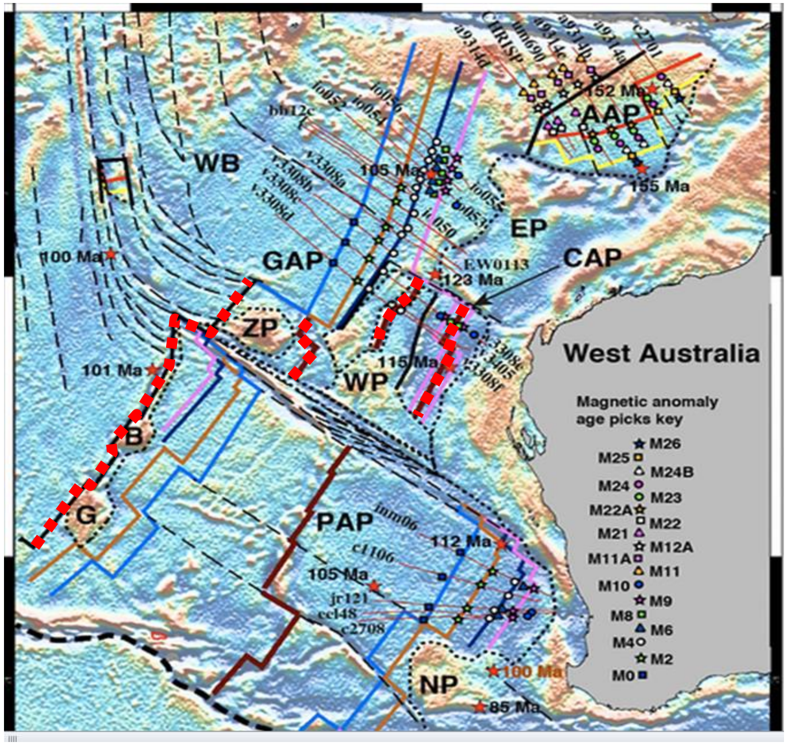
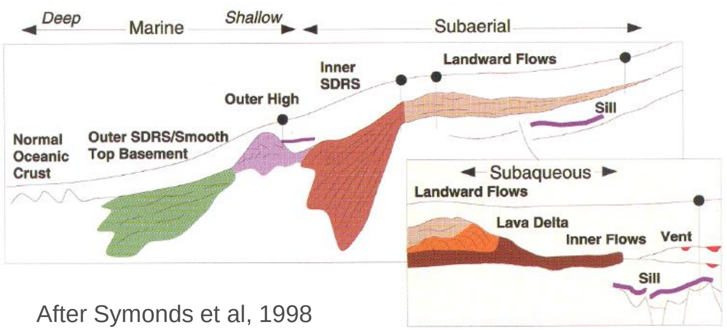


~20Ma of breaking up!

Seaward Dipping Reflector Sequences (SDRS)



After Symonds et al, 1998

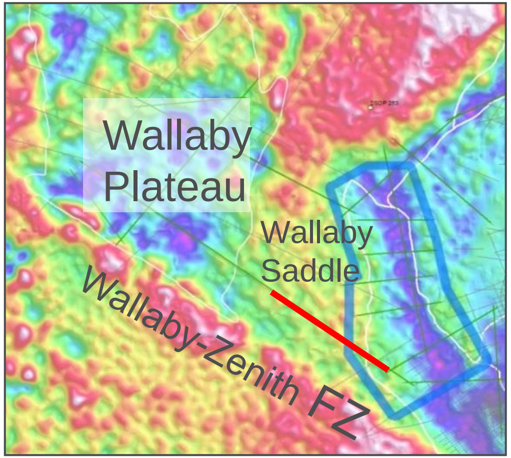
What are SDRS?

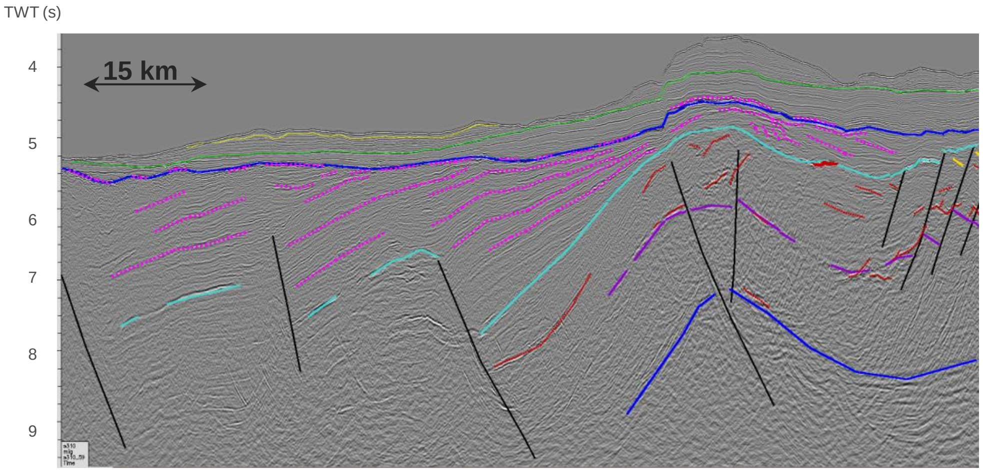
SDRS are composed of 5-10 km thick interbedded subaerial volcanic flows, volcaniclastic and non-volcanic sediments.

