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Geological evolution and hydrocarbon plays of Madagascar (with occasional reference to Australia).



Geography of Madagascar: transform margin vs passive margin

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Tsimiroro,
Bemolanga

Davy
Fracture
Zone

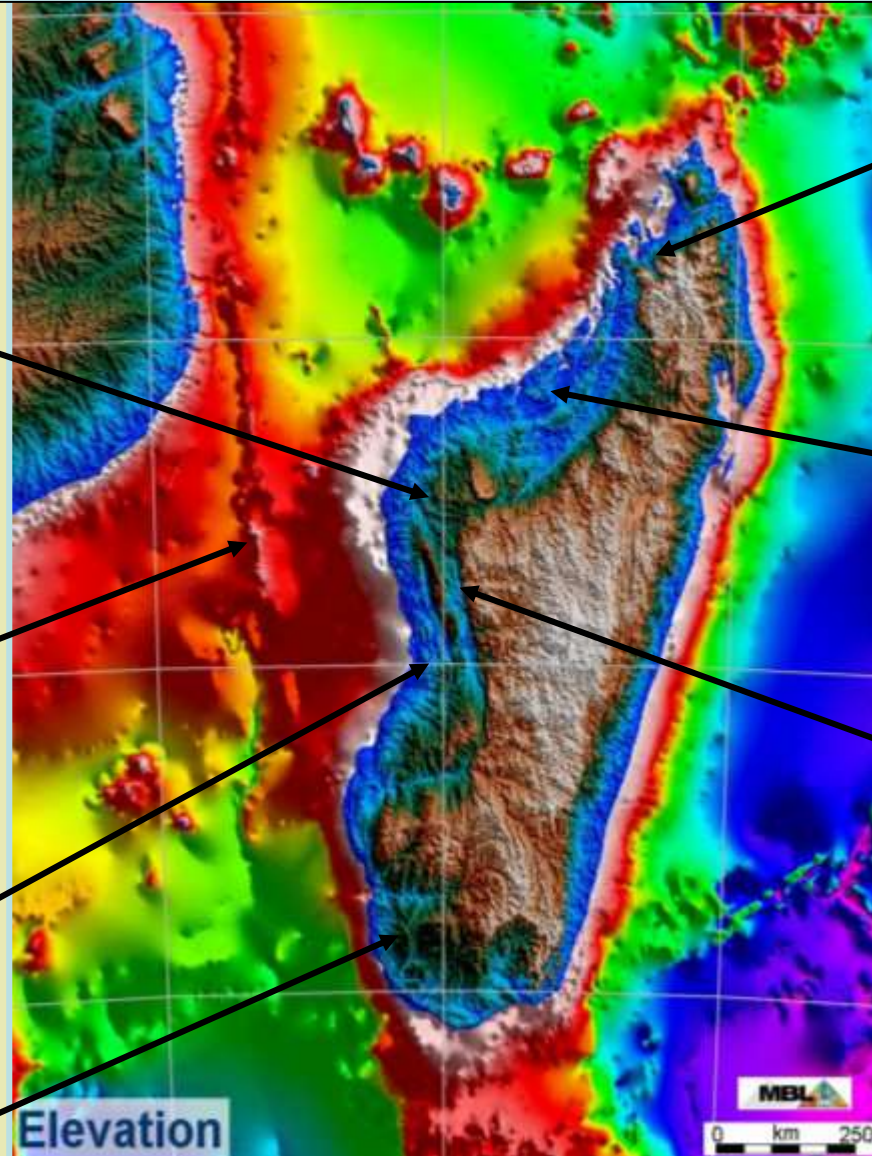
Morondava

Tulear Fault Zone

Ambilobe

Majunga

Karoo
Corridor



East Africa / Madagascar Rifting

Karoo rifting (abortive)

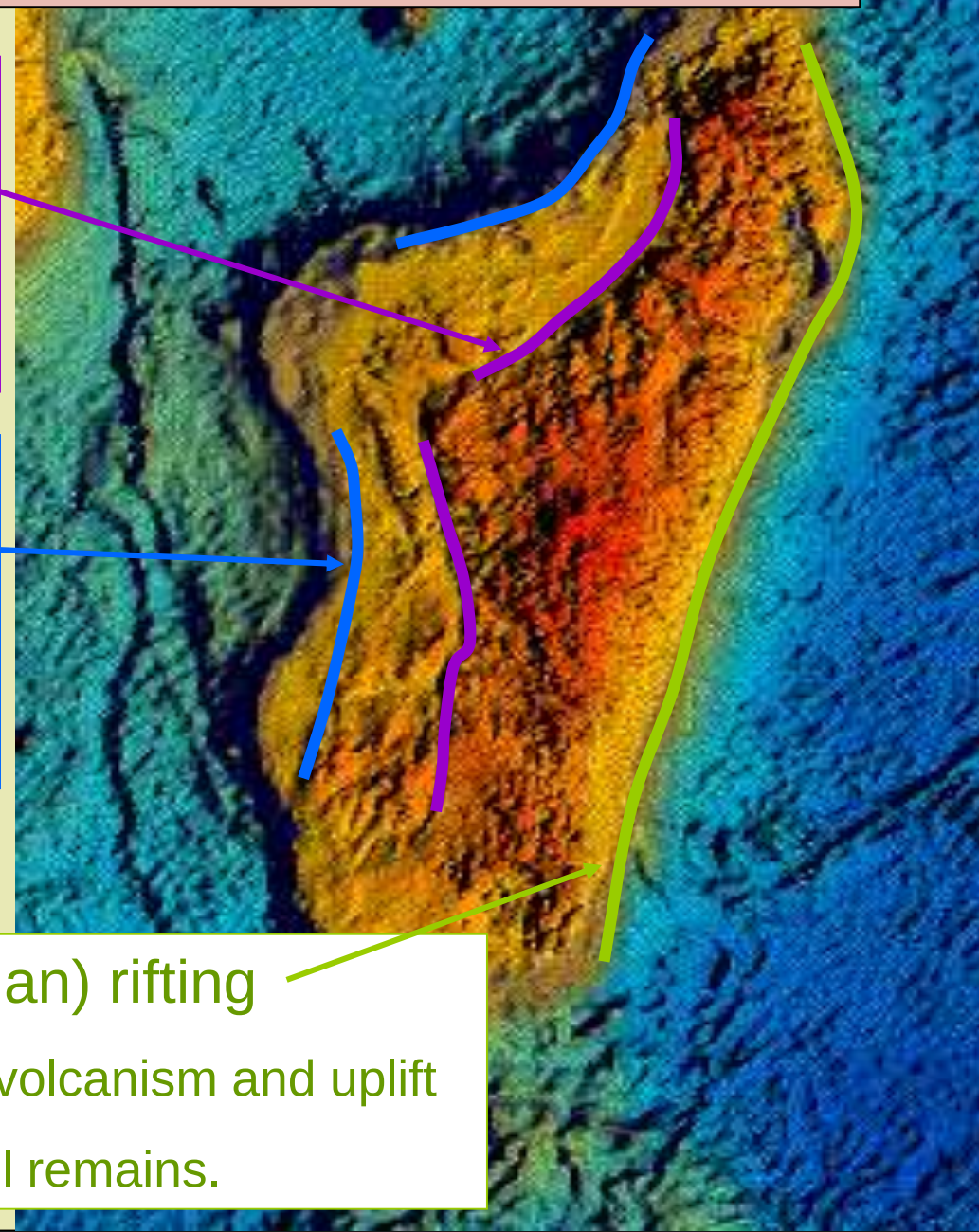
- tillites; coal
- remote from eventual line of separation

Lower Jurassic rifting

- evaporites; source rocks
- adjacent to eventual line of separation (W, E Gondwana)

Late Cretaceous (~ Turonian) rifting

- no apparent antecedents; widespread volcanism and uplift
- Wernicke style – only footwall remains.

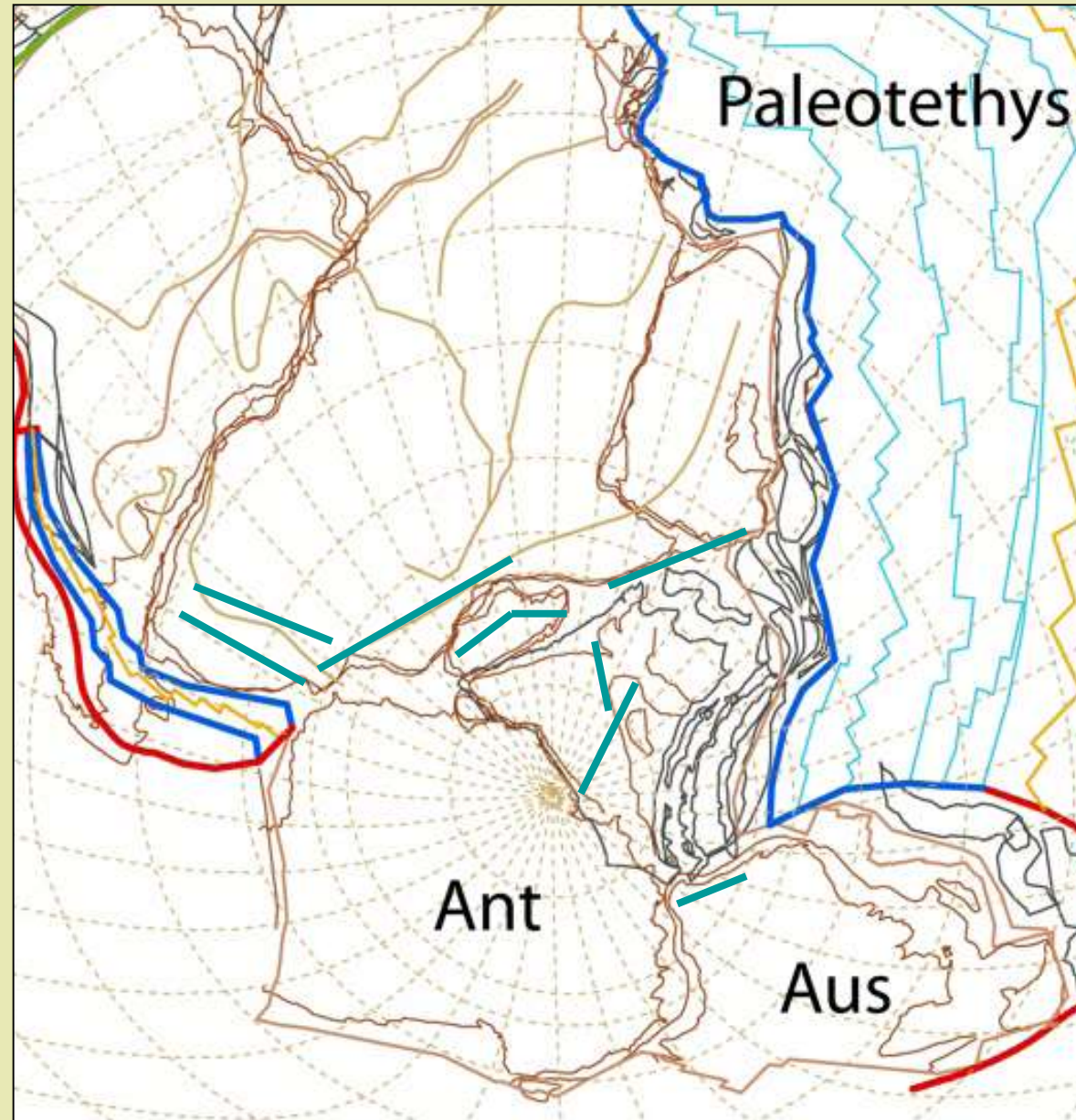


**Late Carboniferous
(~316 Ma)**

**Onset of Karroo
rifting in response
to closing of Cape
Fold Belt**

Circum polar latitudes –
Karoo glacials

(Stampfli, AAPG Search and Discovery)



Early Permian (~290 Ma)

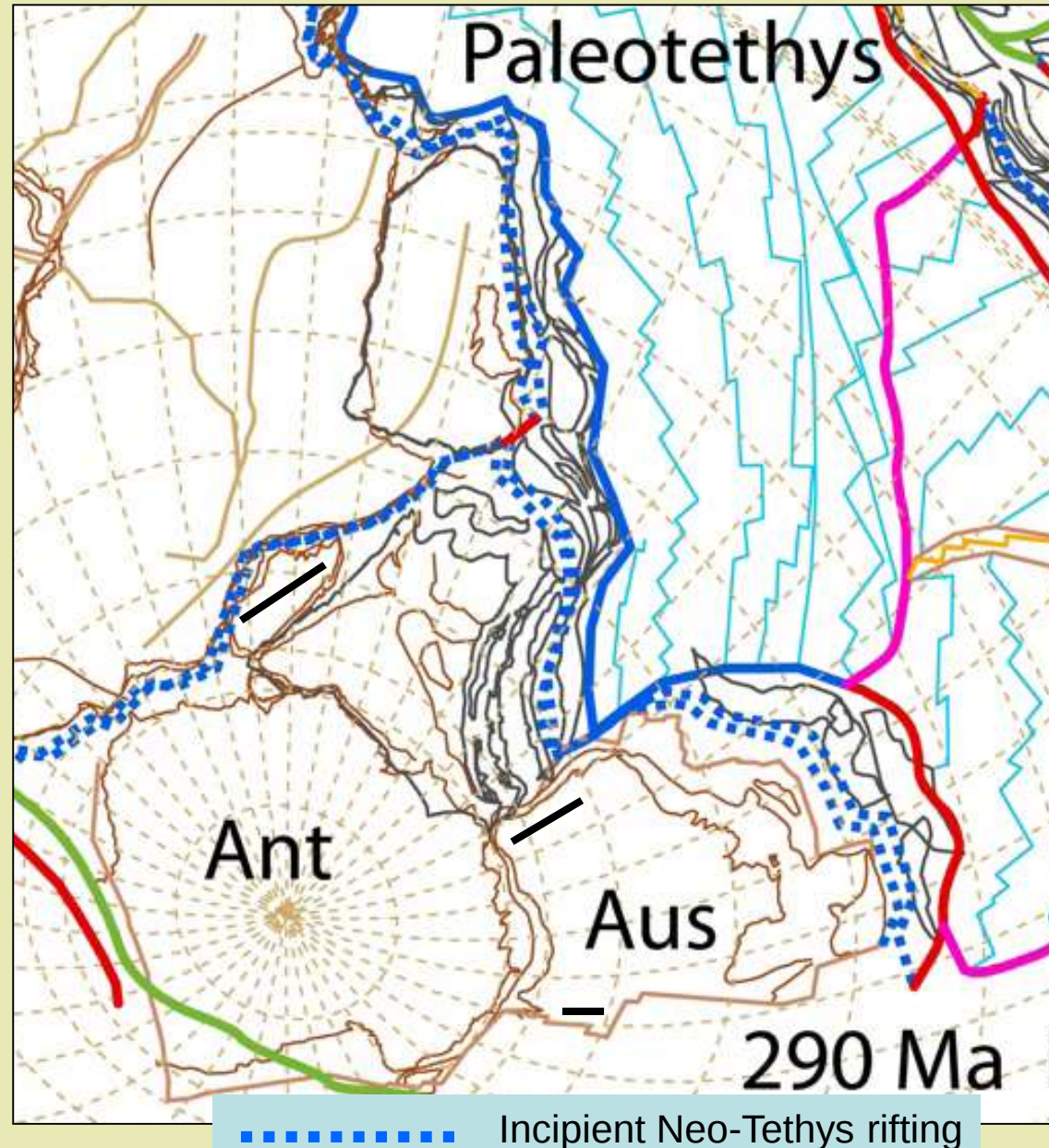
Karoo rifting continues.

Proceeds to sea-floor spreading on N margin of Gondwana; rifting off of Cimmerian continents; and opening of Neo-Tethys.

Glacials -> Coal swamps.

Intra-cratonic rifting aborted in late Permian.

