Prospectivity of Cauvery Basin in Deep Syn-rift Sequences, SE India*

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Abstract

Spread over 62,500 sq. km, covering land area and offshore up to 200m isobath, Cauvery Basin is the southernmost among a string of Mesozoic rift basins on the east coast of India. A part of this basin lies between India and Sri Lanka.

Late Jurassic fragmentation of eastern Gondwanaland into India, Antarctica, and Australia had initiated the formation of Mesozoic rift basins on the east coast of India including Cauvery Basin. Almost entire Cauvery Basin has been covered with 2D/3D seismic data except large area in Gulf of Mannar.

Drilling activity has largely been concentrated near the Basement highs and their flanks. Very few wells were drilled targeting deeper syn-rift sequences.

Hydrocarbon pools have been discovered in all the sub basins of Cauvery Basin with the reservoirs ranging in age from Precambrian (basement) to Oligocene except in less explored Gulf of Mannar.

In this article, we examine the syn-rift sequences in different sub basins in terms of their spatial distribution and maturity for hydrocarbon generation.

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BY

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8th June 2009 **AAPG** DENVER ***ONGC INDIA***

Course of the Presentation

Introduction to the Basin

Present work

Methodology

Results

Conclusions

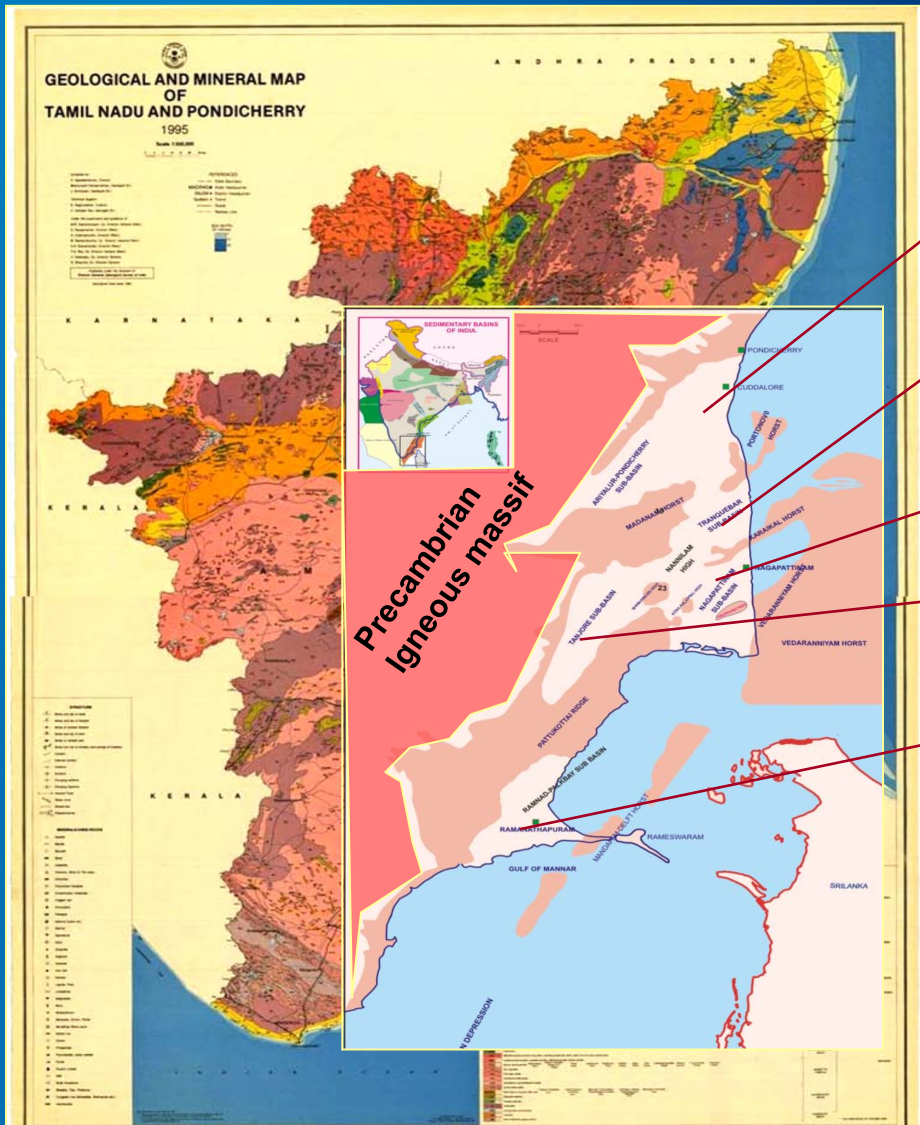
INDIA

GEOLOGICAL MAP OF TAMILNADU

Cauvery Basin is the southernmost among a string of Mesozoic rift basins on the Indian east coast.

A part of this basin lies between India and Sri Lanka

BASIN CONFIGURATION



ARIYALUR-PONDICHERRY

TRANQUEBAR

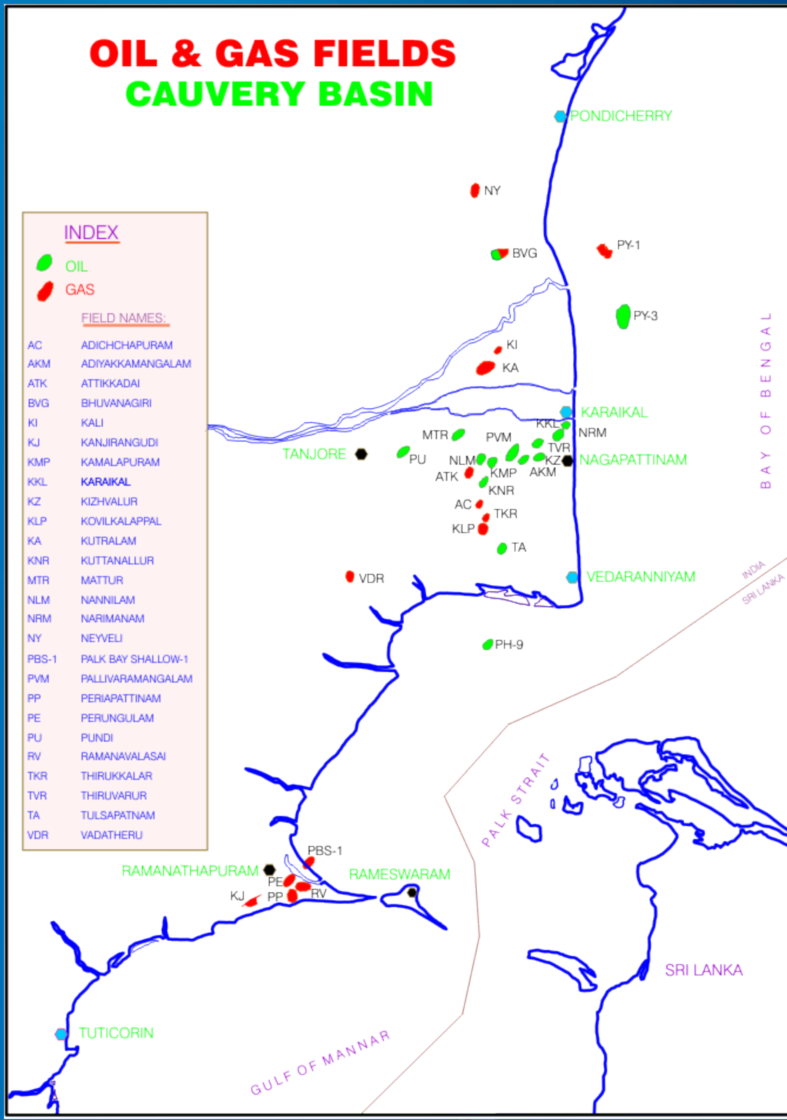
NAGAPATTINAM

TANJORE

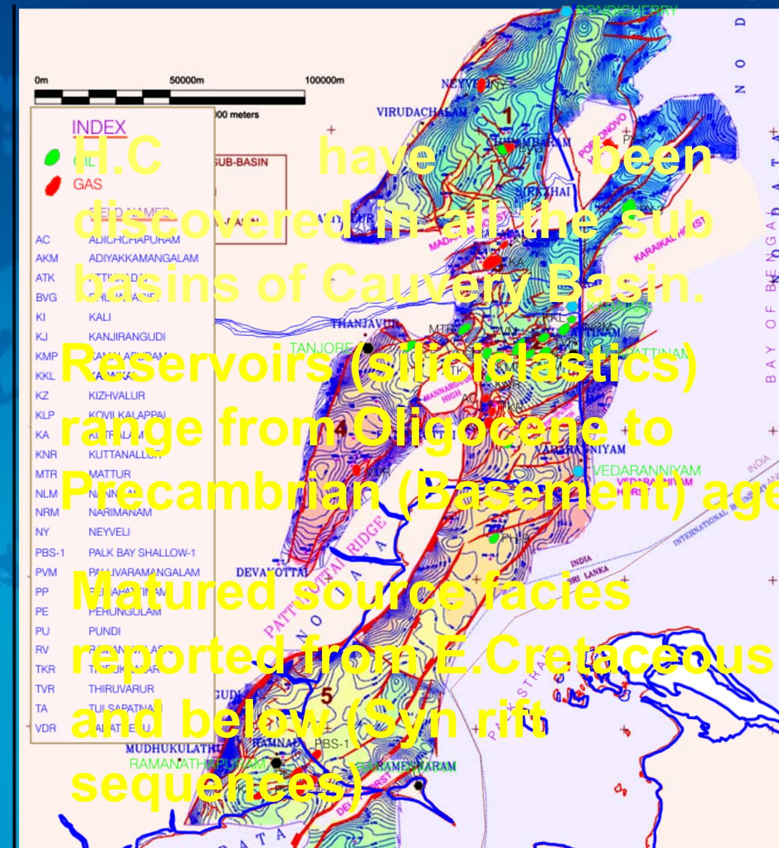
RAMNAD

syn-rift sediment supply was not adequate to fill the grabens. Antecedent rift topography controlled the sedimentation even after the extension ceased till end of cretaceous.