Inner SDRS overlie transitional crust, outer SDRS – oceanic crust

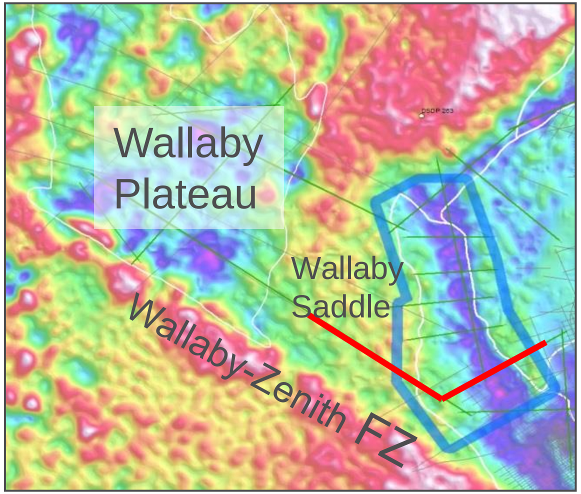
SDRS on the Wallaby Plateau:

- Dipping to the WNW
- 2-3 s thick (4 - 6 km)



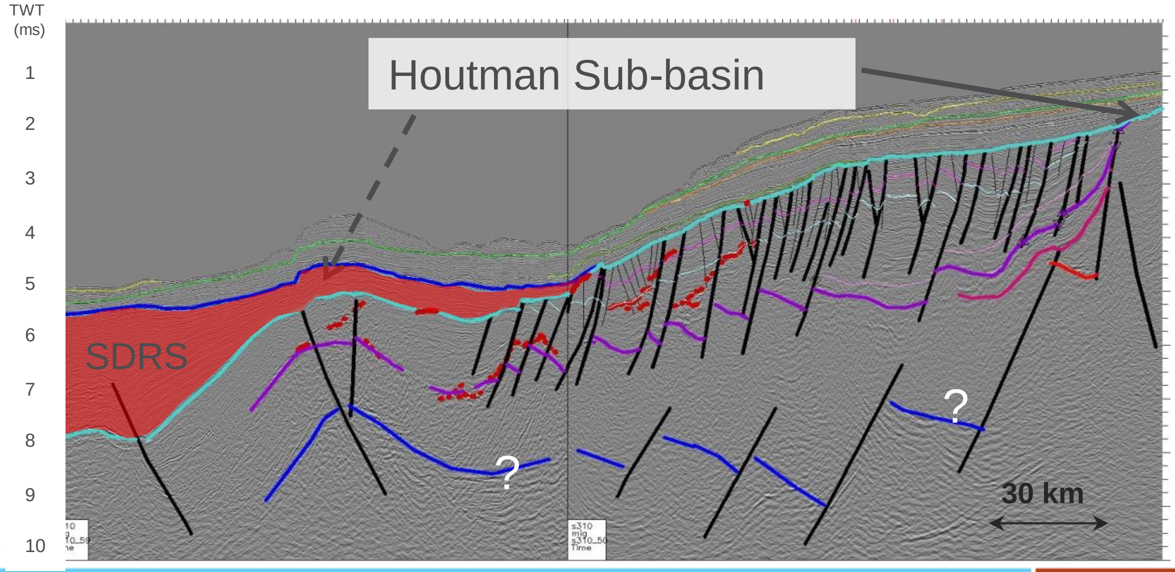


Volcanic margin

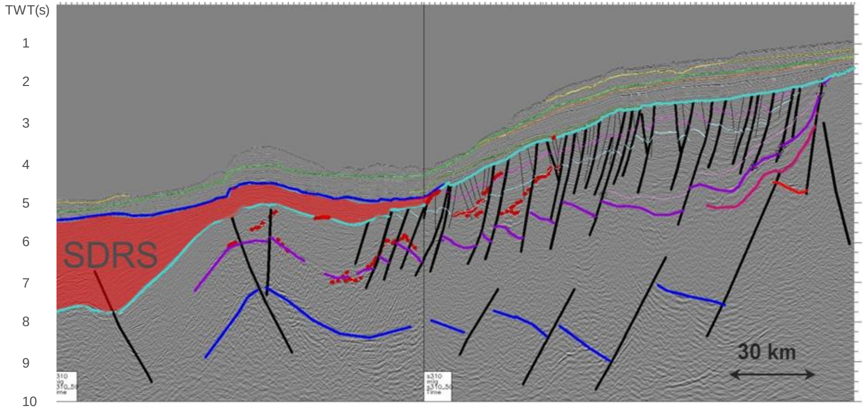


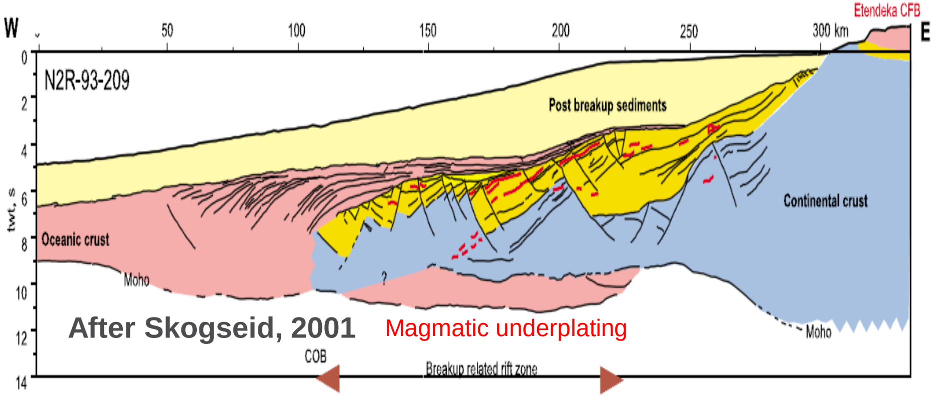
How thick is the basin underneath SDRS?

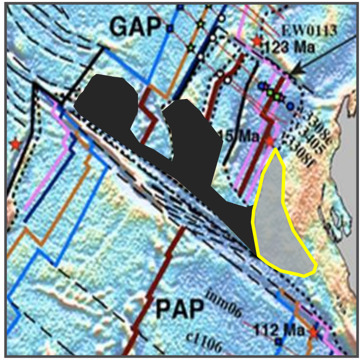
- Inner SDRS appear to overlie outboard part of the Houtman Sub-basin
- Two regional unconformities:
  - breakup of the margin (Valanginian)