(Stampfli, AAPG Search and Discovery)



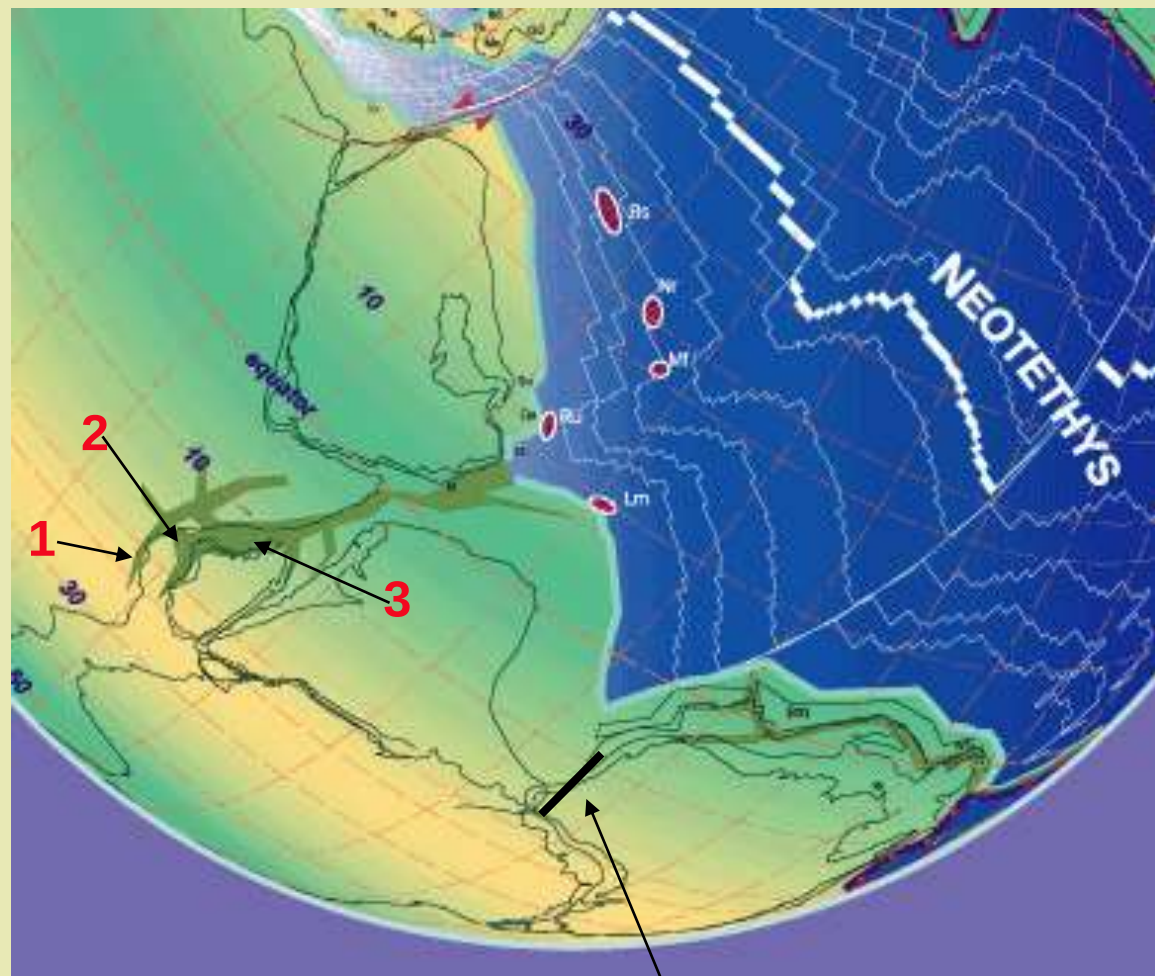
Sinemurian

**Renewed rifting in
Lower Jurassic.**

**Tropical latitudes,
salt deposition**

1. Mandawa Basin
2. Lamu Embayment
3. Ambilobe / Majunga Basin

(Stampfli, U. of Lausanne)



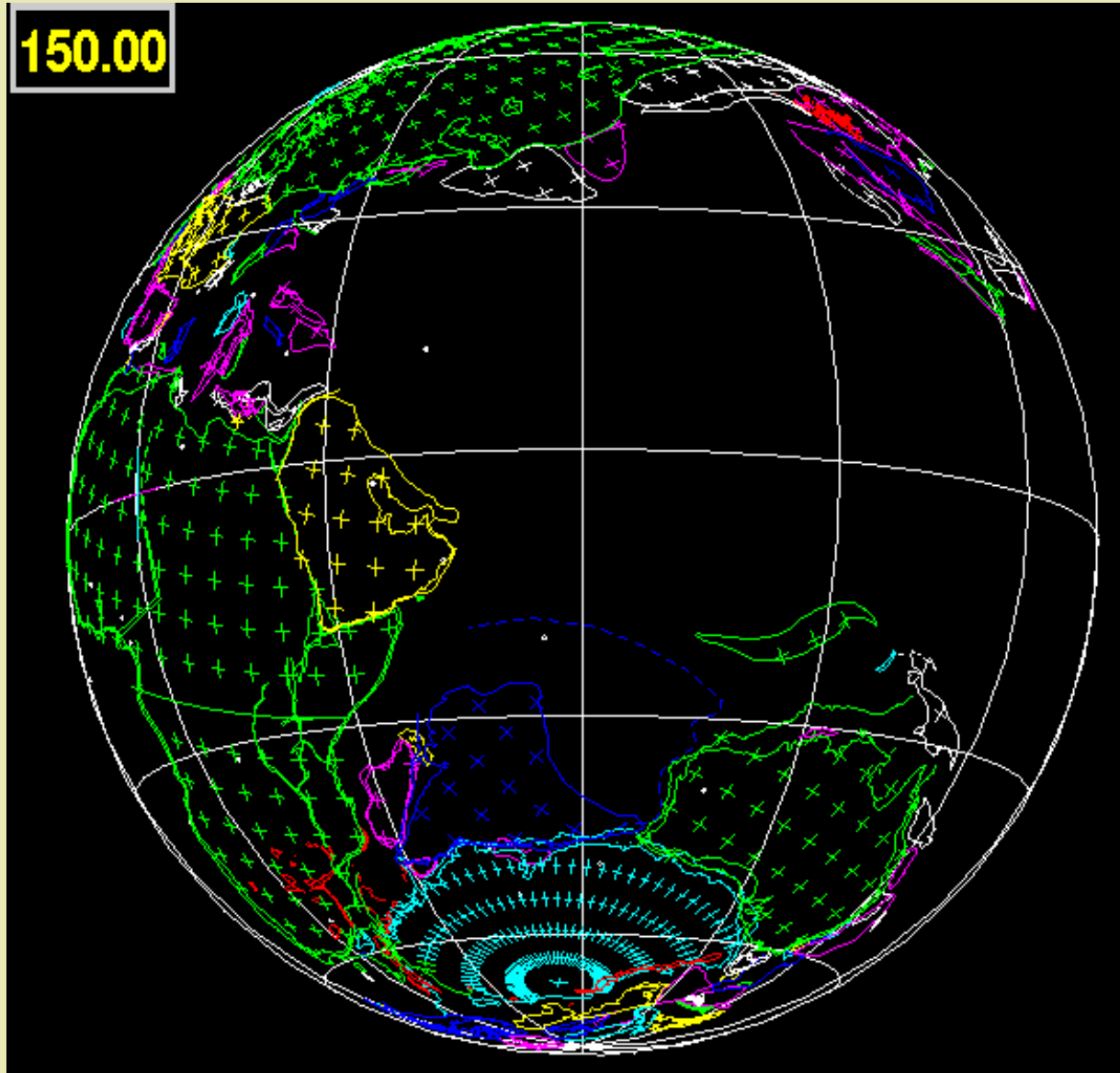
Rifting in Perth Basin slightly later

Kimmeridgian

Rifting proceeds to separation; East Gondwana drifts south along Davy Fracture Zone

First sign of rifting between Australia and Argo Plateau

www.cornell.org

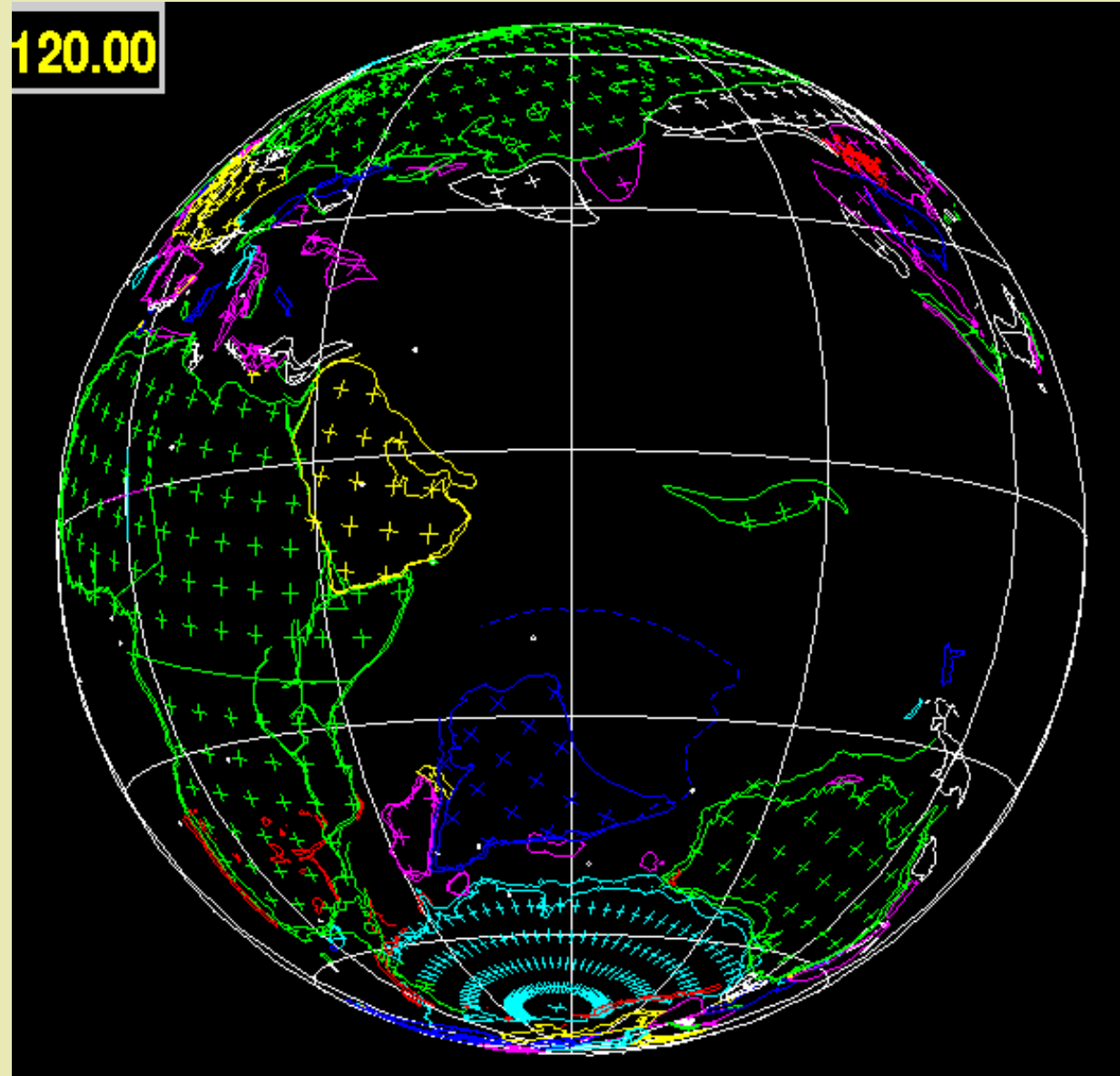


Early Aptian

**Madagascar
reaches current
location w.r.t.
Africa.**

**Australia separated from
India (~135 Ma).
India/Antarctica rifting**

(www.cornell.org)



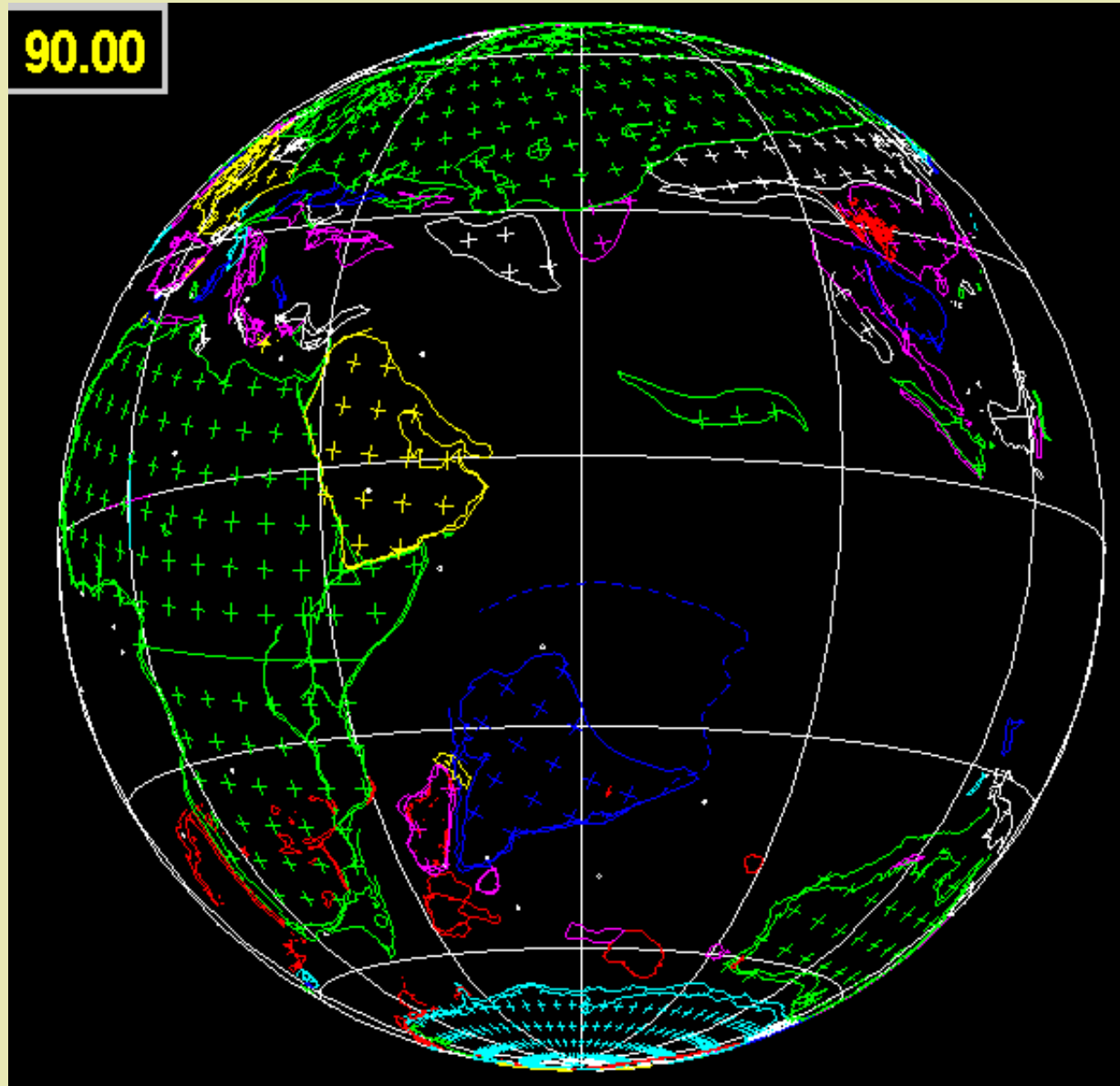
Turonian

**Onset of rifting of
Madagascar from
Seychelles + India.**

**Volcanism, uplift,
unroofing of Madagascar**

**Australia / Antarctica
rifting, and onset of
opening of Coral Sea**

(www.cornell.org)