Important Oil & Gas fields In Cauvery Basin



Faults are established as proven conduits for the established pays.



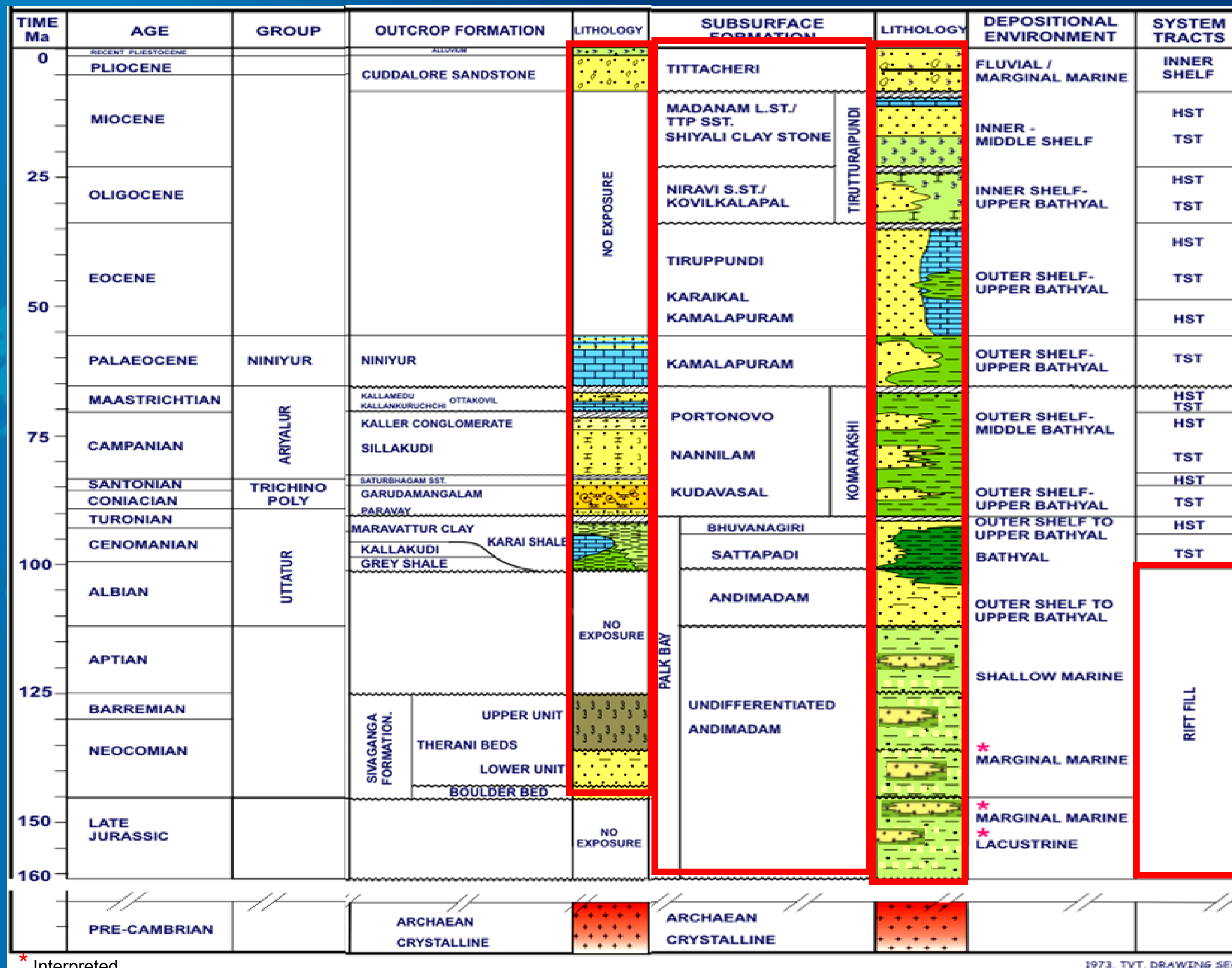
H.C have been discovered in all the sub basins of Cauvery Basin.

Reservoirs (siliciclastics) range from Oligocene to Precambrian (Basement) age

Matured source facies reported from E.Cretaceous and below (Syn rift sequences)

Distinct relation between deep basement penetrating faults and hydrocarbon migration is observed in most accumulations.

General Lithology of Cauvery Basin, outcrop to subcrop



Present Study

Exploration focus in Cauvery Basin has been mostly restricted to post rift reservoirs. Probing syn-rift sediments involve uncertainties like

- **Quality of reservoirs**
- **Timing of hydrocarbon generation**

Objective

To bring in a shift in focus, availability of hydrocarbons during syn-rift period needs to be established

Accordingly, prospectivity in syn rift sediments in terms of one element of petroleum system that is timing of expulsion i.e peak generation time has to be worked out

Methodology

Determining critical moments of syn-rift source rocks in sub basins of Cauvery Basin by Basin Modeling.

Assumptions made in analogy with other rift basins

Available geo-chemical Studies indicate matured source facies mainly below Albian (pre/syn rift sediments).

- **Similar to rift basins in the world, Cauvery Basin is likely to have source rich lacustrine facies in the early syn-rift stage**

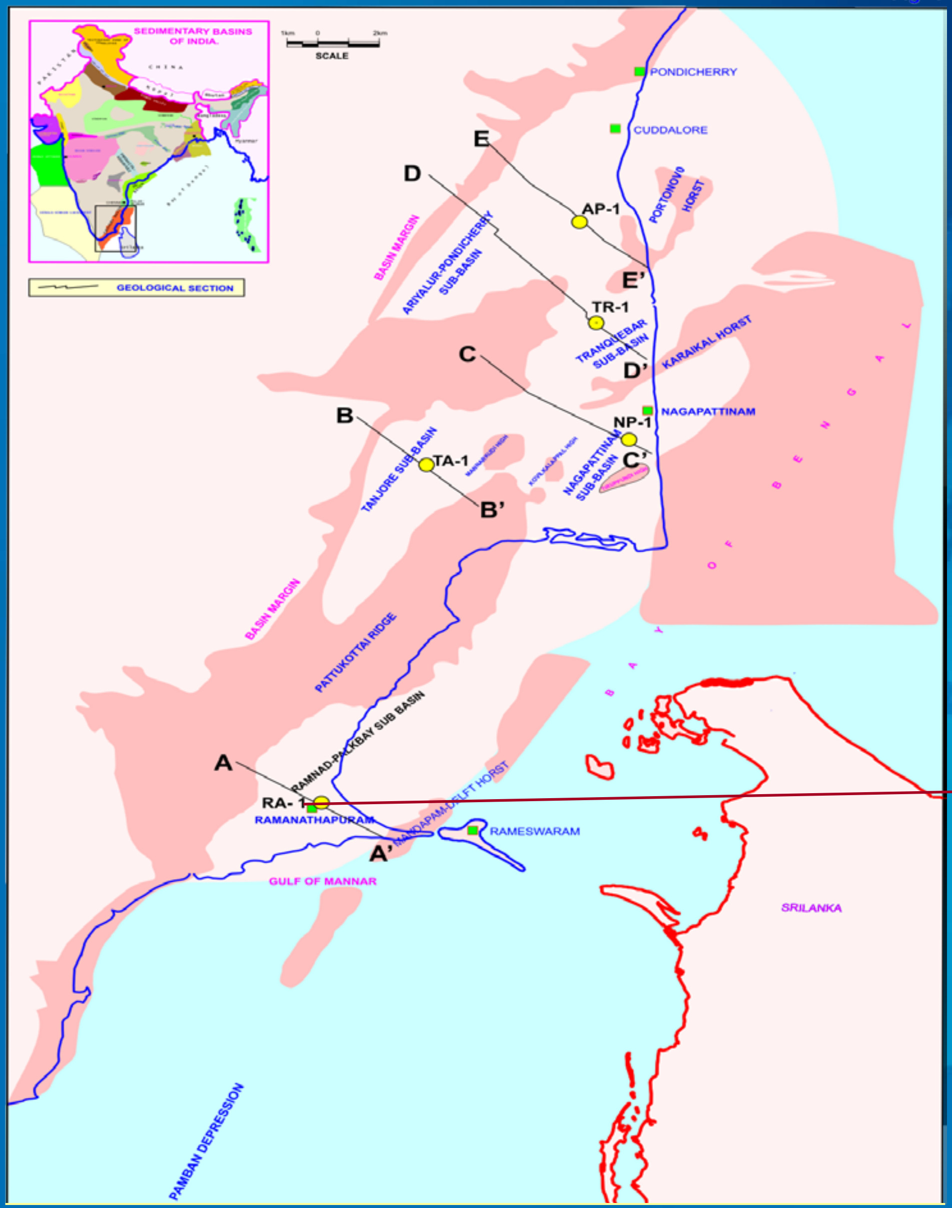
- **Presence of source rocks in Oxfordian, Berriasian and Hauterevien is assumed (besides proven source in Aptian and Cenomanian periods)**