  - breakup in the Wallaby Plateau/Saddle area (Barremian?)

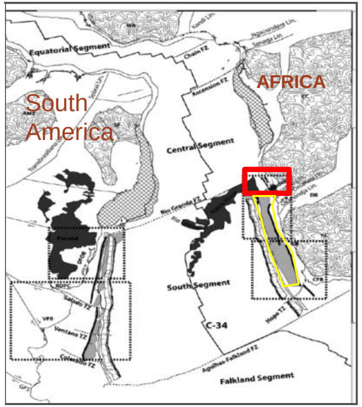


Wallaby Zenith margin vs Namibian margin









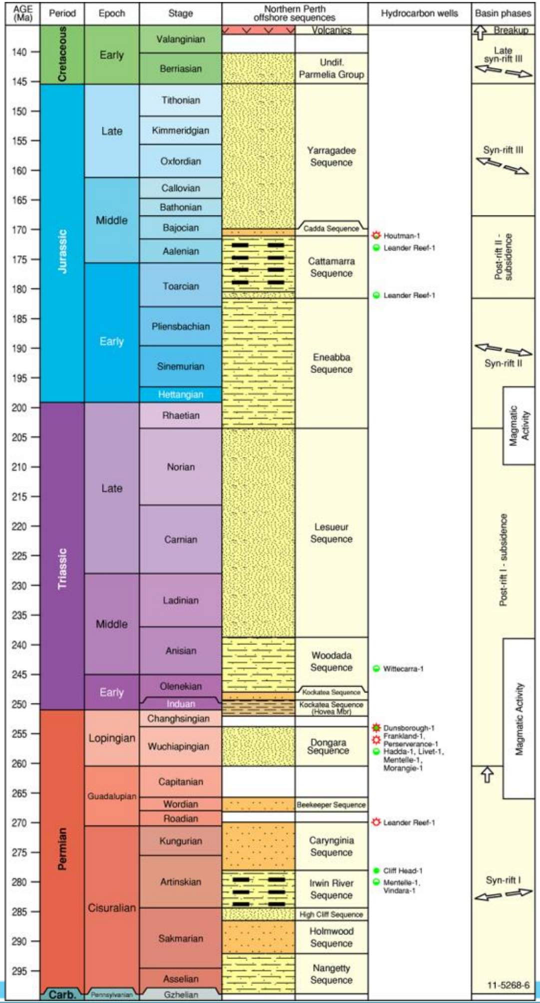
Volcanic transform margin

Similarities in overall architecture:

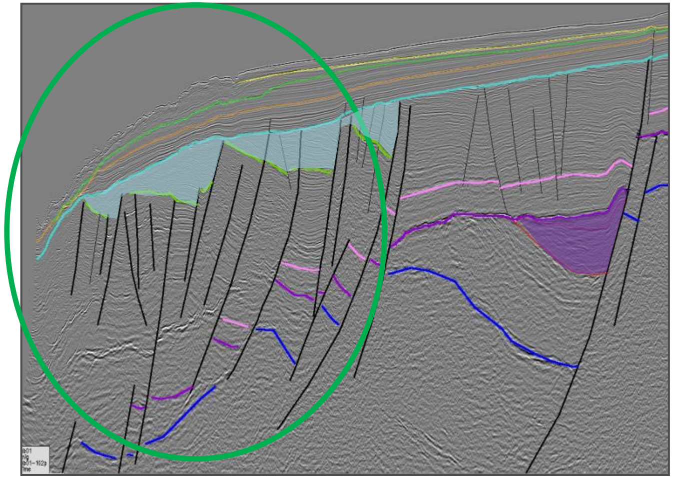
- A series of volcanic plateaus (LIP) extending along the transform margin
- Outboard part of the basin buried under SDRSs
- Large number of sill and dykes closer to SDRSs

Is formation of the LIPs linked to evolution of the transform margin?