Turonian volcanics, and unroofing

Dogger shelf margin

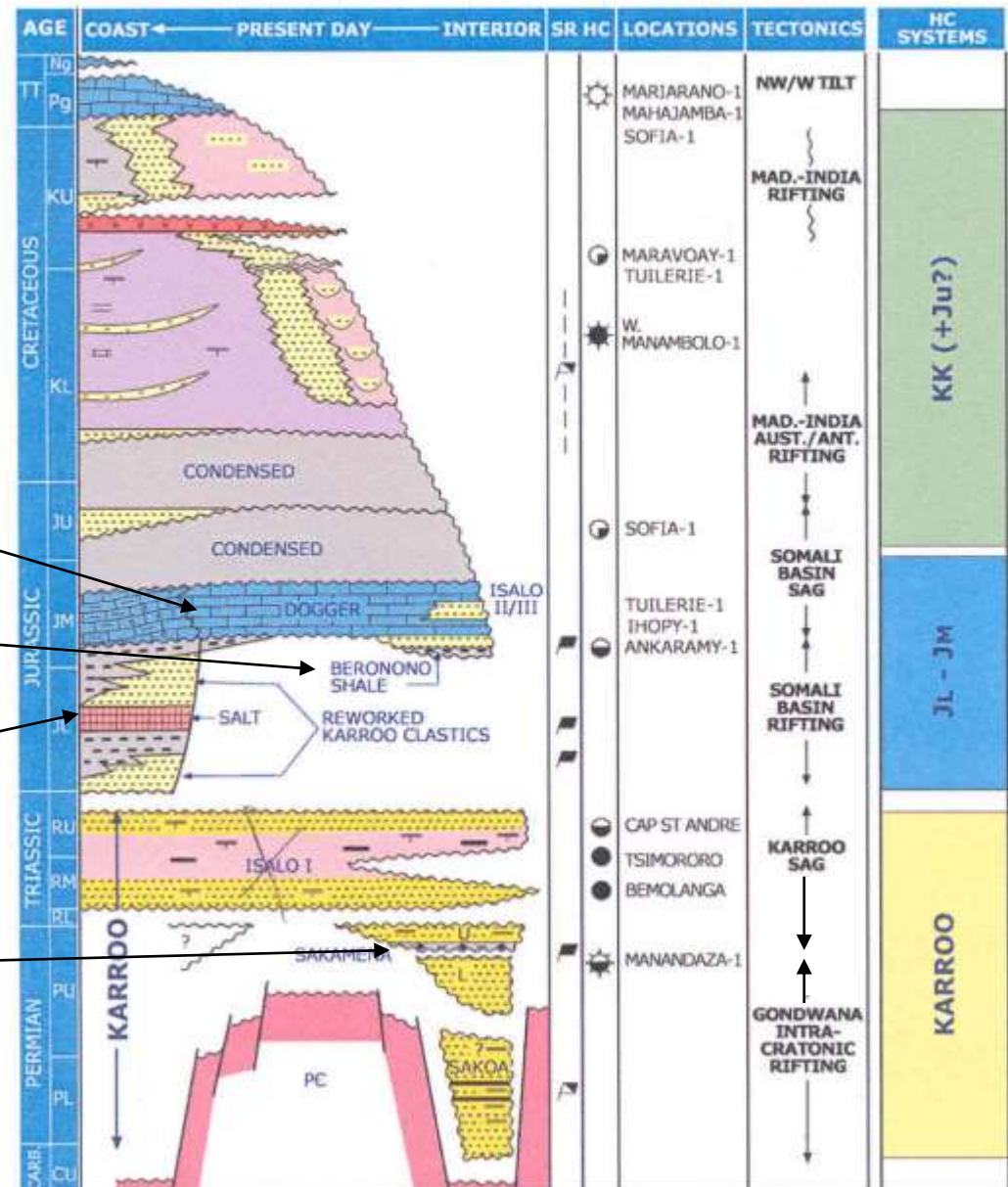
Regional inboard J_L / J_m unc

J_L salt deposition in outboard rift basins

P – Tr boundary, and TrL source rock in Manadaza-1

Summary stratigraphy of western Madagascar

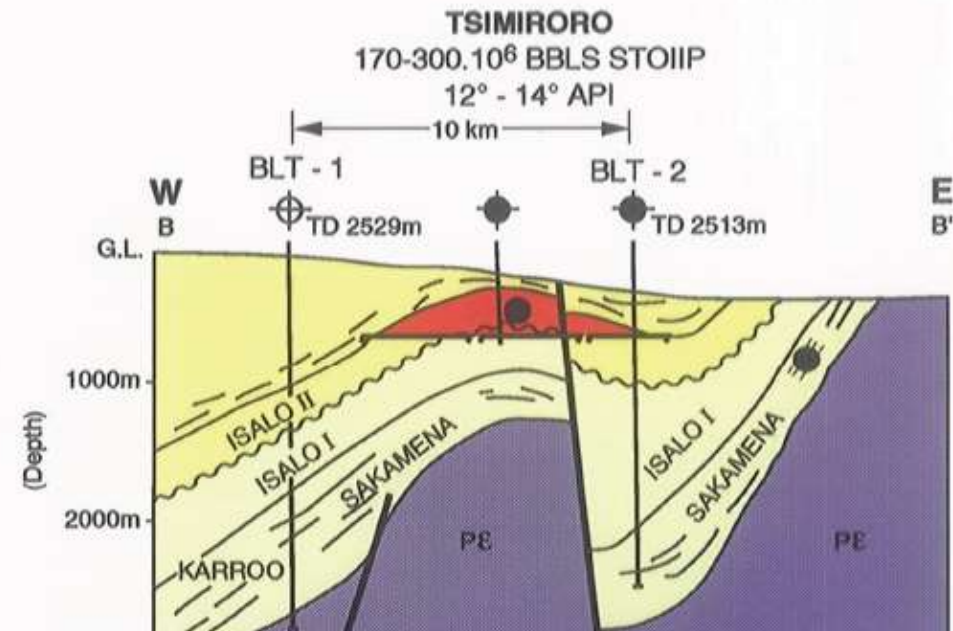
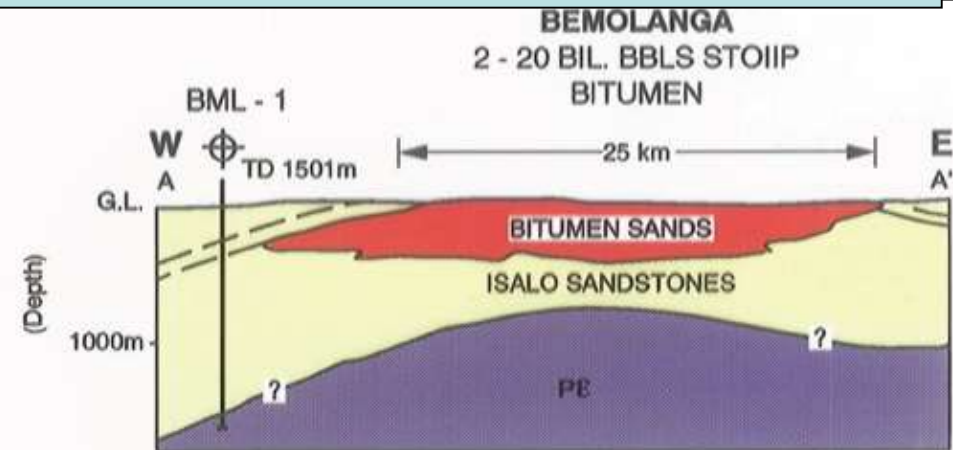
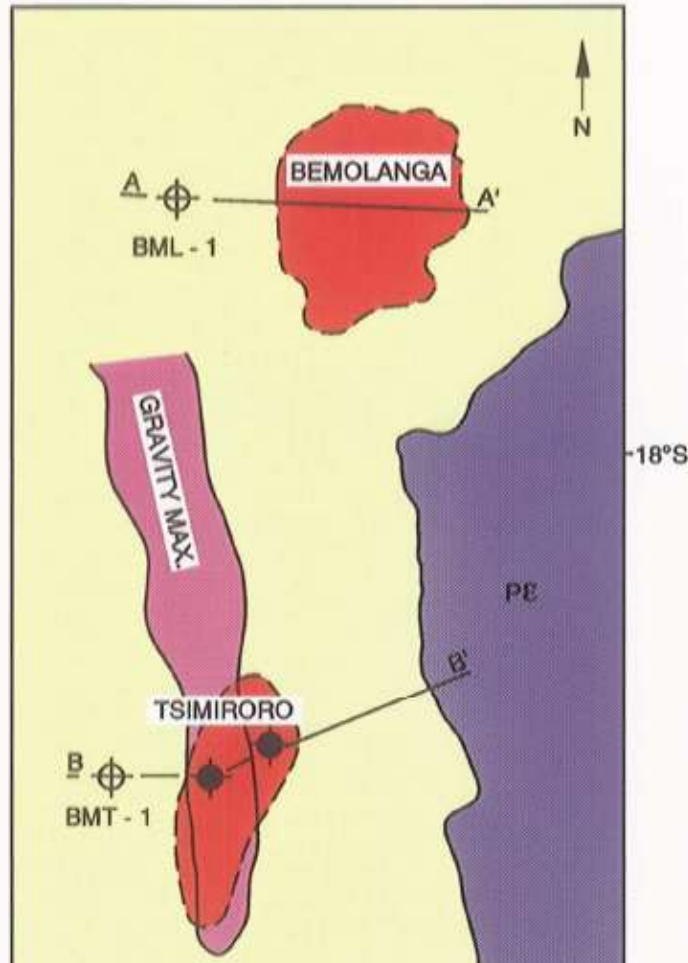
(adapted with significant changes from Jeans and van der Meerbeke, 1996)





Early 1900s: first major HC discovery in Madagascar were the tar sands and heavy oils of Bemolanga and Tsimiroro

**MALAGASY
MORONDAVA BASIN**
BITUMEN-HEAVY OIL
ACCUMULATIONS



Tsimiroro (2008): 1.3 BBO (STOIIP). Steam pilot on line 2008; 14 API. Steam flood expected to increase RF from 15% to >50%



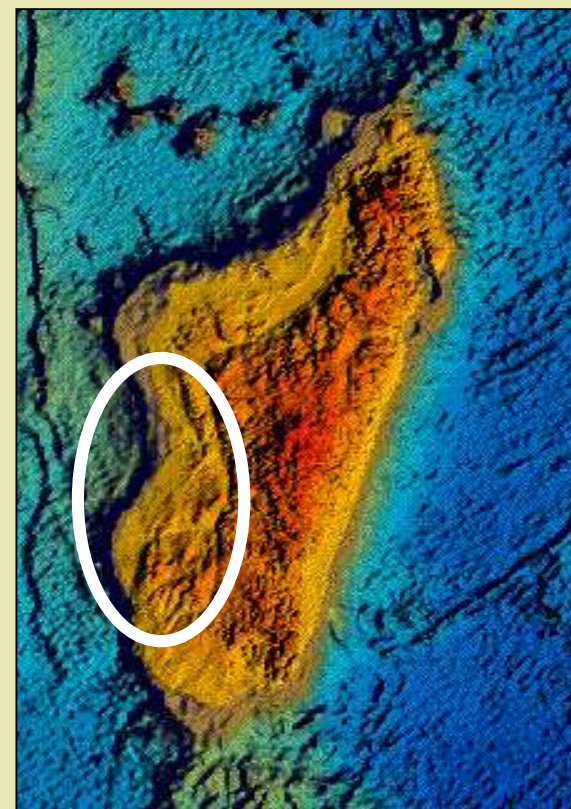
After the heavy oil discovery, the various plays of Madagascar have been successively targeted by many Opcos:-

- Karroo rifts: Shell / Amoco (1988-1993) and others earlier; Majunga Basin, Karroo Corridor. **Manandaza-1: 10 bbls 41 API oil.**
- Ju - Ku passive margin: Amoco and many others(?); Morondava Basin on and offshore. **West Manambolo: 17 mmcf/d + cond.**
- Dogger limestone platform margin: Hunt (1998-2000); Majunga Basin
- TT basin fill : Agip (1971); offshore Majunga. **Gas tested (n-c)**
- Jurassic syn-rift play: Wilton, Exxon, Sterling, and Roc; coastal and DW Majunga, Ambilobe, and Morondava Basins. **To be tested 2009+**



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KARROO CORRIDOR / MORONDAVA BASIN



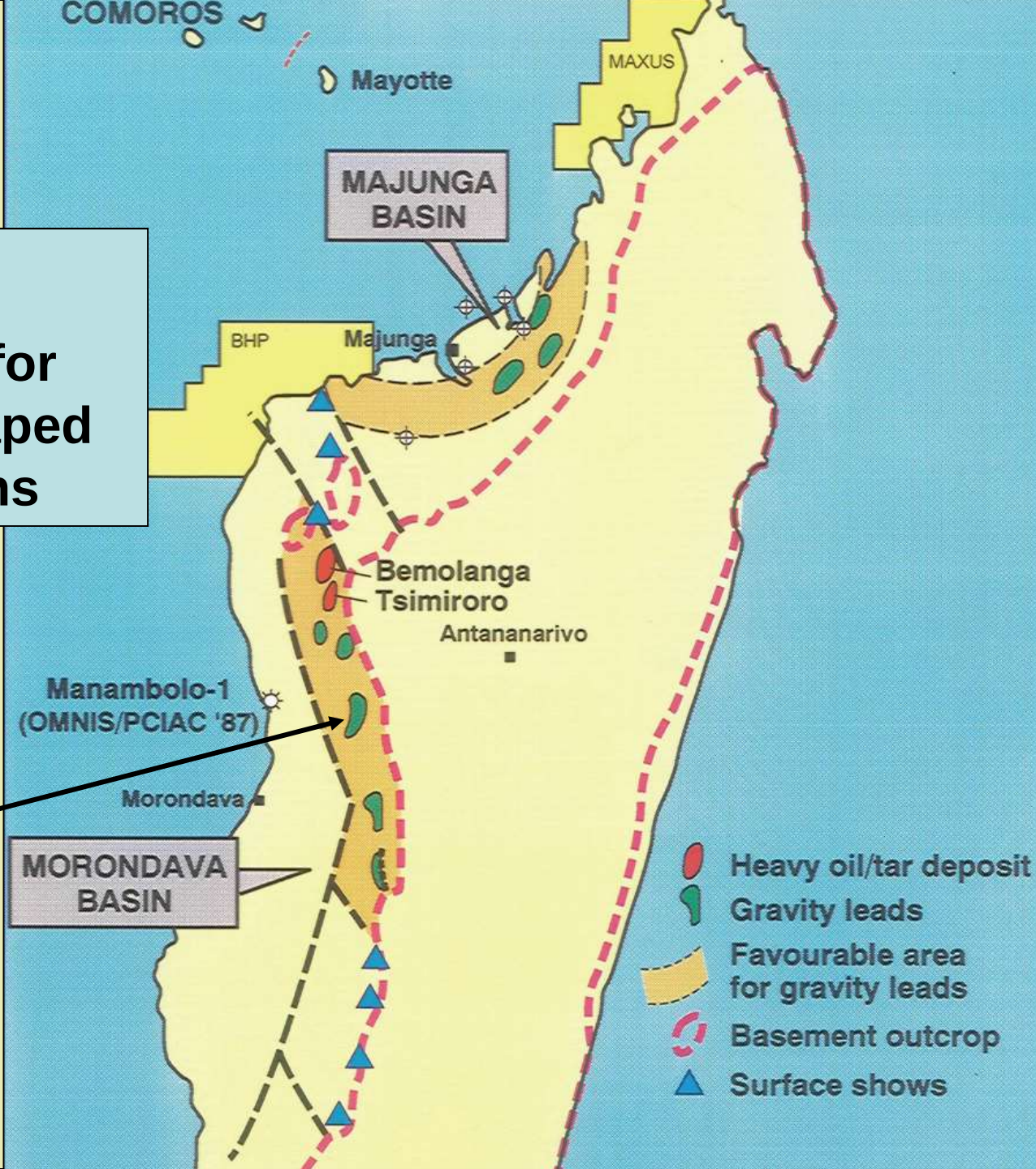


Madagascar

Gravity-driven play for
Karoo structures draped
over basement highs

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Eventually drilled as
Manadaza-1



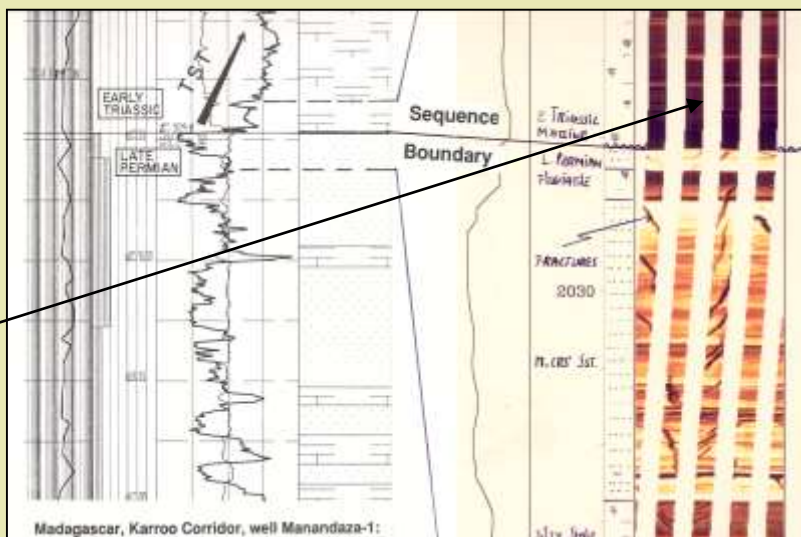


Manandaza-1:

Permian Lwr Sakamena sands had 100m oil column sealed by base Trias shales (source rock).

Phi av. = 4%, max 10%, Sw~50%.

Rec ~10 bbls 42 API oil w ~20% BSW.



TrL shale
equiv to
Kokatea Sh
of Perth
basin

Jurassic scarp

Karoo Corridor

BASE ISALO II
FAULT/DIP CLOSURE

MANANDAZA-1

89-KA-04
MIGR.

2 KM

BASE ISALO II

TOP MIDDLE SAKAMENA

BASE MIDDLE SAKAMENA

MIDDLE-LOWER
SAKAMENA
FAULT/DIP CLOSURE

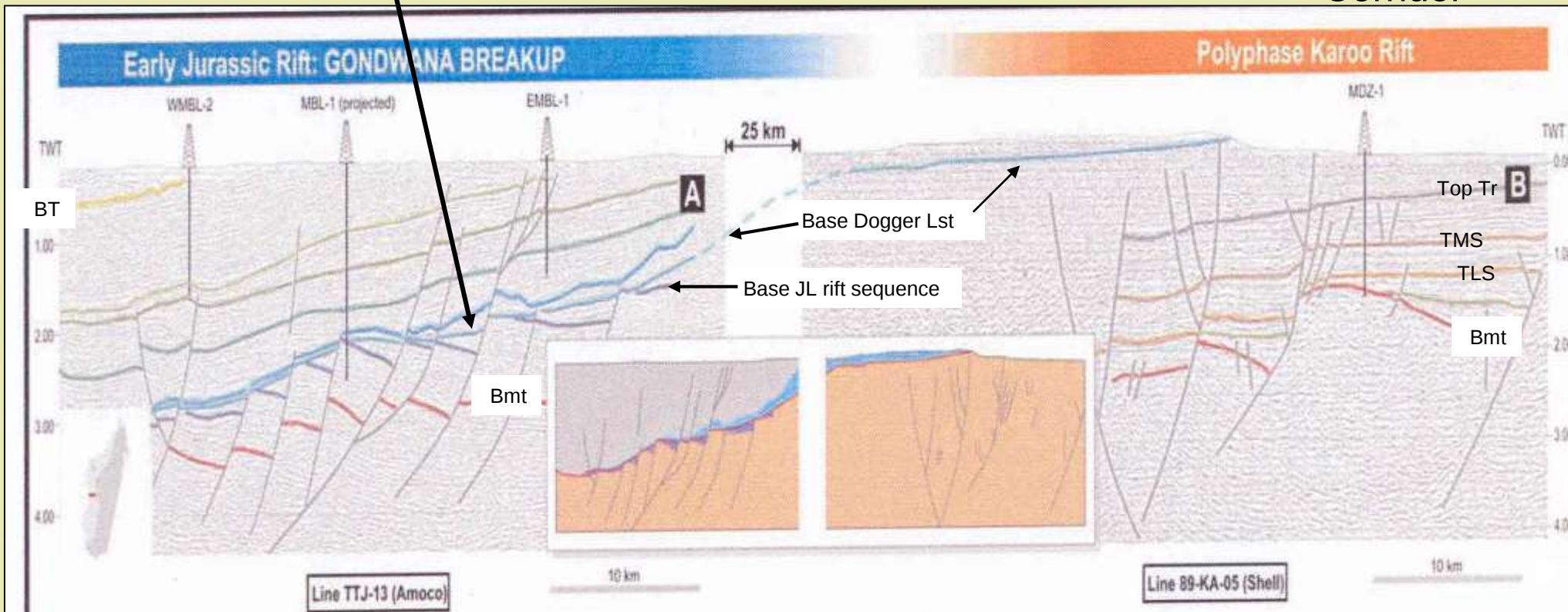
TOP BASEMENT

TD 2508m



3 wells in Morondava Basin
found Jm-JL black shales,
Toc upto 5%

Karoo
Corridor



Welch, R, and G. Hyden (2005), HGS / PESGB 4th Conf on Africa E&P. Vert scale = 4.5 s TWT, section ~ 150 km long.