Syn -rift reservoirs

- **In analogy with other rift basins, Cauvery Basin syn-rift sediments may as well consists of reservoirs like fan deltas and channel sands resulting from axial drainage and hanging wall transverse drainage.**

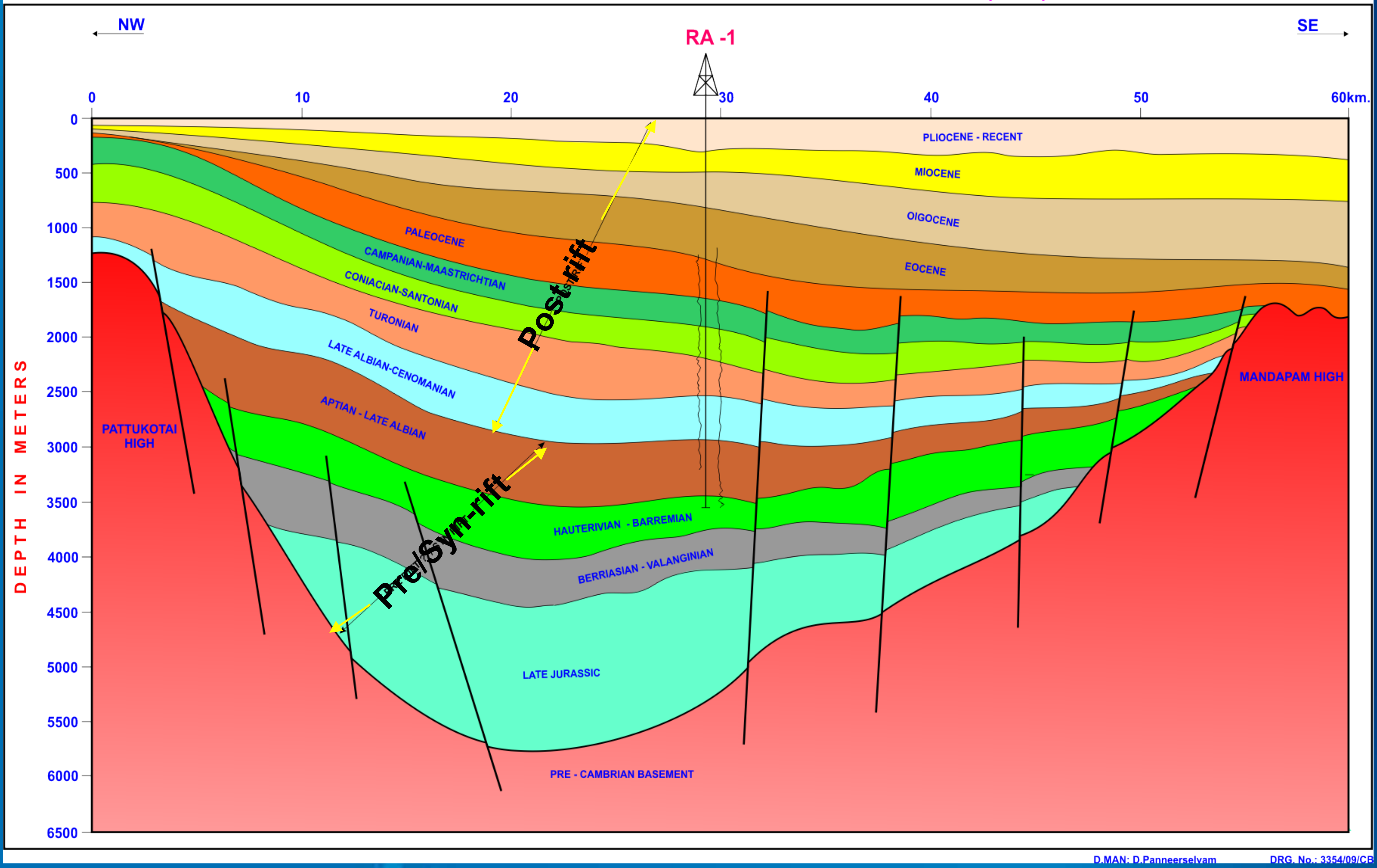
- **Existence of traps**

LOCATION OF GEOLOGICAL SECTIONS ACROSS SUB BASINS & WELLS CONSIDERED IN BASIN MODELLING

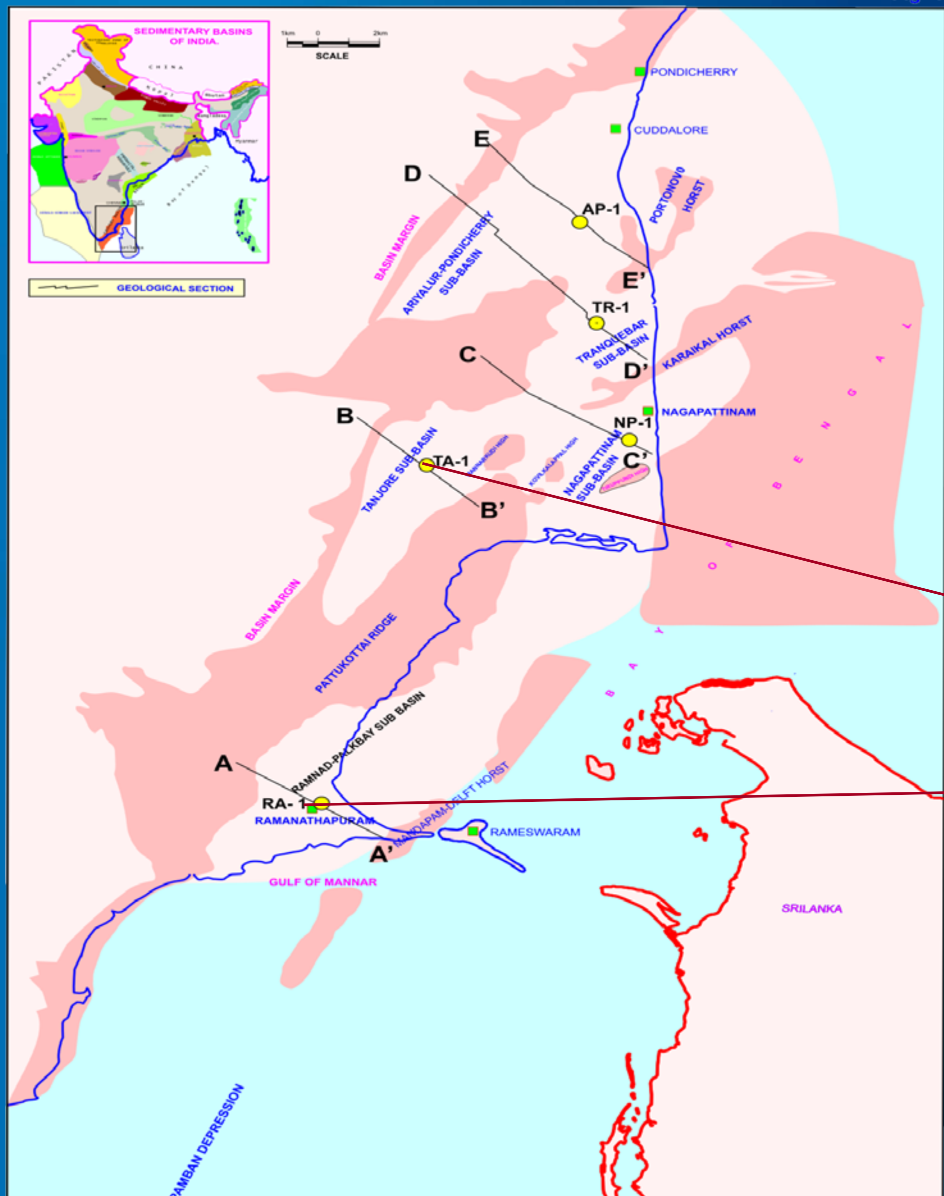


RAMNAD
WELL- RA-1

GEOLOGICAL SECTION ACROSS RAMNAD SUB BASIN (A-A')