Recent numerical modelling of melt generation on rifted margins (Koopmann et al, 2014) showed that crustal-scale transfer faults act as rift propagation barriers and lead to excessive magmatism.



Tectono-stratigraphy of the Houtman Sub-basin



Three phases of rifting:

Permian

Early Jurassic

Late Jurassic/Early Cretaceous

Two major uplift events:

Mid/Late Permian

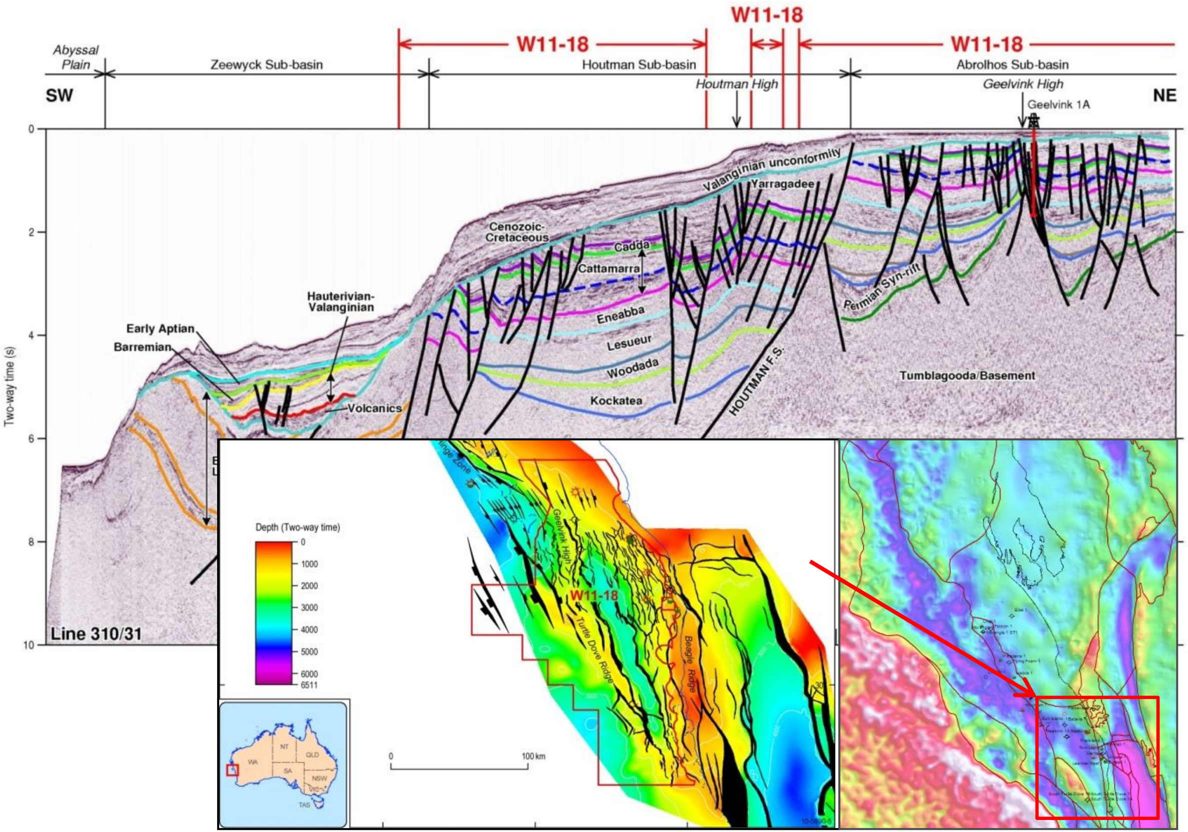
Early Cretaceous

GA North Perth study:

Jones et al, 2011

Rollet et all, 2013

Structure in the southern Houtman Sub-basin

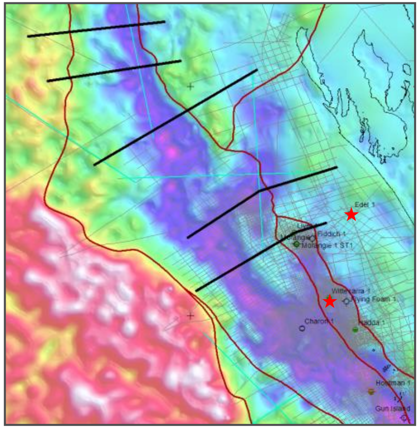


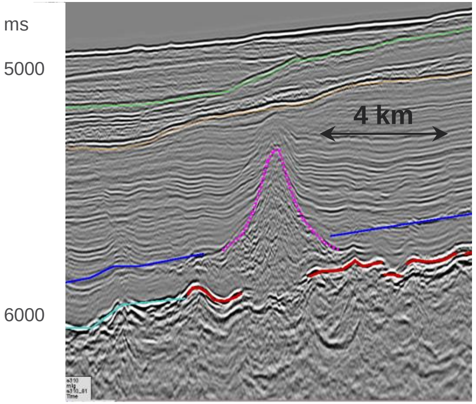
N-S trending Permian rifts incising into Ordovician “basement”

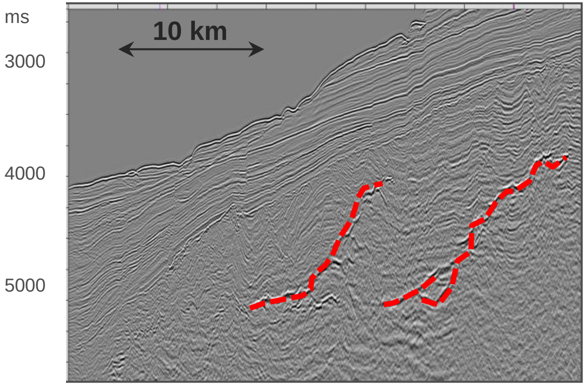
NW-SE trending Jurassic fault system influenced inboard by Permian structures and transfer faults

Transpressional deformation and inversion

Summary of magmatic events







Late-Permian – early Triassic intrusions (Gorter and Deighton, 2002)

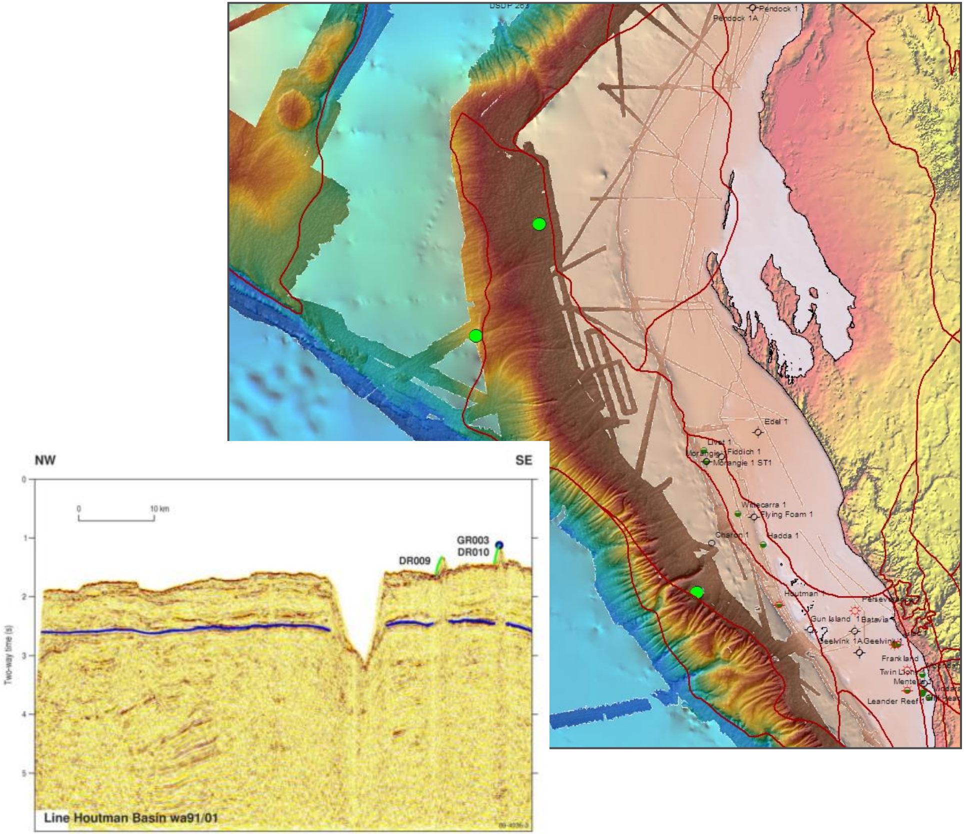
- Intersected at Edel-1, Wittecarra-1
- Not well imaged on the seismic data