Location of section on next slide

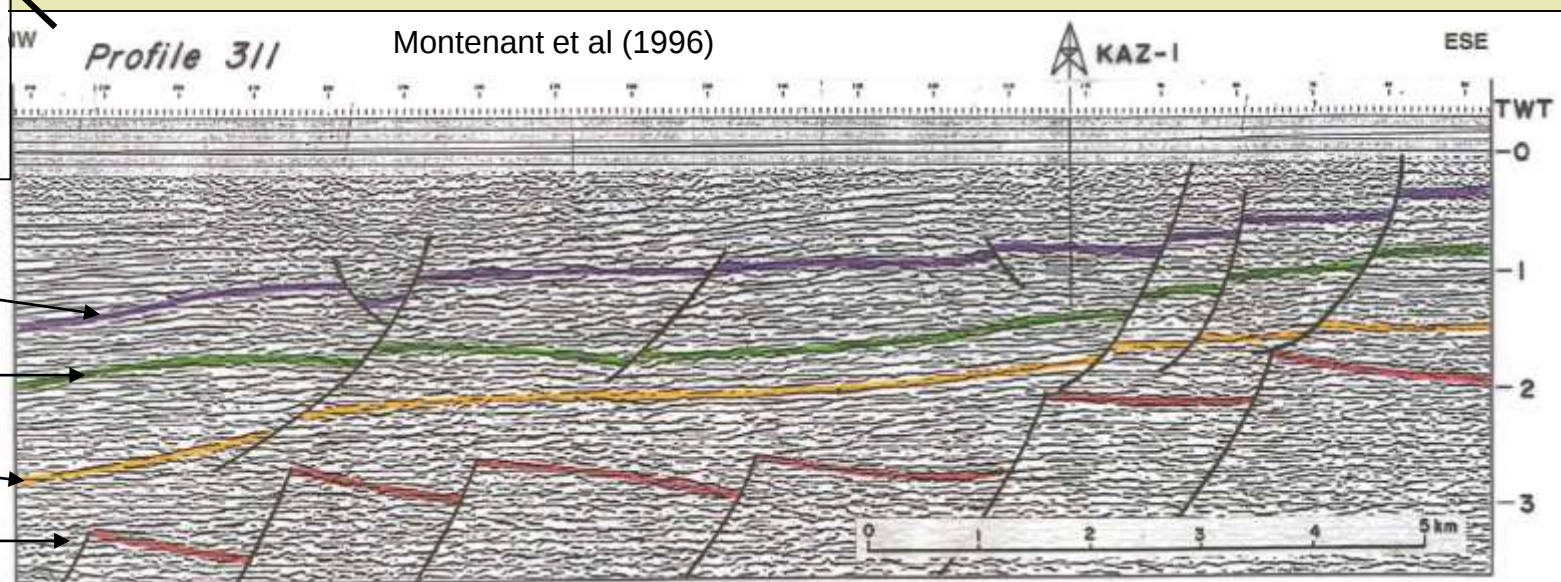
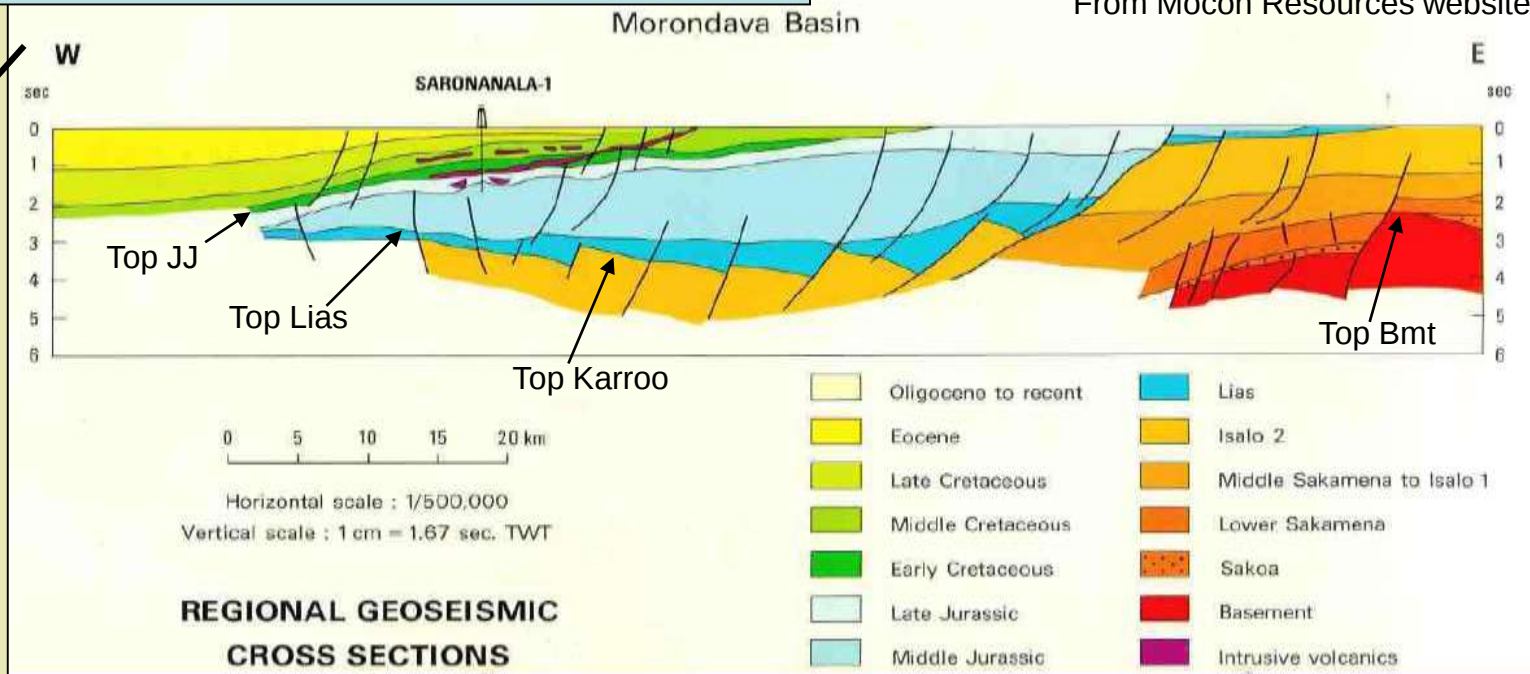
Section across Morondava Basin showing the transition from first cycle Karoo rifting inboard (E), to second cycle JL rifting outboard(W)



Cross sections from Morondava Basin showing outboard Liassic rift basins

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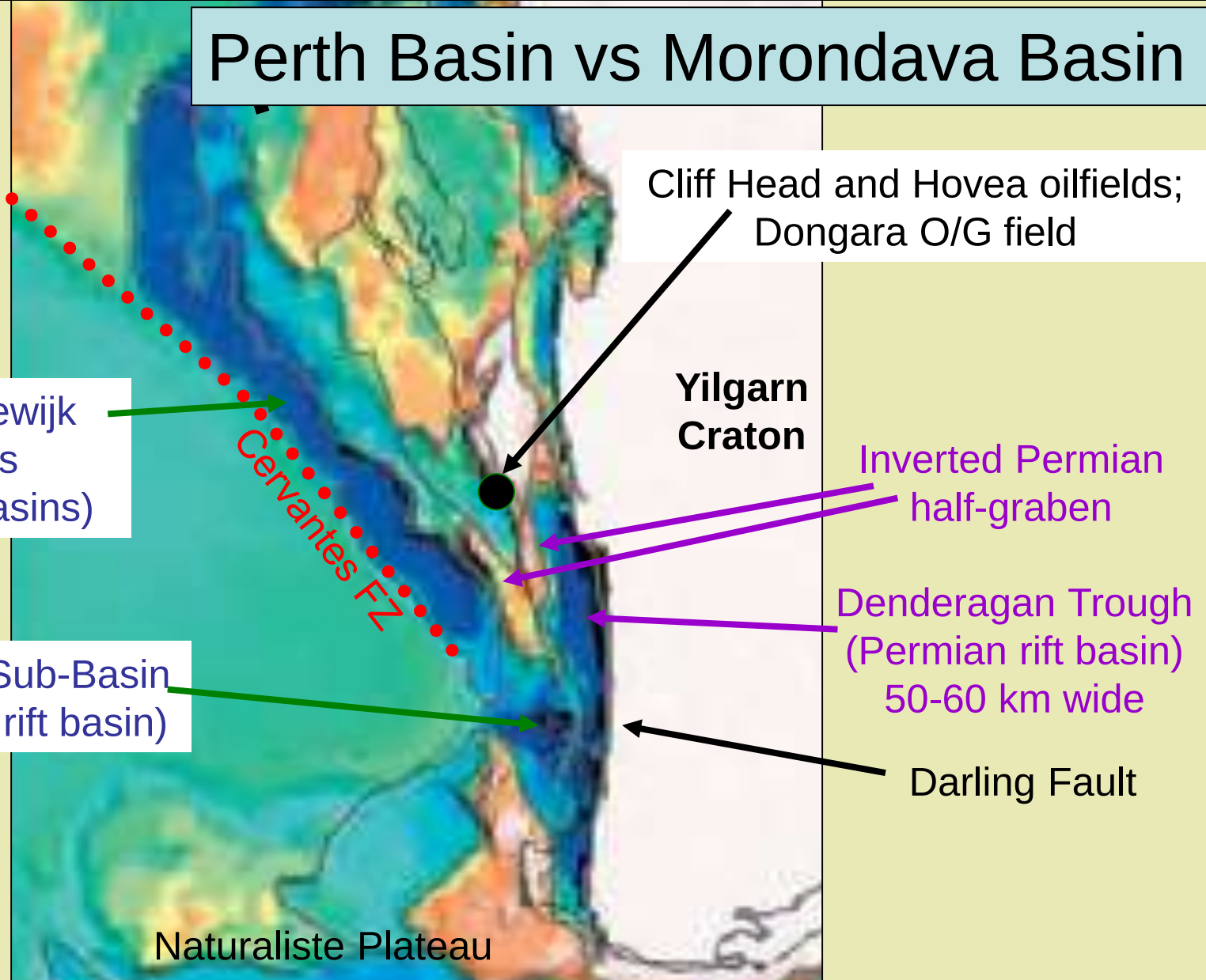
From Mocoh Resources website



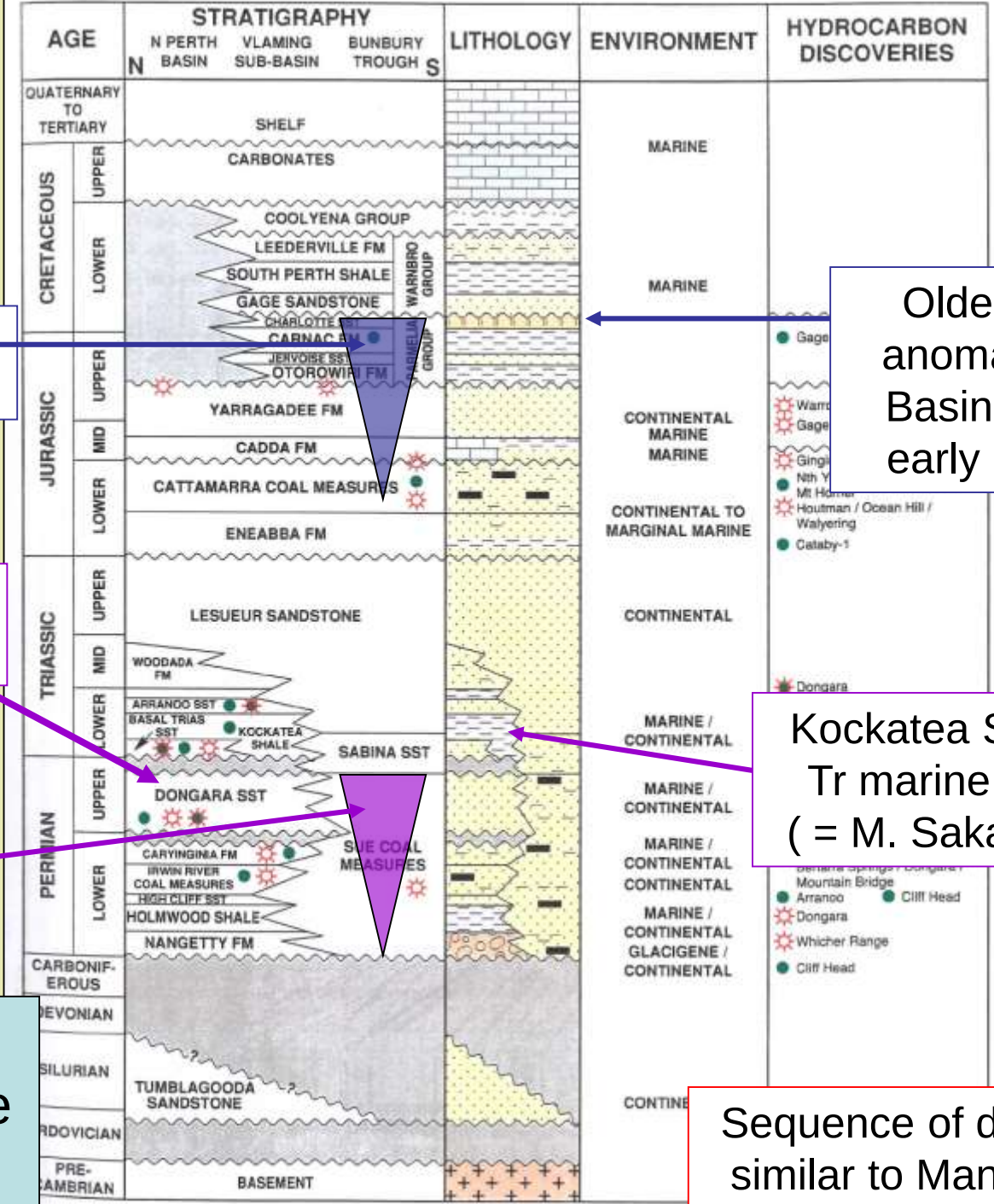


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Perth Basin vs Morondava Basin



Both have N-S elongate Permian rift basin in East, ~50 - 60 km wide, adjacent to Basement, with Jurassic rift basin outboard. Difference is that Morondava is a passive margin, whereas Perth suffered oblique extension



JL – KL rifting (successful)

Oldest sea-floor anomaly (Vlaming Basin = 135 Ma = early Hauterivian).