LOCATION OF GEOLOGICAL SECTIONS ACROSS SUB BASINS & WELLS CONSIDERED IN BASIN MODELLING

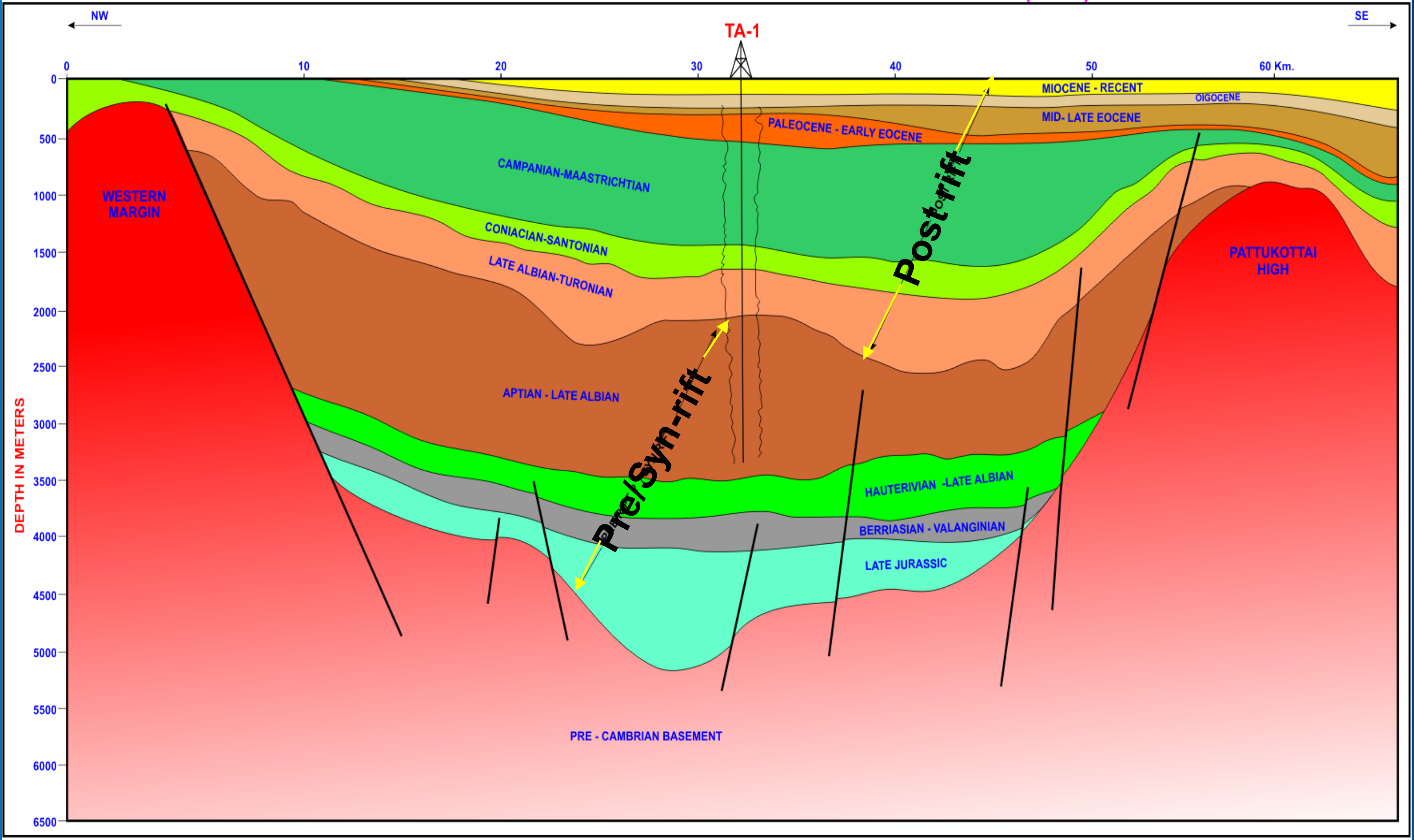


TANJORE
WELL- TR-1

RAMNAD
WELL- RA-1

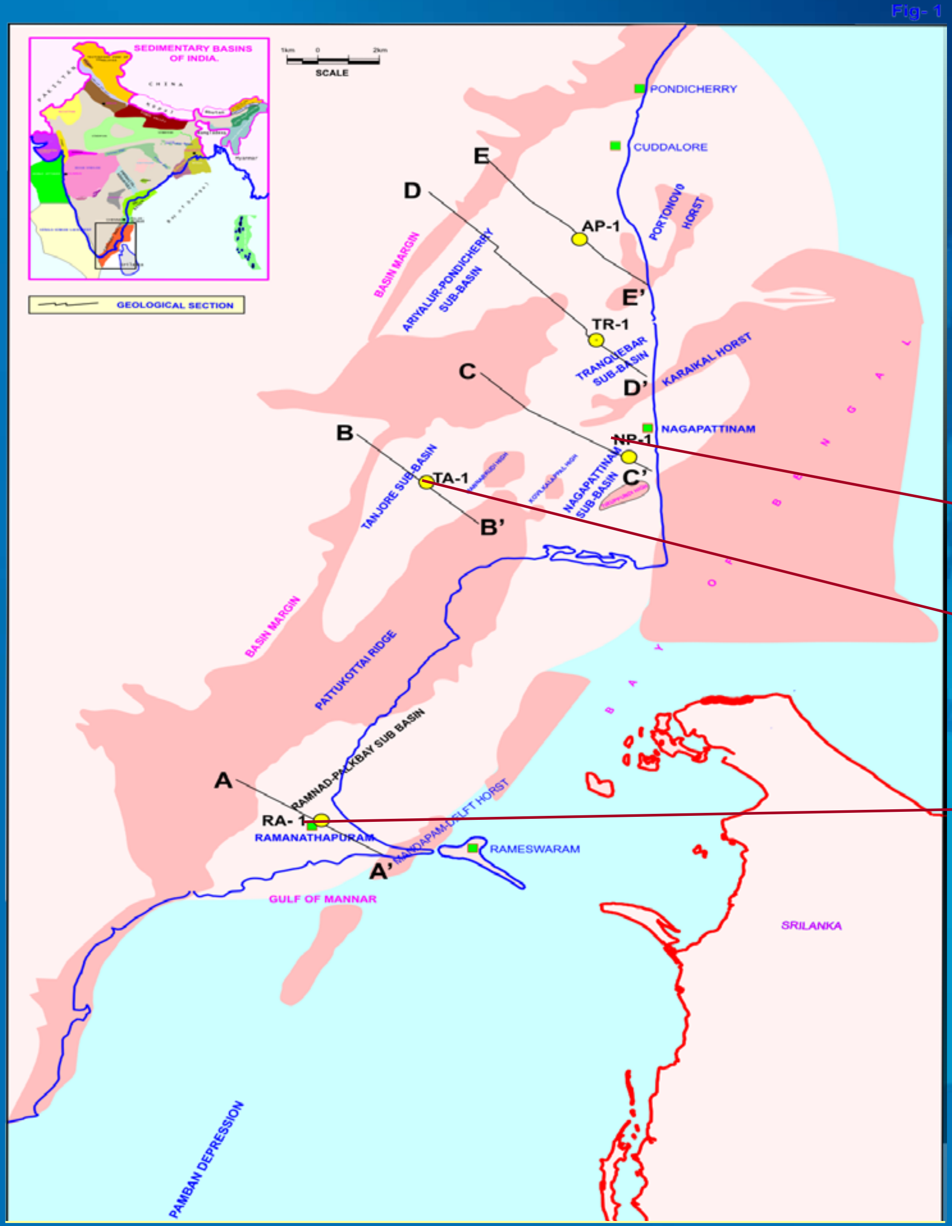
GEOLOGICAL SECTION ACROSS TANJORE SUB BASIN (B-B')