Jurassic and/or Early cretaceous dykes and sill complexes

Valanginian-Hauterivian SDRS and lava lows on breakup unconformity

Barremian-Aptian(?) volcanic features in the post-rift succession

Recent volcanism – results form 2008 dredges



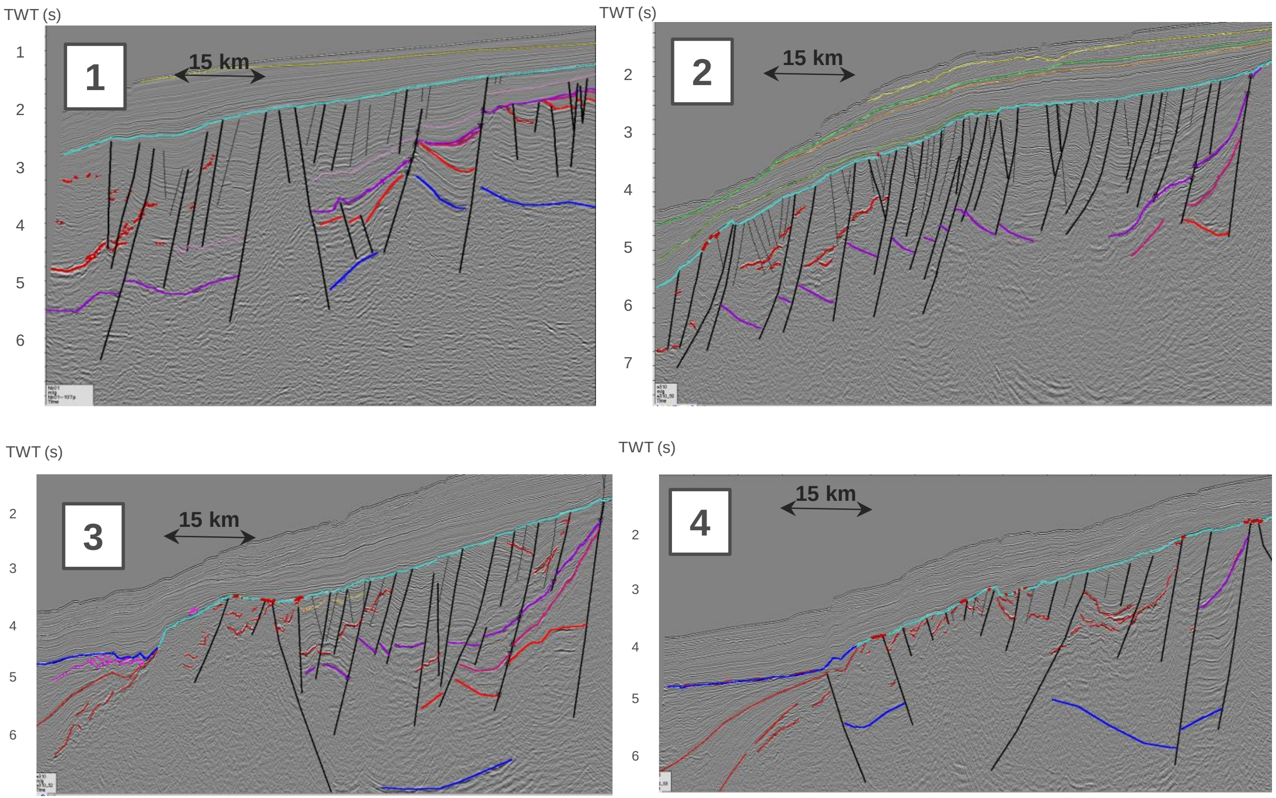
Basalt, volcaniclastic breccia and volcaniclastic conglomerate recovered at 6 sites.

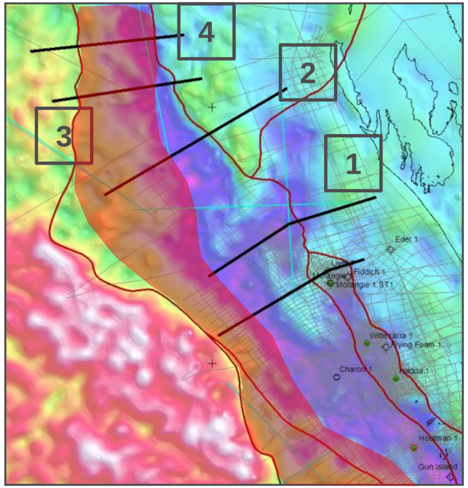
Basalts dredged from 2 volcanic pinnacles and one scarp

Analysis of samples from pinnacles (Dadd et al, 2015) - low-silica, alkalic rocks about 5 Ma old.

Geochemistry is consistent with a small degree of partial melting at the source.