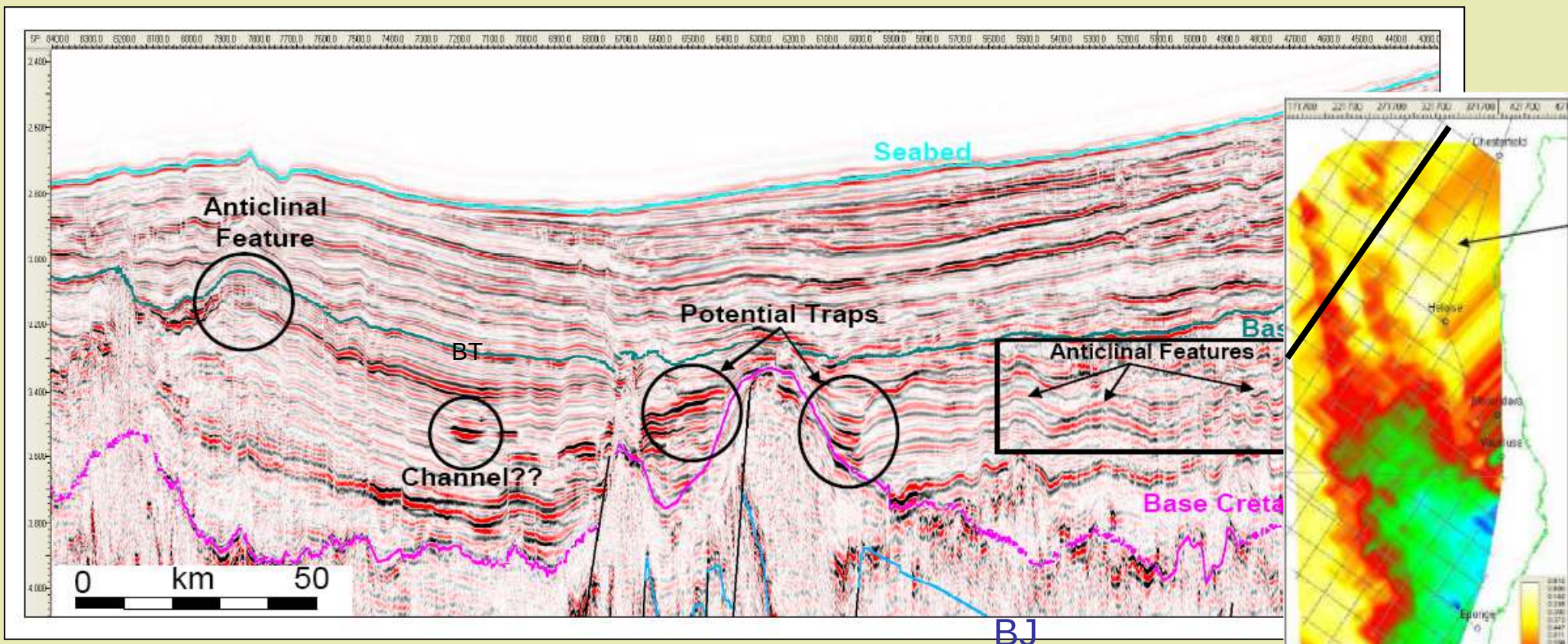
Hovea, Dongara resvr (= Lwr Sakamena)

Kockatea Shale – basal Tr marine source rock (= M. Sakamena shale)

‘Karoo’ rifting (abortive). Glacials / coal.

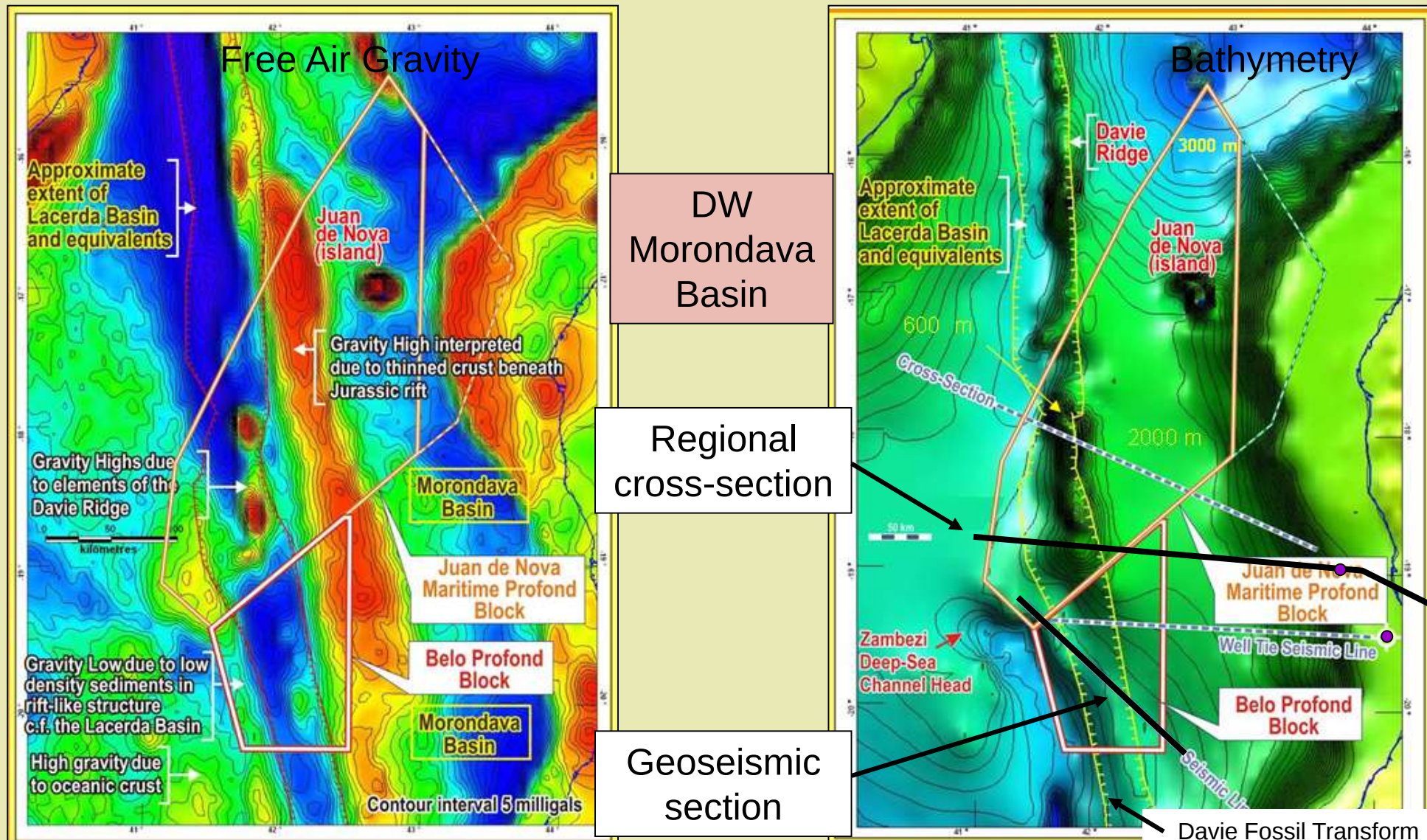
General Stratigraphy of the Perth Basin

Sequence of depo envir very similar to Manandaza Basin



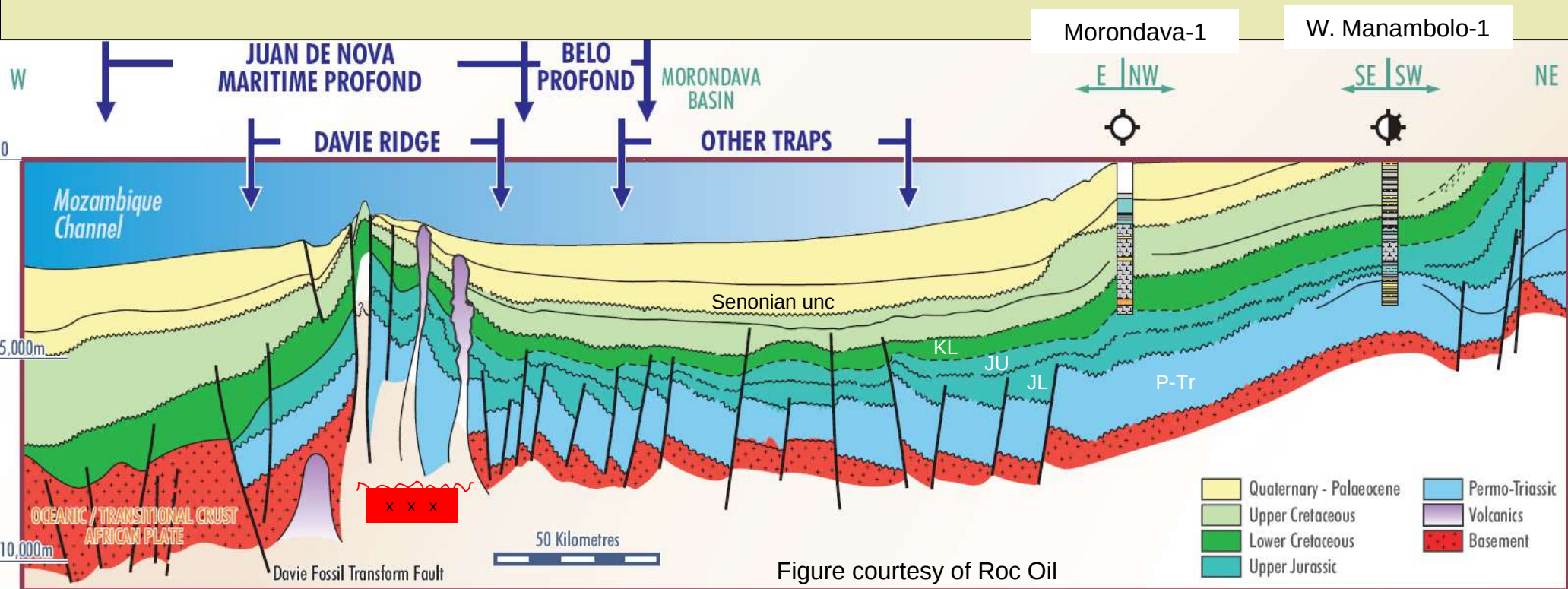
Deep Water Morondava basin seismic line (Tammanai, 2008 – AAPG Search and Discovery)

- Gravity high does not correspond to Bathymetric high (Davie Ridge)
- Davie Ridge is crest of inverted, sediment-filled graben (JL / KL age)
- Similar pattern seen at N. end of Davie-Walu Ridge, offshore Kenya





Regional cross-section: Davie Ridge - DW Morondava Basin



Bathym high

Gravity high

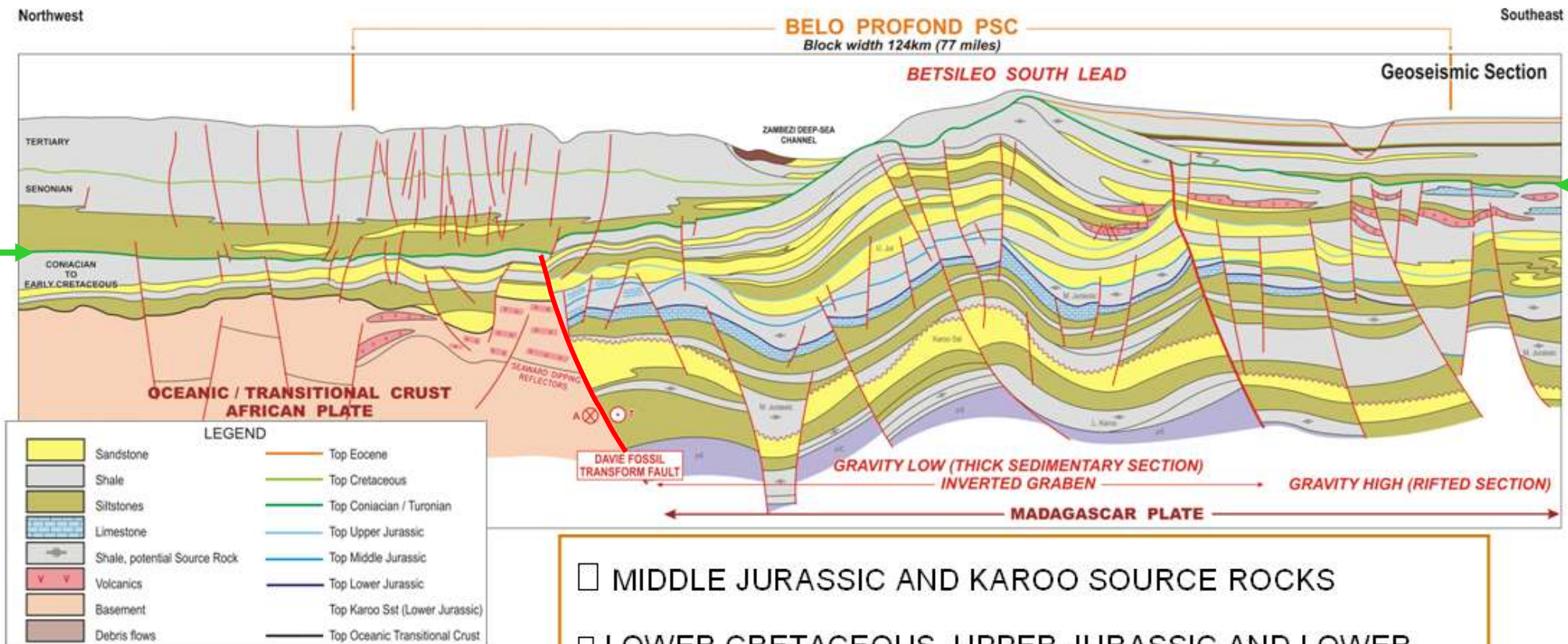
Davie Ridge is an inverted graben and forms huge regional anticline

Gravity high due to thinned cont crust &/or widespread igneous intrusion

• no sign of JL salt

• Senonian inversion of Davie Ridge due to intra-plate compression from India – Madagascar separation

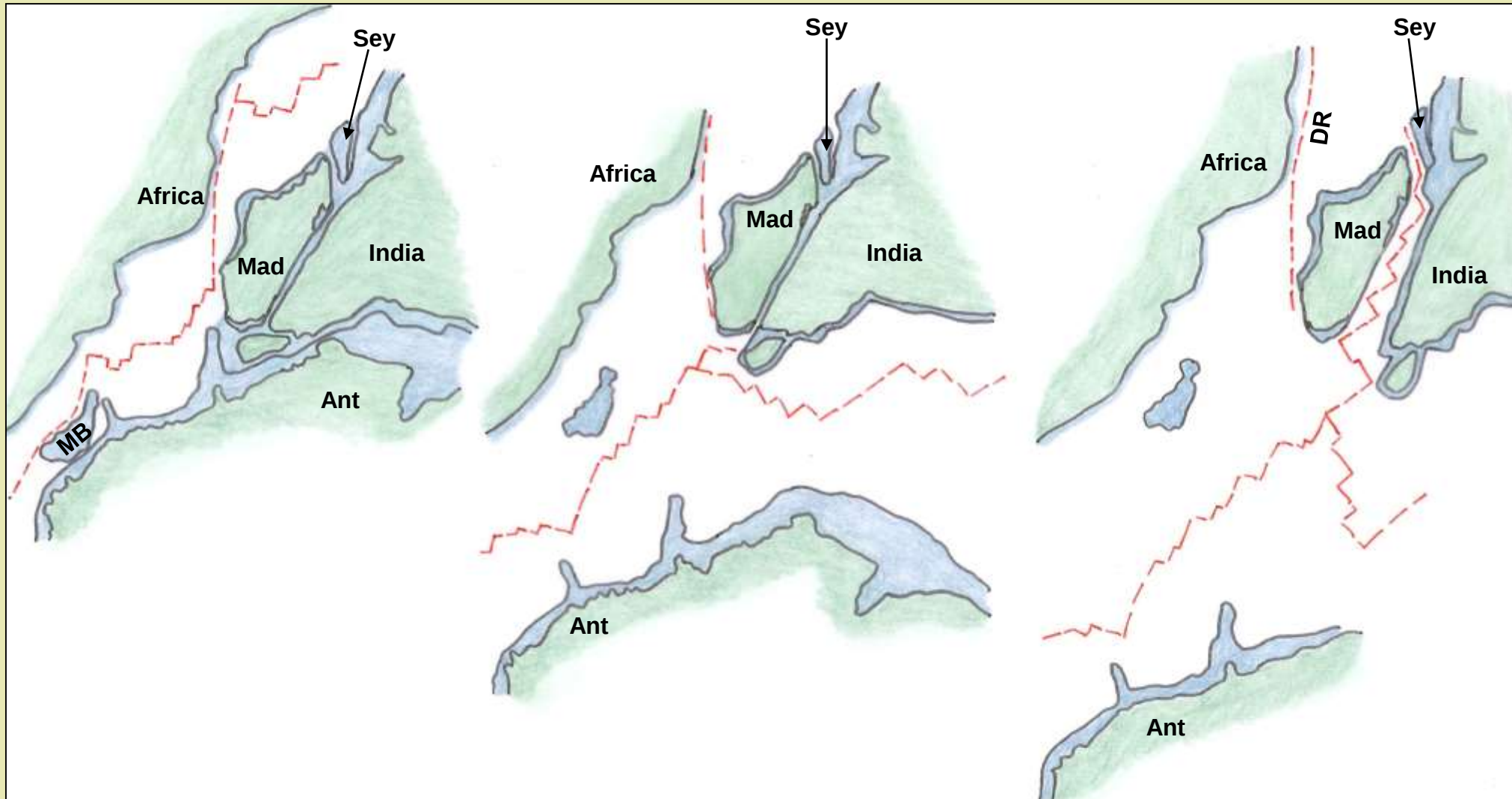
Geoseismic section across the Davie Ridge, showing the Senonian inversion of the ridge.