Fig. 4



D.MAN: D.Panneerselvam DRG. No.: 3353/09/CB

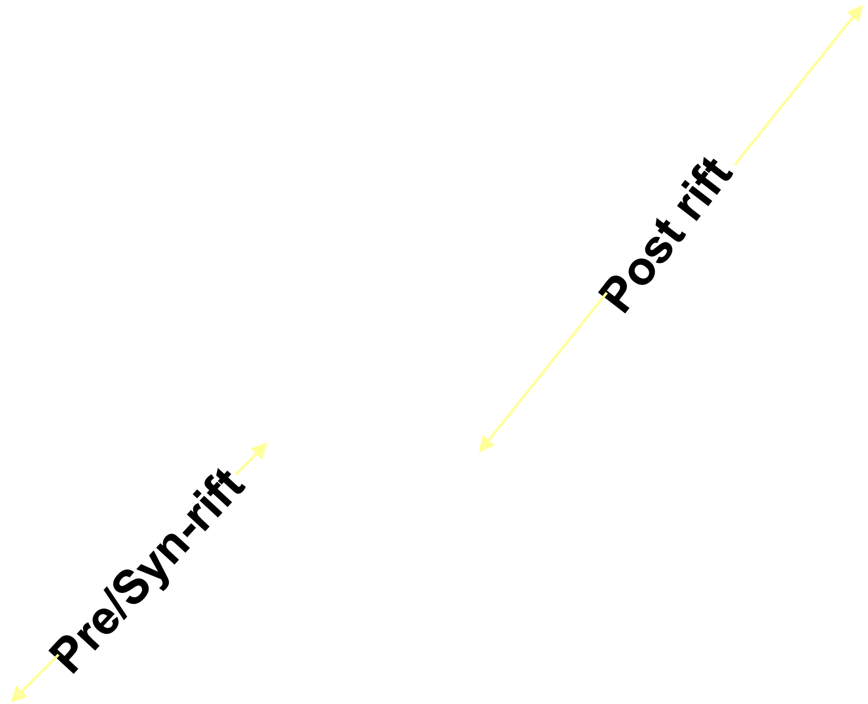
LOCATION OF GEOLOGICAL SECTIONS ACROSS SUB BASINS & WELLS CONSIDERED IN BASIN MODELLING



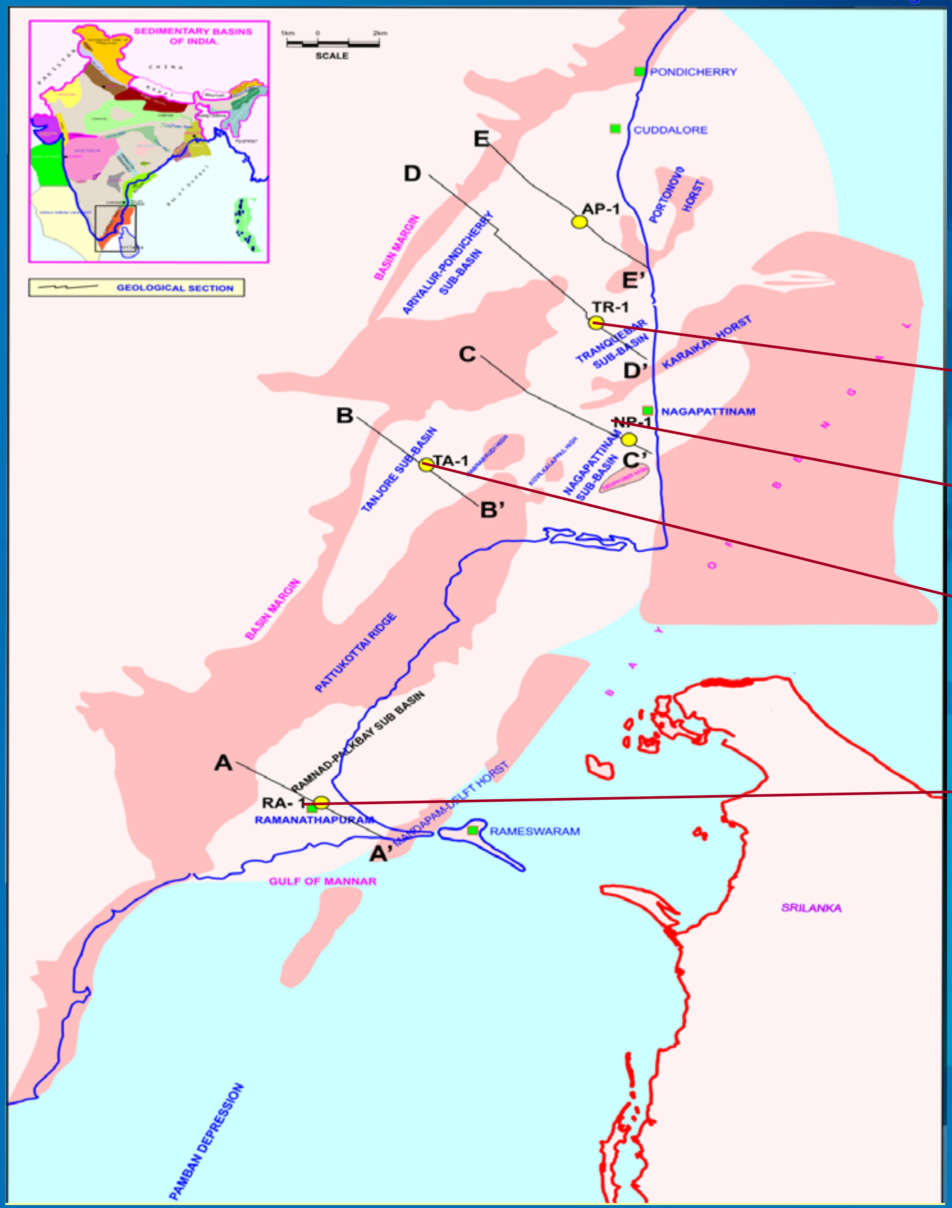
NAGAPATTINAM
WELL- NP-1

TANJORE
WELL- TR-1

RAMNAD
WELL- RA-1


Post rift
Pre/Syn-rift

LOCATION OF GEOLOGICAL SECTIONS ACROSS SUB BASINS & WELLS CONSIDERED IN BASIN MODELLING



TRANQUEBAR
WELL- TR-1

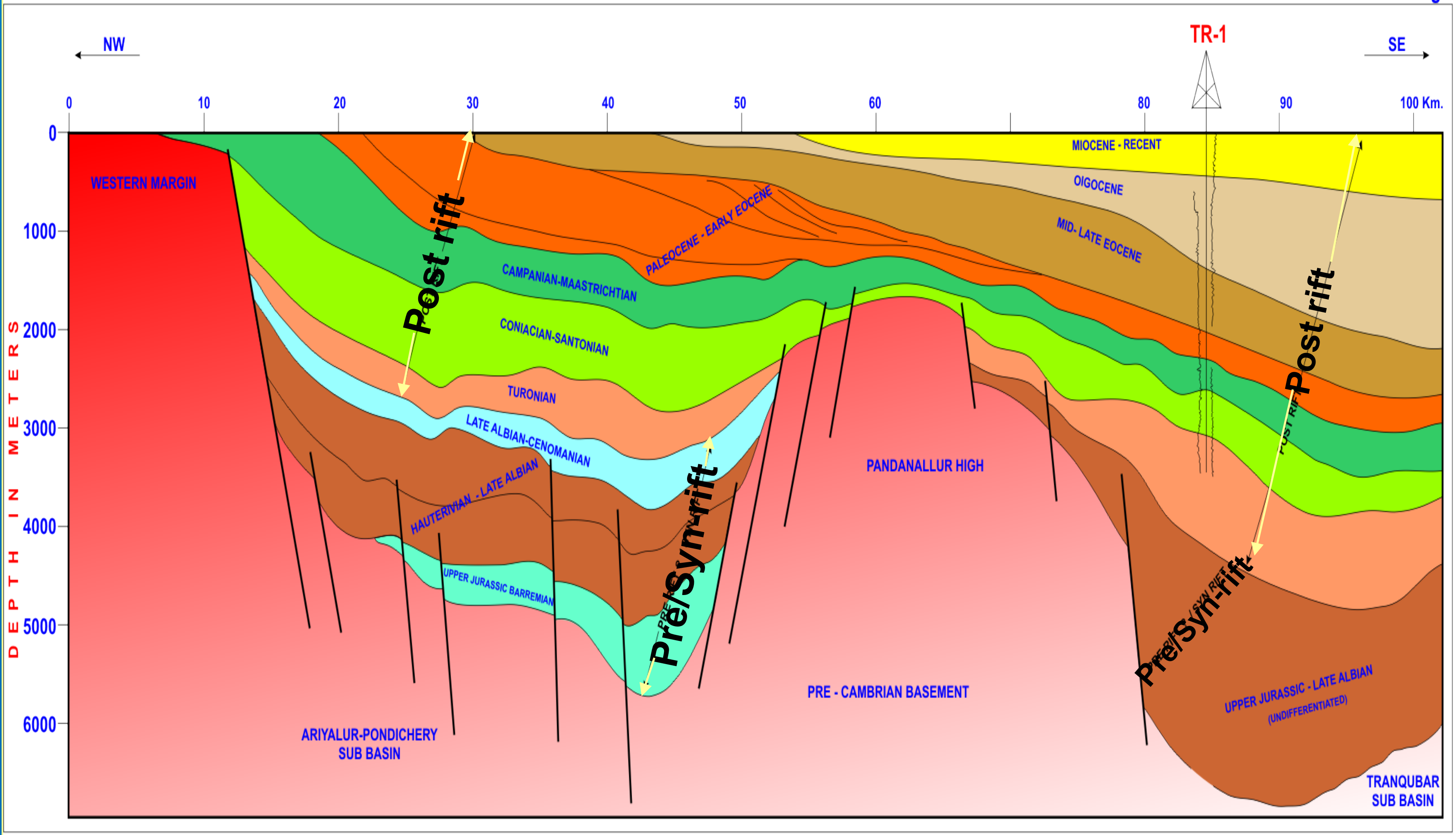
NAGAPATTINAM
WELL- NP-1

TANJORE
WELL- TR-1

RAMNAD
WELL- RA-1

GEOLOGICAL SECTION ACROSS ARIYALUR - PONDICHERRY AND TRANQUEBAR SUB BASIN (D-D')