Spatial distribution of sills and dykes



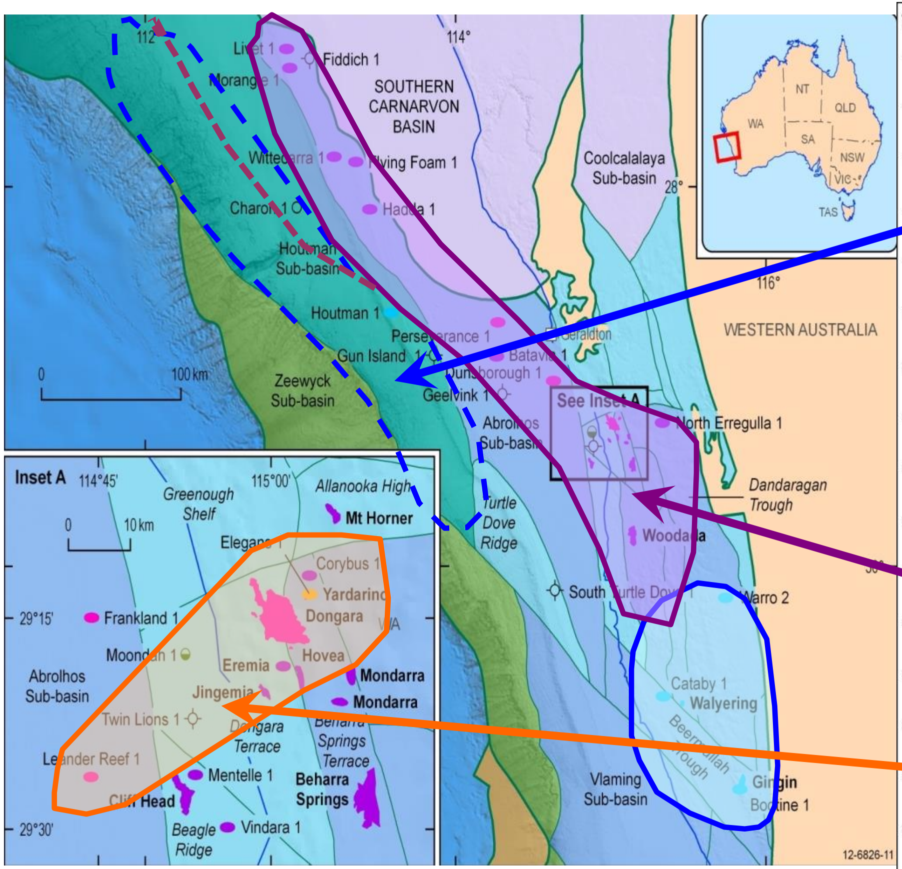


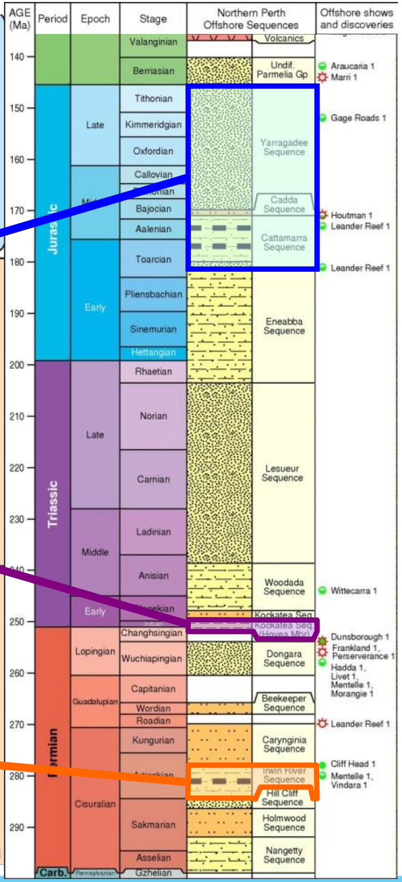
In the outboard part of the depocentre in the southern and central Houtman Sub-basin