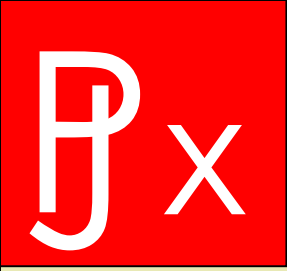


→ Near Top Turonian Unc

- ☐ MIDDLE JURASSIC AND KAROO SOURCE ROCKS
- ☐ LOWER CRETACEOUS, UPPER JURASSIC AND LOWER JURASSIC SANDSTONE RESERVOIR OBJECTIVES
- ☐ HUGE ANTICLINAL LEADS AND COMBINATION TRAPS

Summary of progressive Gondwana break-up, highlighting the possible cause of Turonian inversion of the Davy Fracture Zone



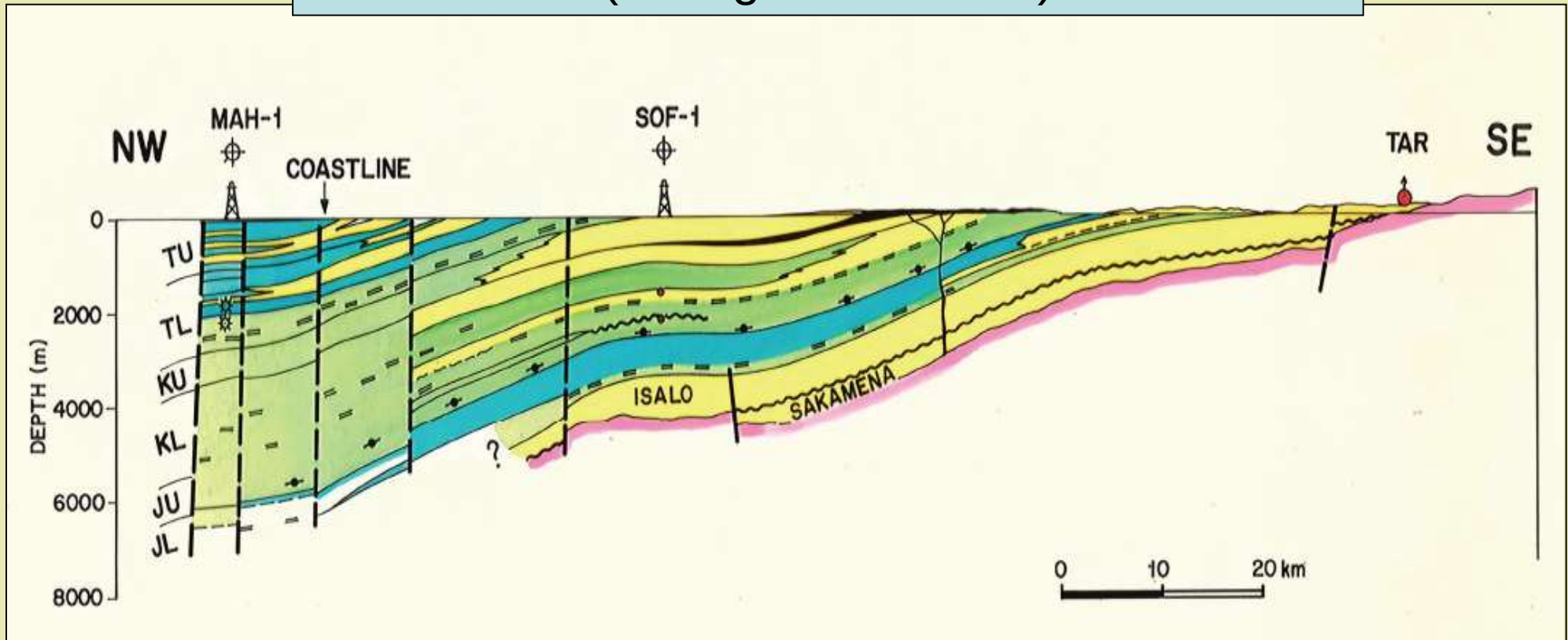


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MAJUNGA BASIN



Majunga Basin Cross-section (Vintage mid-1970s)



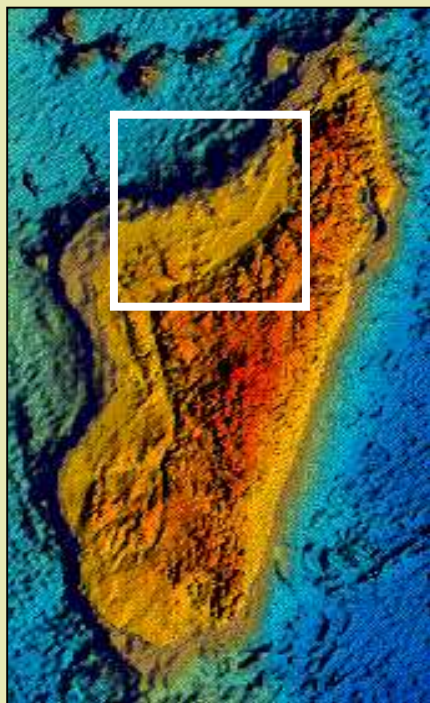
No Karroo rifting identified



Majunga Basin Play Map

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Target was
Karoo horsts
or tilted fault
blocks

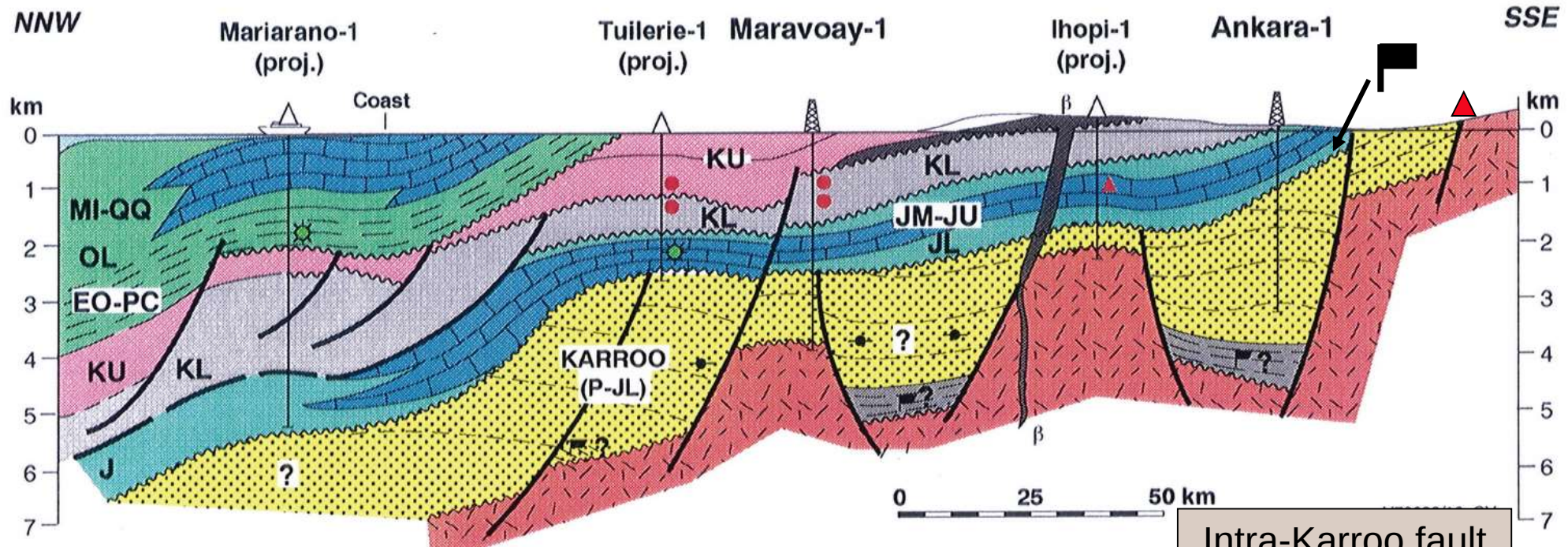


MADAGASCAR

MAJUNGA BASIN GEOLOGICAL CROSS-SECTION

(Vintage 1990 – Karroo rifting identified)

Tar belt?



Jm shelf margin

Low-relief drape
closure over Bmt
horst

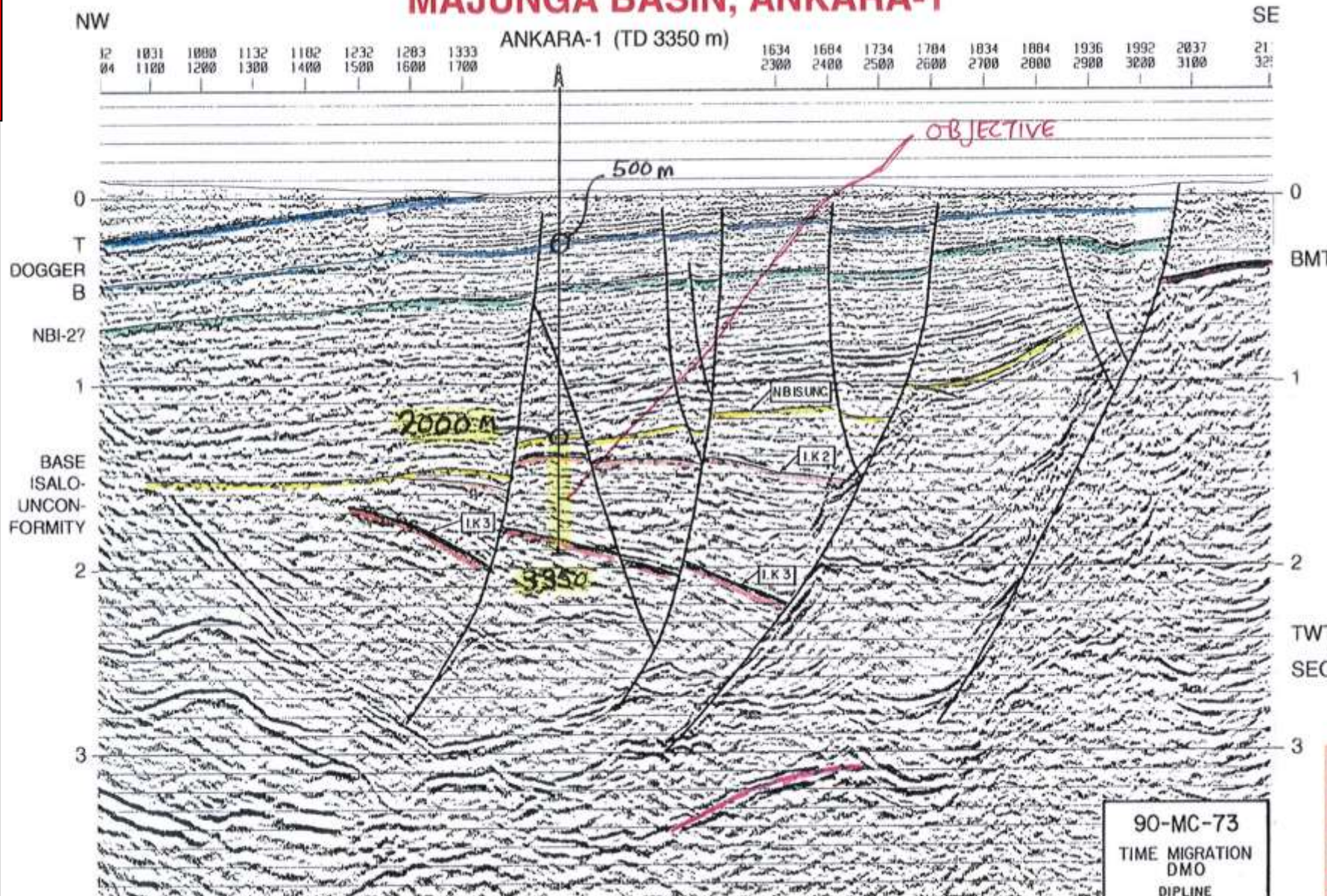
Intra-Karroo fault
/ dip structures in
inboard graben

KK passive
margin growth
faults

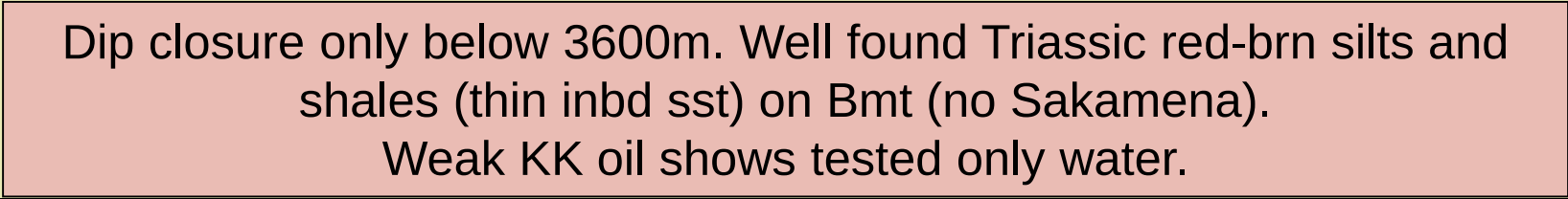
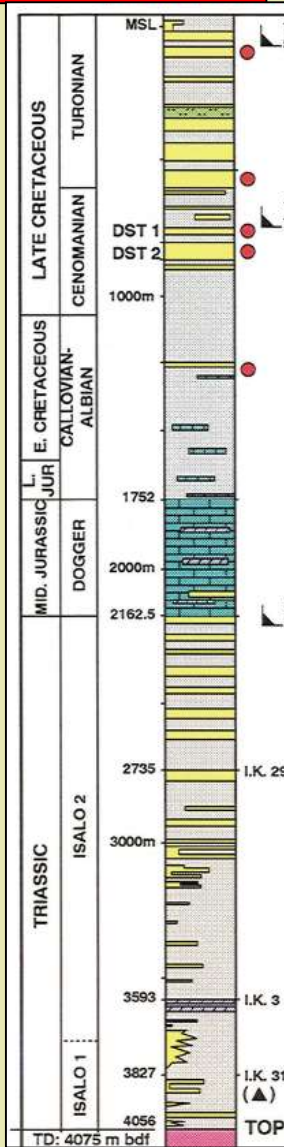
Postulated Karroo source rocks



MAJUNGA BASIN, ANKARA-1

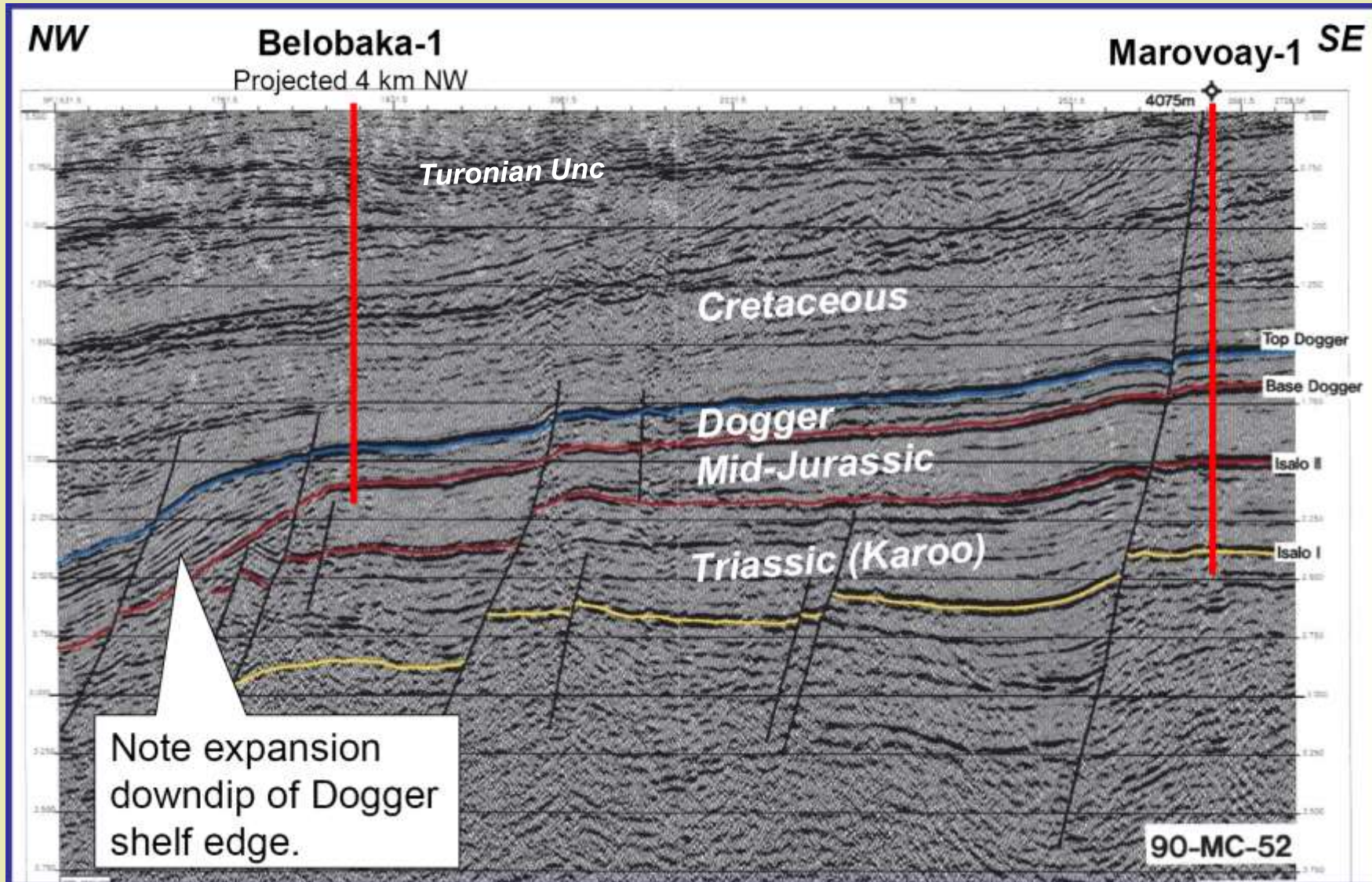


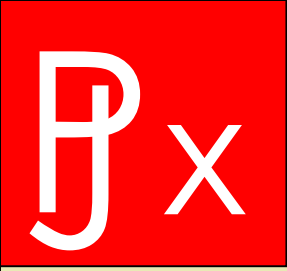
Valid structural test; no shows; no decent seals in entire well





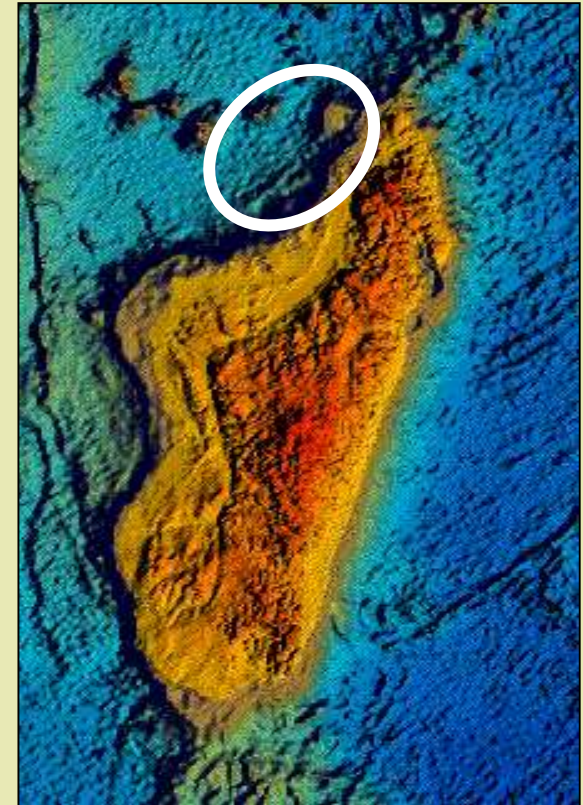
Majunga Basin: Dogger shelf margin, amplitude-driven, strat trap test drilled by Hunt in 2000. Found porosity, but no shows. No updip seal.