Fig. 6



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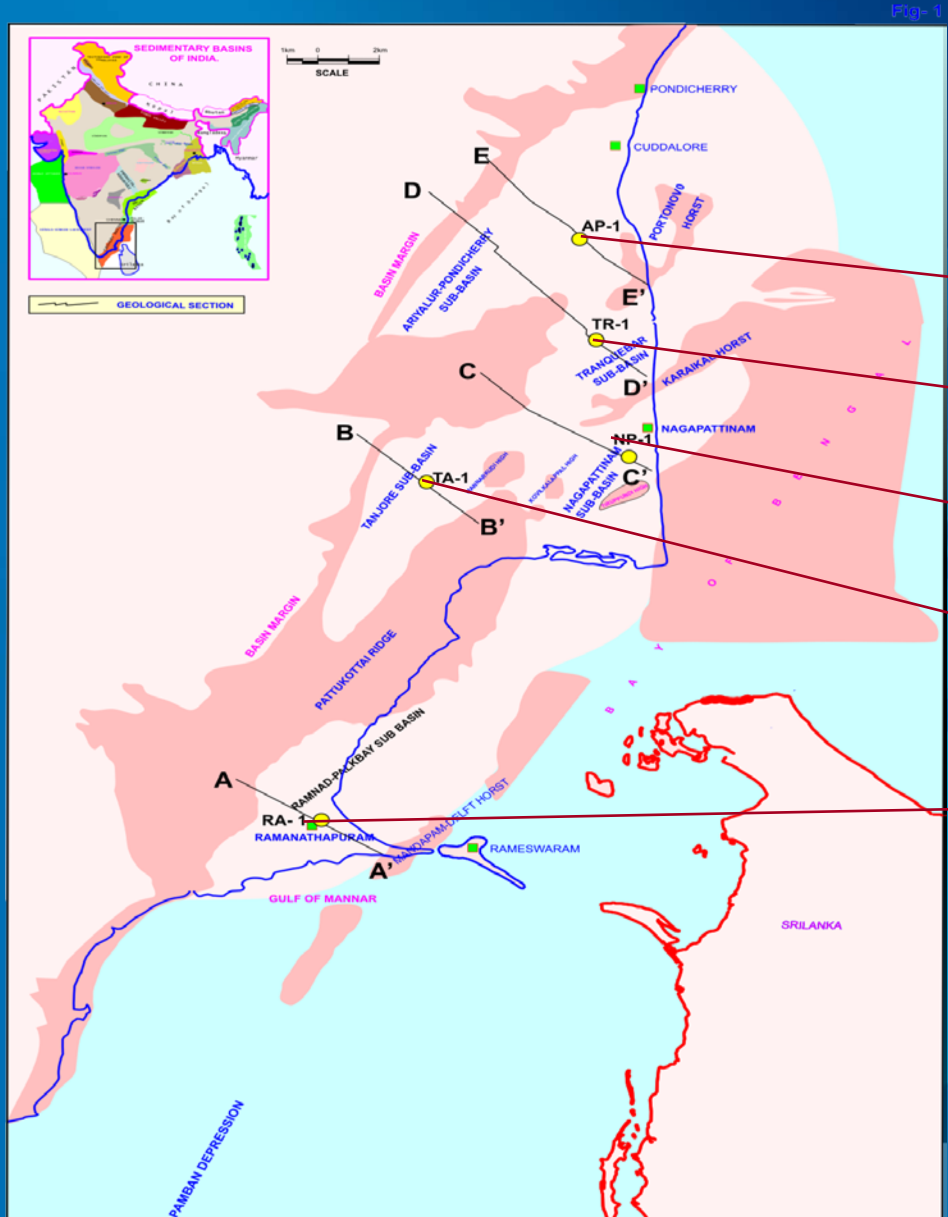