Across the whole depocentre in the northern Houtman Sub-basin

Increase in number of lava flows on breakup unconformity

Petroleum prospectivity of the Abrolhos and southern Houtman Sub-basin

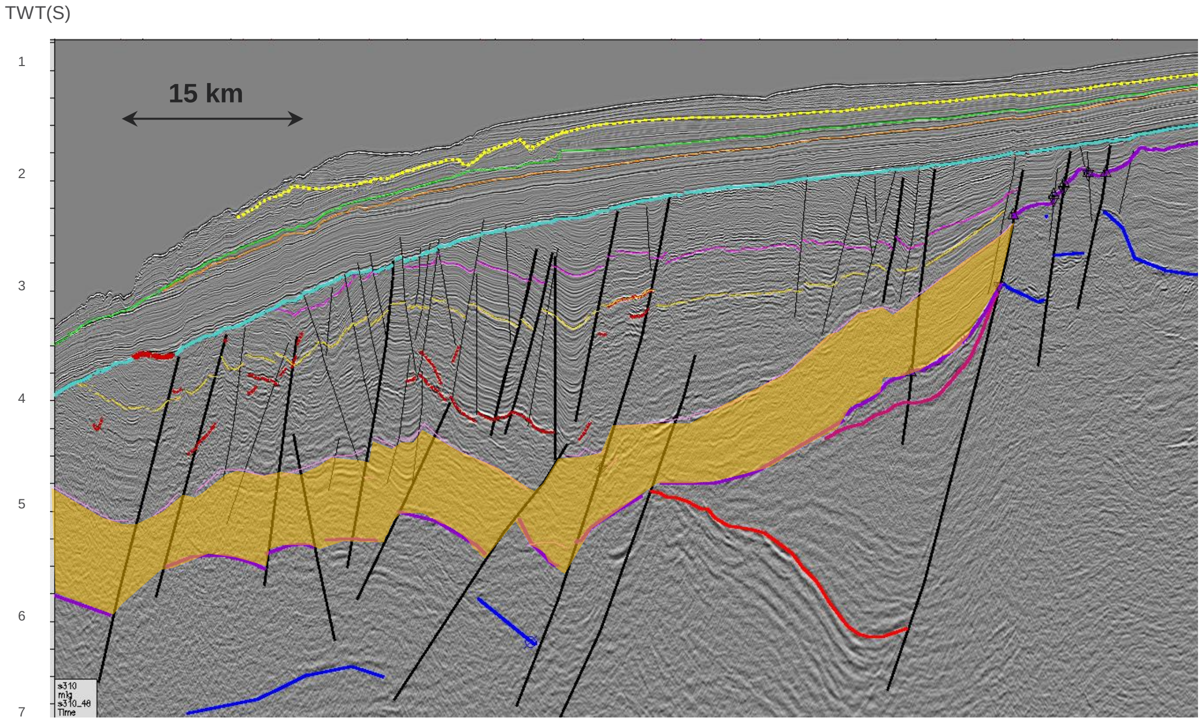




In the Abrolhos Sub-basin shows and accumulations sourced:

- from the Permian Irwin River sequence
- from the Hovea Member of the Early Triassic Kockatea Shale.
- from Jurassic Cattamarra, Cadda and Yarragadee sequences

Potential source rocks



Kockatea Shale extends at least to the centre of the study area

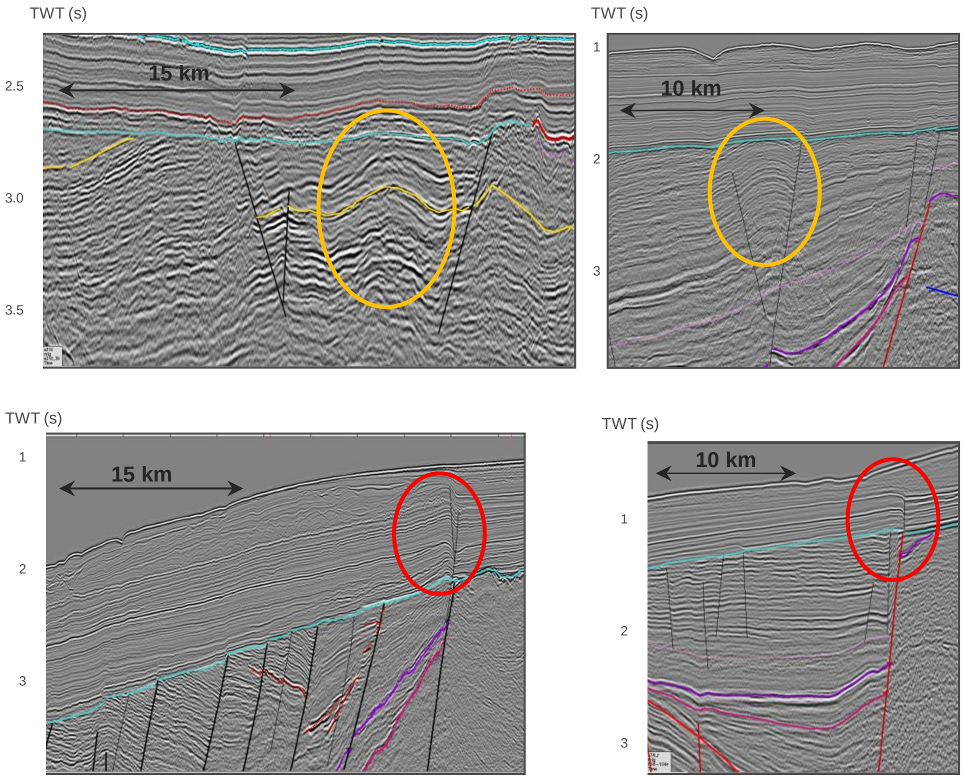
Jurassic-Early Cretaceous succession is about 3-4 km thick and is likely to contain source rocks (SR)

Maturity of the Jurassic-Cretaceous SR is unknown

It may be higher than the same age SR in the southern Houtman Sub-basin due to excessive volcanism during and after the breakup

Borissova et al, AAPG SEG, 16 Sept 2015

Possible Plays



Trapping:

Fault-block plays

Sub-unconformity plays

Synrift inversion anticlines in the synrift

Small anticlines in the postrift created by inversion of the large synrift faults

Conclusions

Northern Part of the Houtman Sub-basin contains 4 to 6 km of synrift Permian to Early Cretaceous sediments overlain by 1-1.5 km of postrift sediments

Basinal succession has similar structural characteristics and stratigraphy to the southern part of the basin, but contains increasingly abundant volcanic successions in the Jurassic-Cretaceous section

Triassic and Jurassic source rocks are likely to extend over most part of the northern depocentre

Source rock maturity in the northern Houtman Sub-basin may be higher than in the southern part due to in additional heat from continuing magmatism on the margin from the Valanginian to at least the Barremian.