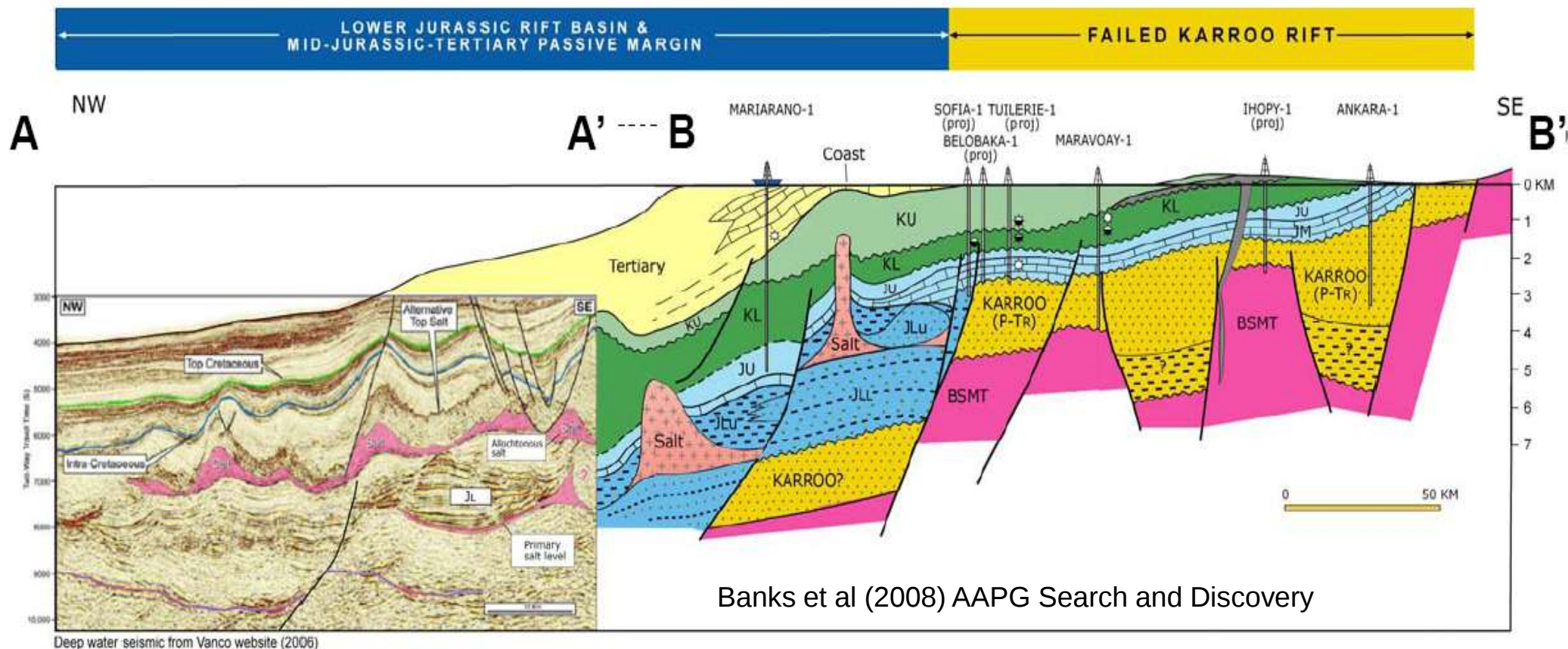
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DW MAJUNGA / AMBILOBE



MAJUNGA BASIN CROSS-SECTION

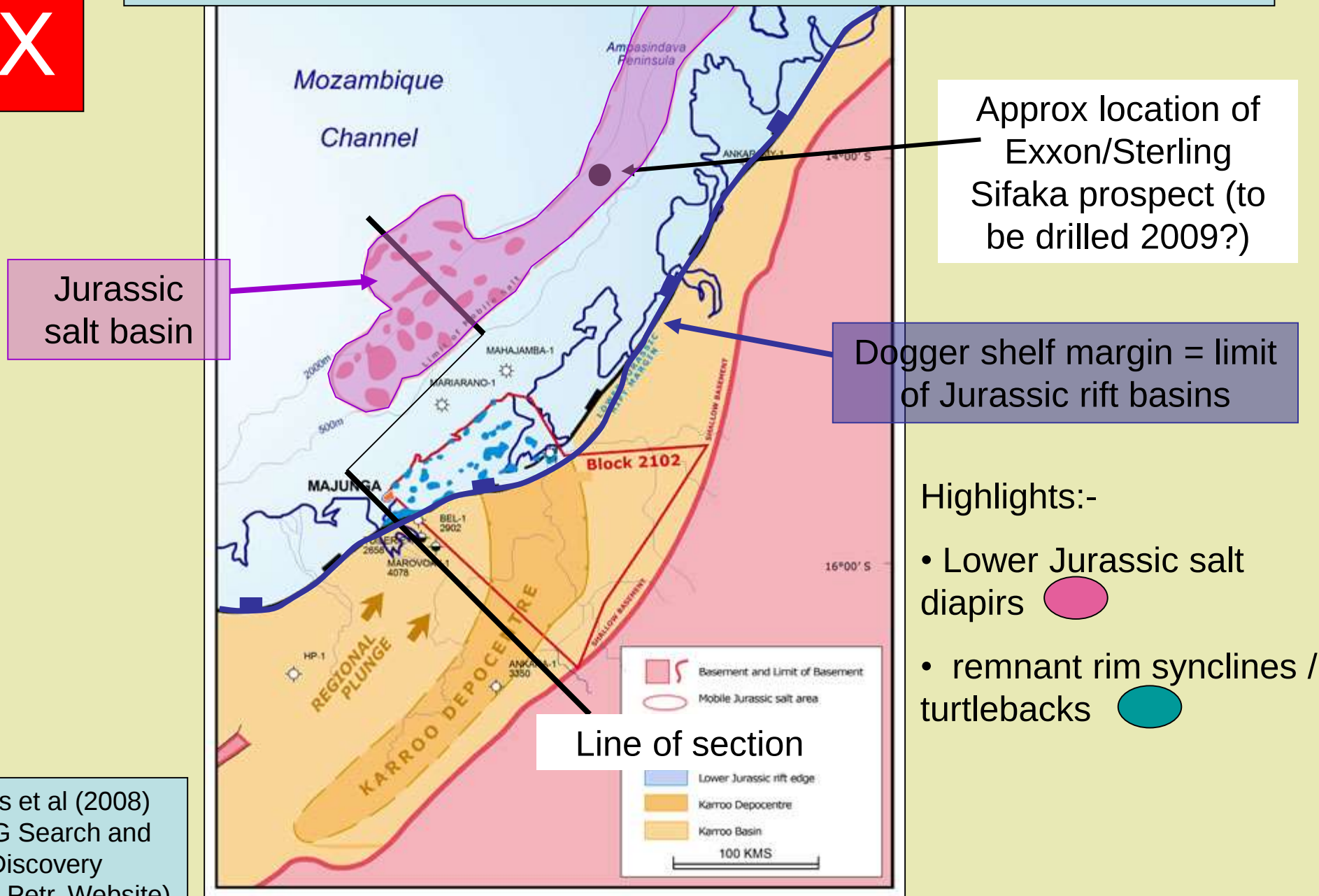
(Vintage 2008: Lower Jurassic rift basins with salt identified)





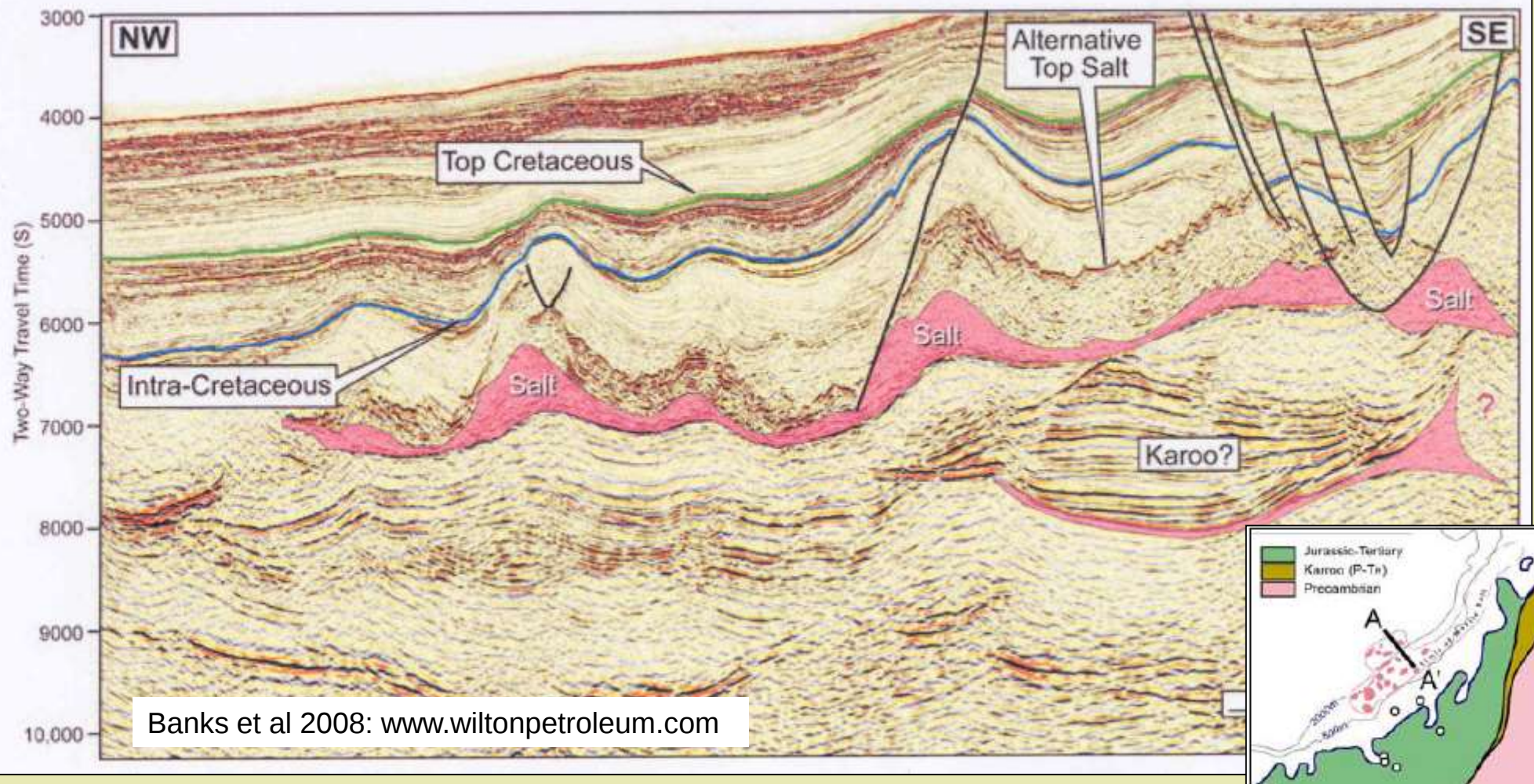
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Summary map of onshore and offshore Majunga Basin



Banks et al (2008)
AAPG Search and
Discovery
(Wilton Petr. Website)

Vanco interpretation of deepwater Majunga Basin (from Vanco website, 2006)



Banks et al 2008: www.wiltonpetroleum.com



Ambilobe Basin, and Ampasindava Peninsula

Onset of faulting, rotation of fault blocks, differential subsidence in earliest Toarcian.

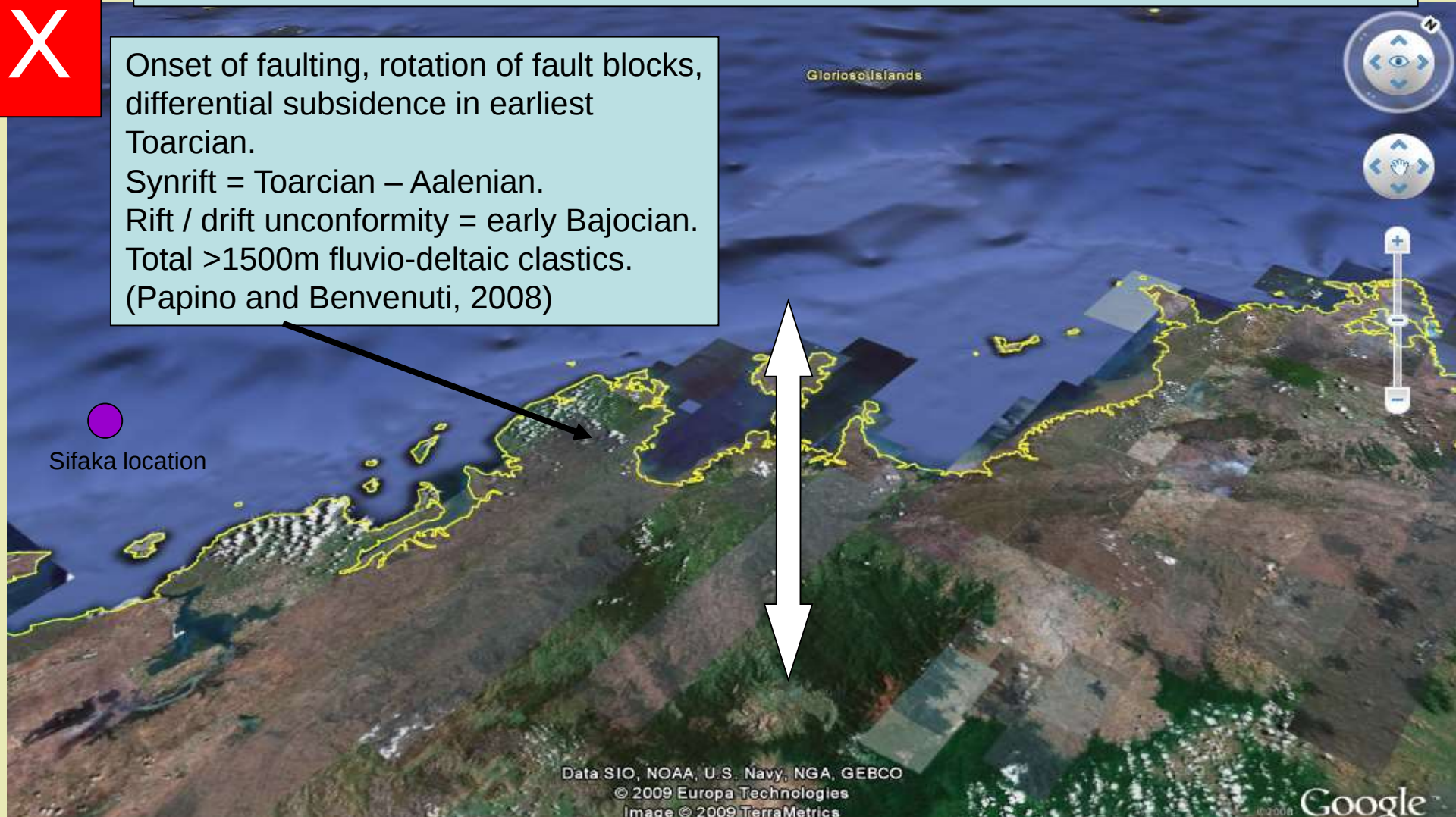
Synrift = Toarcian – Aalenian.

Rift / drift unconformity = early Bajocian.