LOCATION OF GEOLOGICAL SECTIONS ACROSS SUB BASINS & WELLS CONSIDERED IN BASIN MODELLING

ARIYALUR-PONDICHERRY
WELL- AP-1

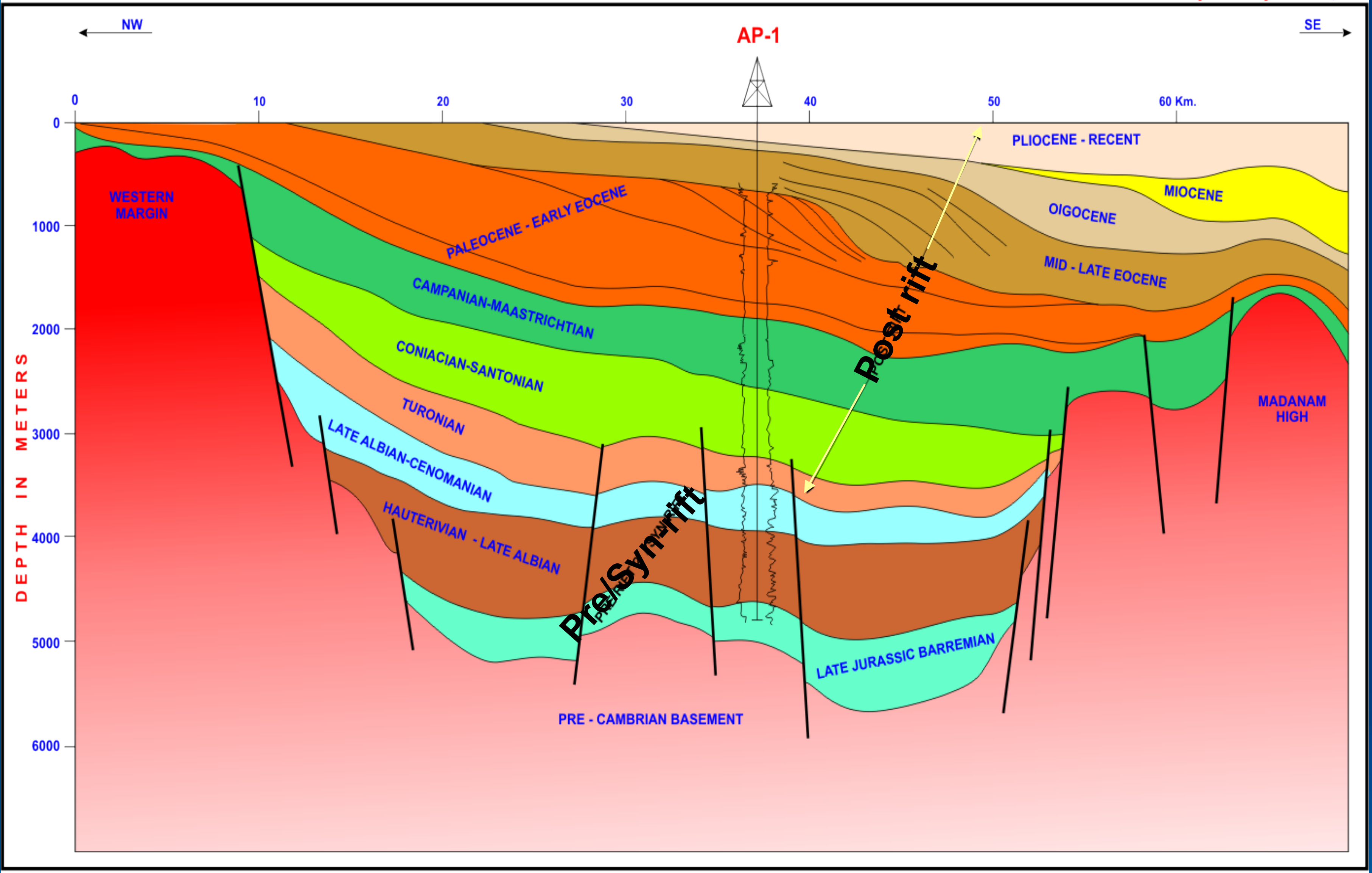
TRANQUEBAR
WELL- TR-1

NAGAPATTINAM
WELL- NP-1

TANJORE
WELL- TR-1

RAMNAD
WELL- RA-1

GEOLOGICAL SECTION ACROSS ARIYALUR PONDICHERRY SUB BASIN (E-E') Fig. 7



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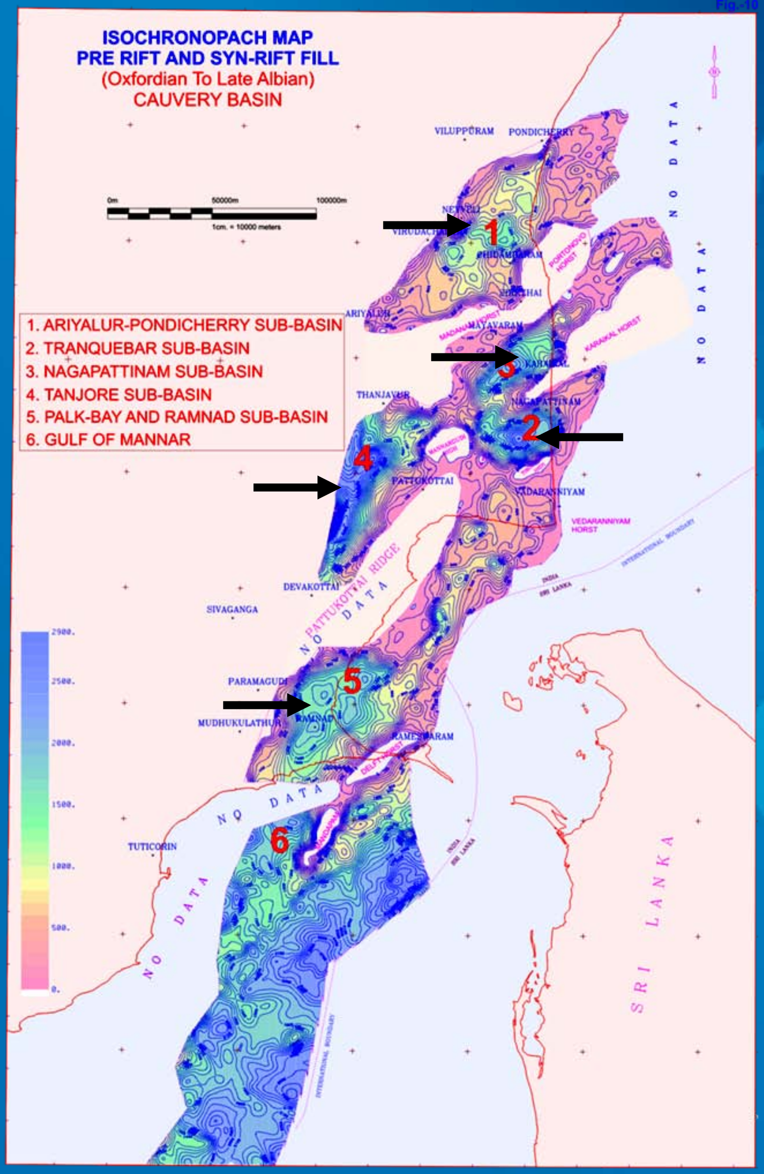
ISOCHRONOPACH CLOSE TO THE TOP OF SYN-RIFT SEDIMENTS



synrift/prerift basin fill map shows the sediment thickness from basement to Late Albian.

Syn rift sediments are thick in Tanjore, followed by Nagapattinam, Tranquebar, Ramnad and Ariyalur-Pondicherry

Modeling

1D modelling at various locations in the sub basins of Cauvery Basin was carried out using PetroMod software package with the following inputs

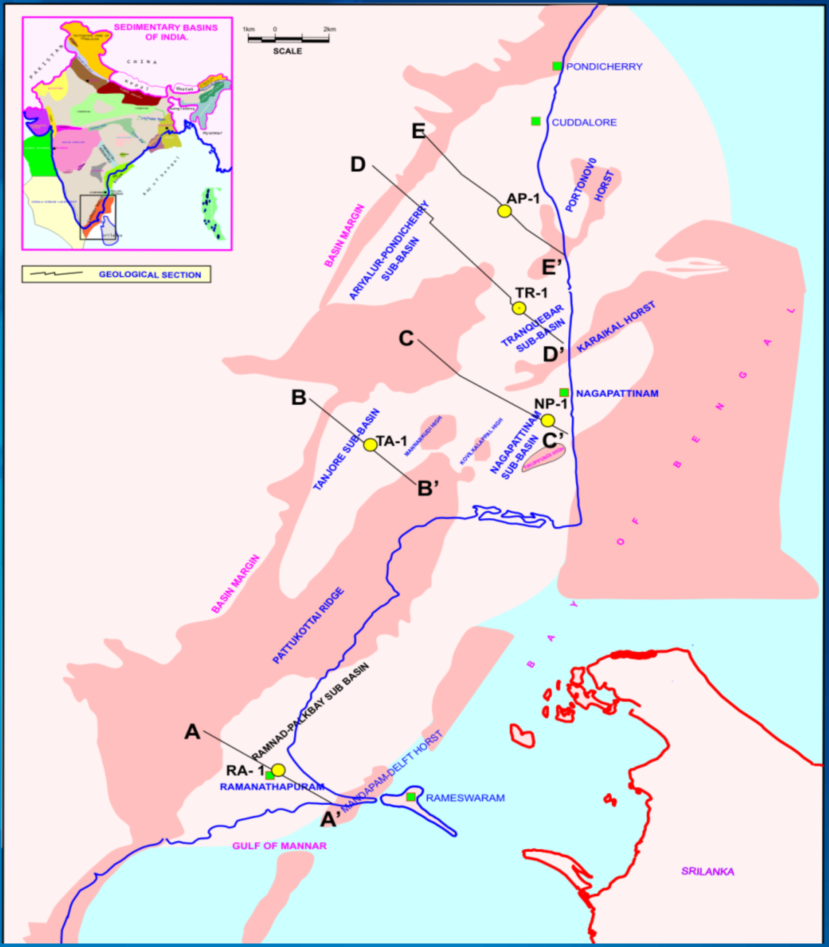
Wells

Deep wells close to syn-rift depo-centers in the sub-basins were used for modeling

Actual well data like lithology, source, bottom hole temperature(for calibration) etc. was used up to the drilled depth.

Beyond drilled depth projected parameters were applied.

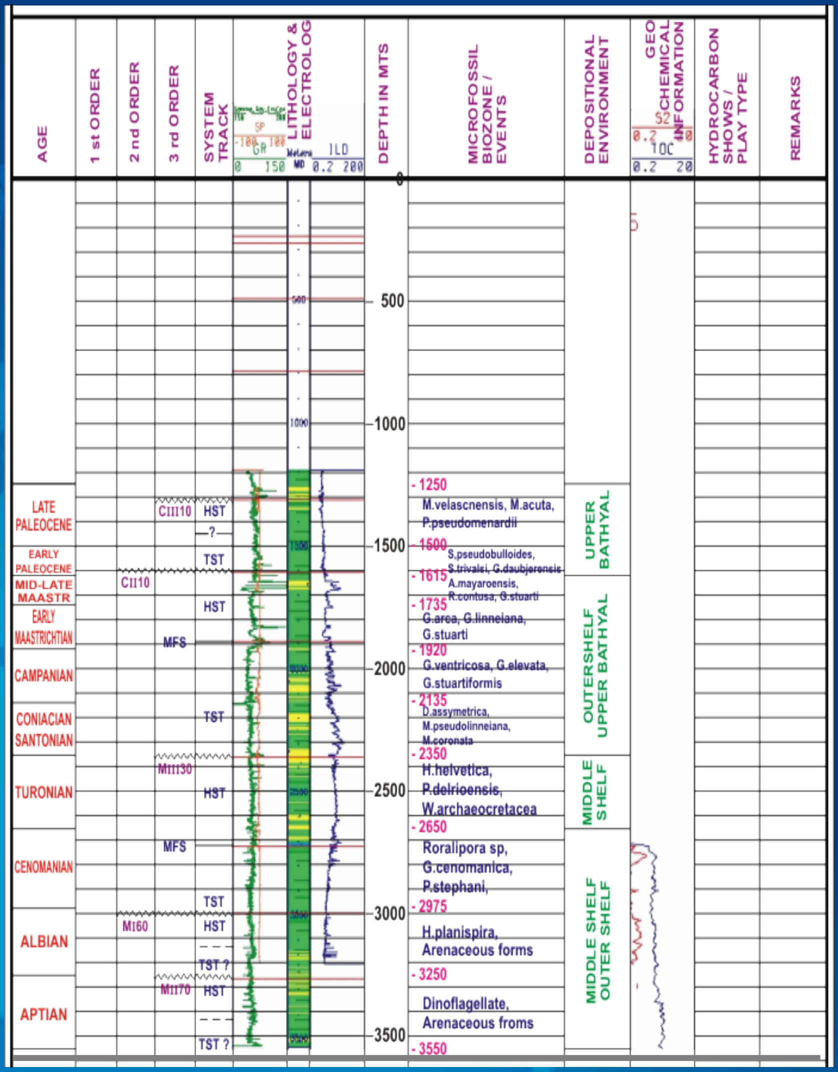
Fig- 1



Lithology

- The total sedimentary column at each location was split into layers (sequences) based on regional unconformities.
- Layer wise lithology was worked out based on drilled data.
- The default lithologies were edited using lithology editor to derive the appropriate lithological mix for a particular layer.
- Beyond the drilled section, sequences have been perceived to contain shale and sand in equal proportion.