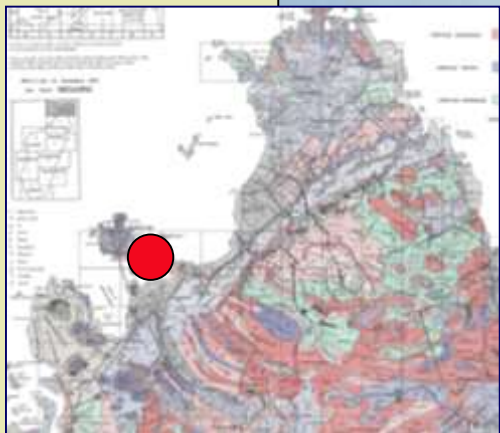
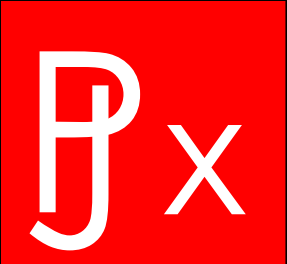
Total >1500m fluvio-deltaic clastics.

(Papino and Benvenuti, 2008)


Sifaka location



Offshore seismic has proven the presence of salt, and Jurassic rift basins, whilst onshore outcrops prove presence of Lower Jurassic source rocks, oil staining, and excellent thick Middle Jurassic sands – in contrast to Dogger limestones elsewhere on the margin.



Dogger of Ambilobe Basin:
thick marine & deltaic sandstones

Images courtesy of

**STERLING
ENERGY**
PLC

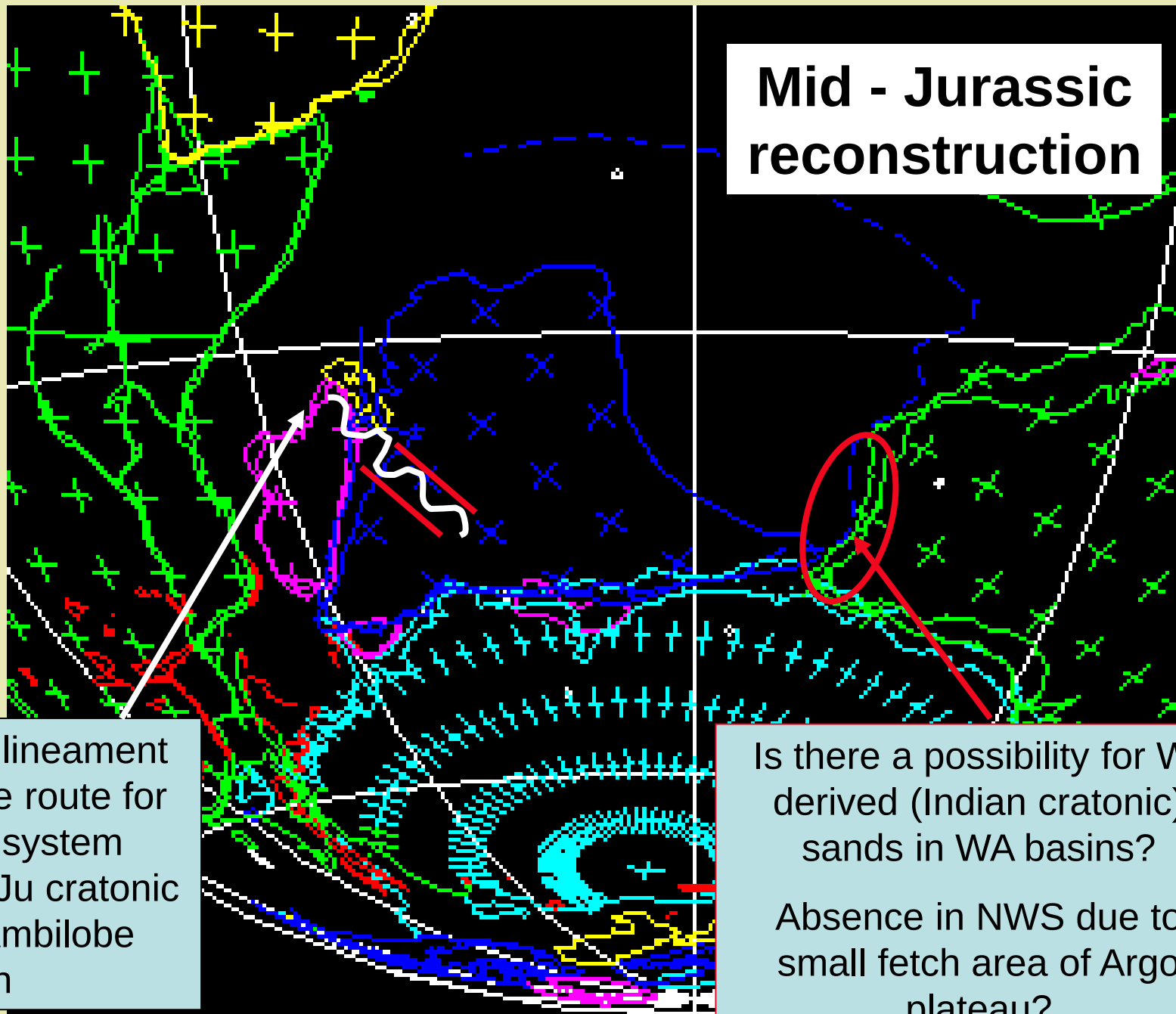
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Mid - Jurassic reconstruction



Namada-Son lineament forms possible route for major river system delivering Jm-Ju cratonic clastics to Ambilobe basin

Is there a possibility for W-derived (Indian cratonic) sands in WA basins?

Absence in NWS due to small fetch area of Argo plateau?



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CLOSING REMARKS

East Africa / Madagascar Rifting

Karoo rifting (abortive)

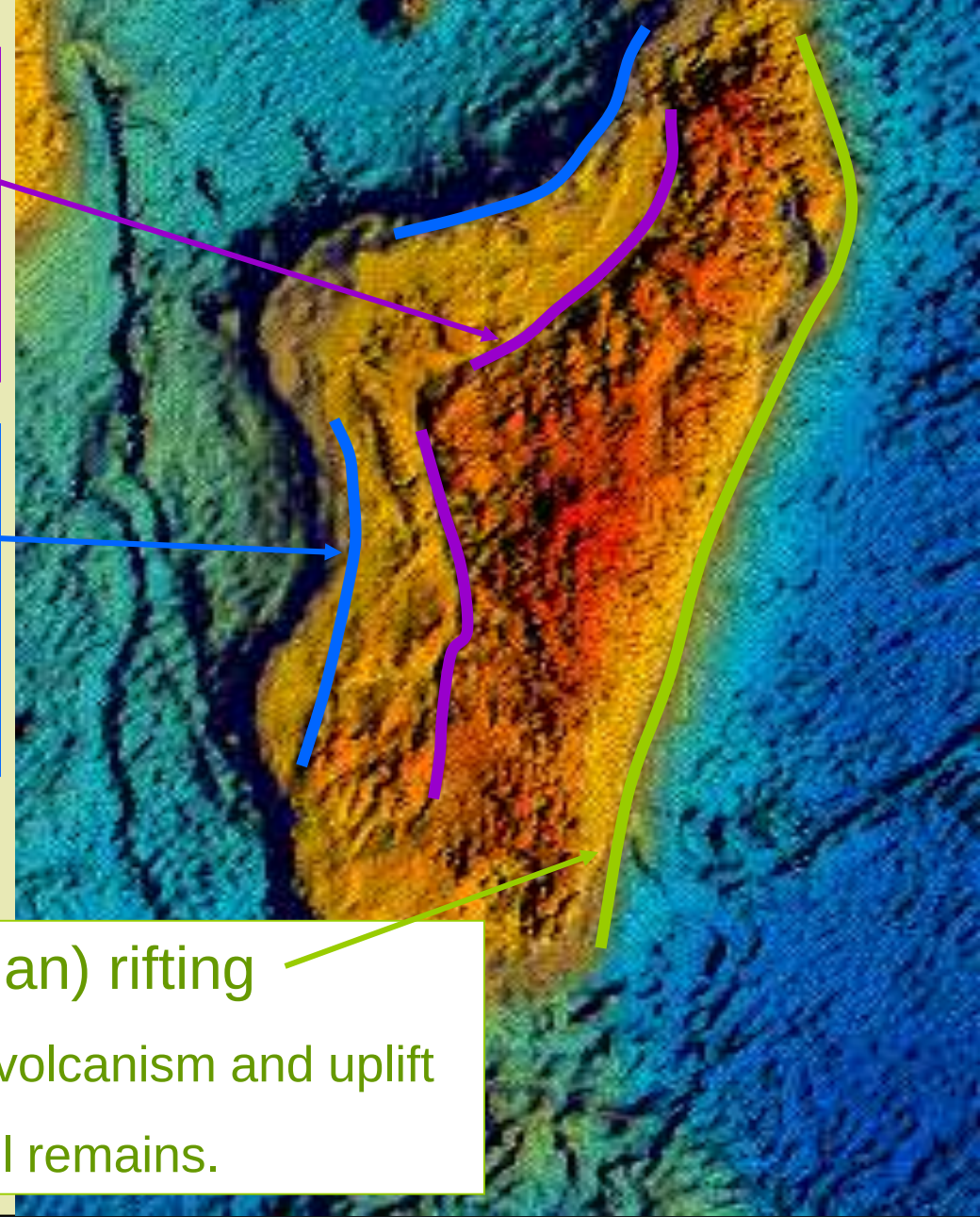
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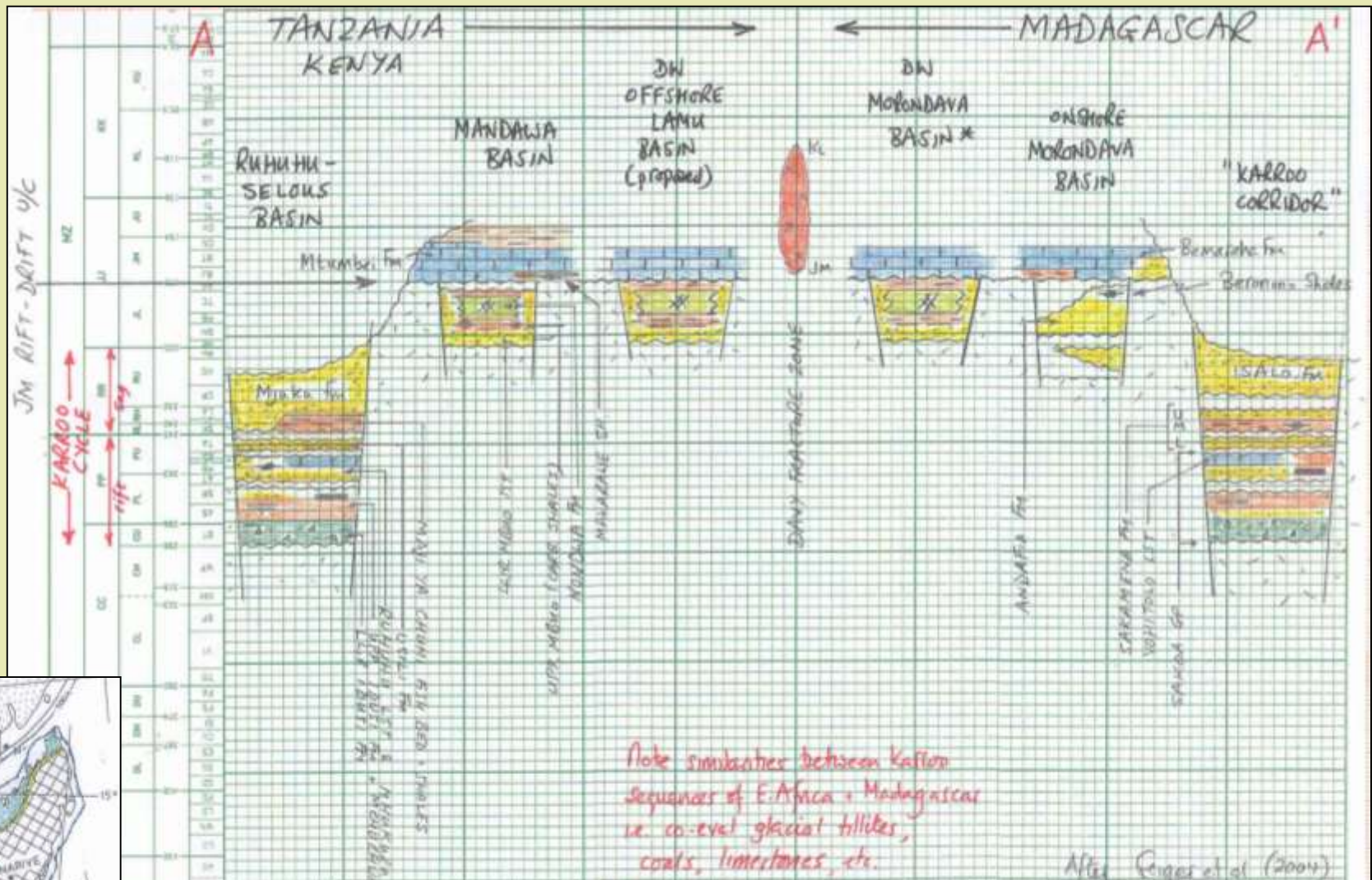
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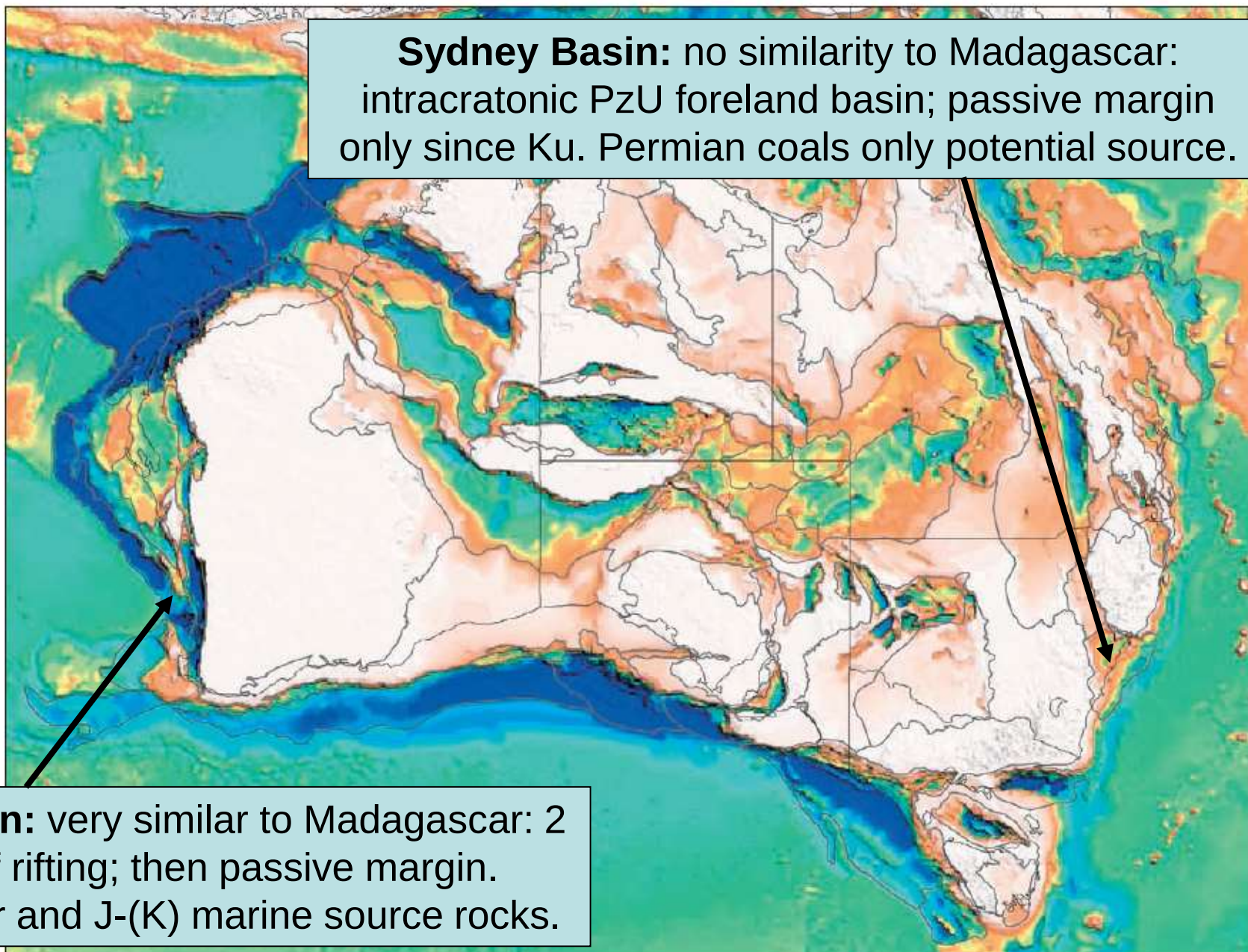


East Africa – Madagascar Rifting:
symmetric; outboard to inboard; either side of
eventual spreading ridge



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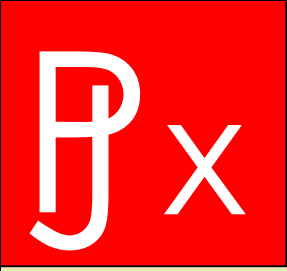
Sydney Basin: no similarity to Madagascar: intracratonic PzU foreland basin; passive margin only since Ku. Permian coals only potential source.



Perth Basin: very similar to Madagascar: 2 ages of rifting; then passive margin. P coals; Tr and J-(K) marine source rocks.

Figure 1. SEEBASE™ image of the Phanerozoic Basins of Australia

www.frogtech.com.au



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THANK YOU

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