RA-1



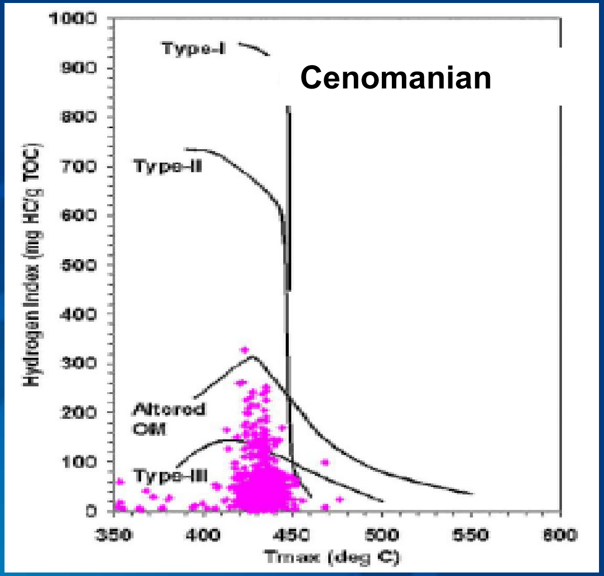
Source facies

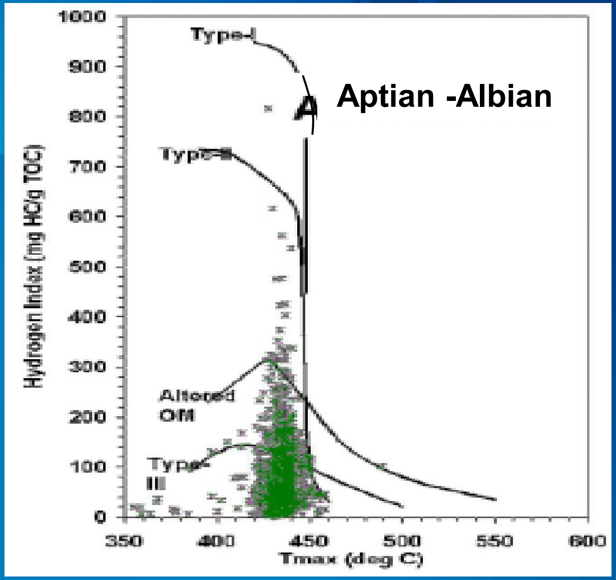
Geo-chemical studies carried out on source rock and oil & gas samples show that Kerogen type vary from pure type III organic matter to a kerogen type of 70 - 80 % type III + 30 – 20 % type II.

In drilled sections proved source facies and actual TOC and HI parameters were applied

In undrilled sections a uniform thickness of 20m source rock with 2-2.5% TOC and 200-250 HI units is adopted in Oxfordian, Berriasian and Hauterivian ages.

The main objective of the study is to determine the critical moments. Thickness of source do not influence the results





Time of Rifting

Initiation of rifting in south has been taken at 160 Ma within Oxfordian age of Late Jurassic.

In the northern sub basin of Ariyalur-Pondicherry the rift initiation has been taken at 150 Ma.

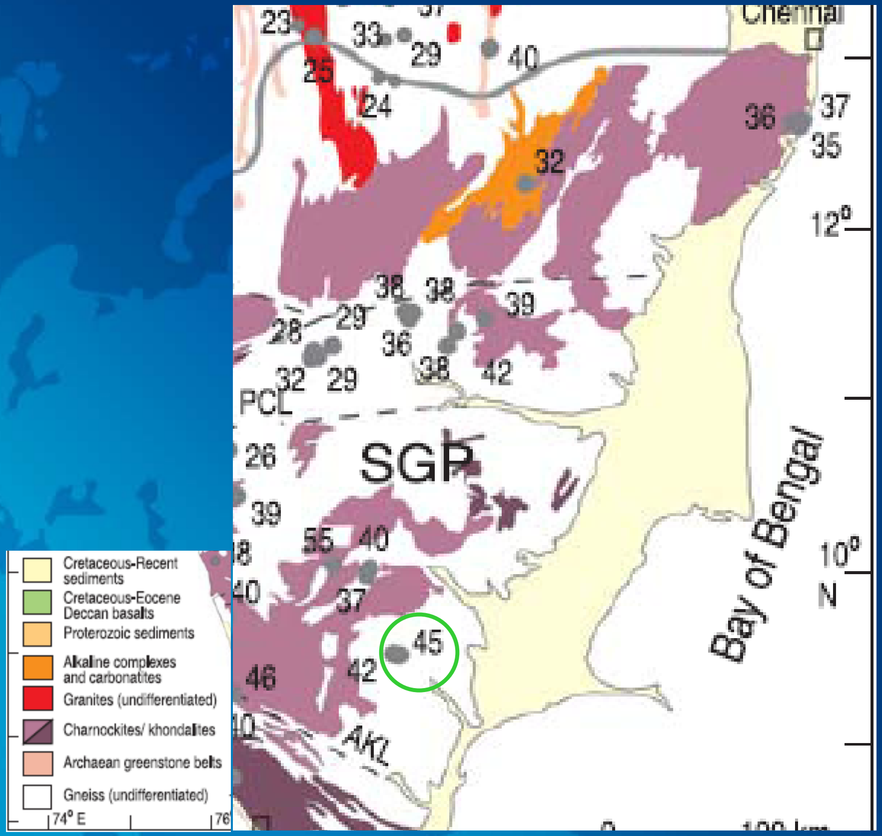
The end of rifting has been taken at 101.5 Ma (base of Nallurian stage of Indian Stratigraphy).

Heat flow

Heat-Flow Studies in India BY
SUKANTA ROY1* and R. SRINIVASAN2

Heat flow of 80mW/m2 during the rift stage and 45 mW/ m2 during post rift has been worked out based on calibration with VRo and bottom hole temperature data.

Measured heat flow in the cratonic area on the basin margin ranges between 37 to 55 mW/m2



Source of the heat-flow data are Gupta et al. (1991), Roy and Rao (2000), Ray et al. (2003), Roy et al. (2003, 2007, 2008)

Sediment Water Interface Temperature (SWIT)

Calibrated with average present day temperature of about 28°C. The temperature based on paleolatitudes provided in PetroMod was coming close to 23°C. The measured average temperature being higher by about 5°C, all the auto calculated temperature data based on paleolatitudes has been raised by 5°C.

Paleo Water Depth (PWD)

The paleobathymetry data is sparse as syn-rift sequences are rarely drilled through. Even in the drilled wells diagnostic forms are rare below the Albian. However, the available paleobathymetry in the drilled sections have been considered.

Kinetics

The kinetics used is based on experimental results of the source facies encountered in the drilled wells. Another variant of kinetics, viz., Pepper & Corvi (1995) TIIIH(DE) available with PetroMod has been attempted.

Erosion

Erosion at various levels has been worked out based on hiatus and seismic data.

Calibration

The selected wells have been calibrated with available VRo and Bottom Hole Temperature recorded during production testing. Data from wells in the vicinity have been used in case it's not available in the well.

Input Data Sheet of well RA-1

Main Input for RA1_3550_AAPG

Layer	Top [m]	Base [m]	Thickness [m]	Eroded [m]	Depo. from [Ma]	Depo. to [Ma]	Ero. from [Ma]	Ero. to [Ma]	Lithology	PSE	TOC [%]	Kinetic	[mg
Pliocene-Recent	0	270	270	300	5.33	2.00	2.00	0.00	SAND&LIME_2	Overburden Rock			
Miocene	270	500	230		23.03	5.33			sh80sd10slt10_2	Overburden Rock			
Oligocene	500	800	300		33.90	23.03			sd65ls35_2	Overburden Rock			
Eocene	800	1315	515		55.80	33.90			sd80sh20_2	Seal Rock			
Paleocene	1315	1600	285		65.50	55.80			SHALE_3	Seal Rock			
Campanian_Maastrich...	1600	1900	300		83.50	65.50			sd90sh10_2	Overburden Rock			
Coniacian_Santonian	1900	2350	450		89.30	83.50			sd75sh25_2	Overburden Rock			
Turonian	2350	2720	370		93.50	91.61	91.61	89.30	SANDcalc._2	Reservoir Rock			
Late Alb_Cenomanian	2720	2990	270		101.50	93.50			SHALEcalc_3	Seal Rock			
Aptian_Late Albian	2990	3530	540		124.50	101.50			SHALE_3	Seal Rock			
RA1_AptianSR	3530	3550	20		125.00	124.50			SHALE_3	Source Rock	2.00	NewKinetic...	200.00
Hauterivian_Barremian	3550	3830	280		136.00	125.00			SAND&SHALE_2	Reservoir Rock			
RA1 hyp_Hauterivian SR	3830	3850	20		136.40	136.00			SHALE_3	Source Rock	2.00	NewKinetic...	200.00
Berriasian_Valanginian	3850	4800	950		144.50	136.40			SHALEsand_3	Overburden Rock			
RA1 hyp_Berriasian SR	4800	4820	20		145.00	144.50			SHALE_3	Source Rock	2.00	NewKinetic...	200.00
Up Jurassic	4820	5730	910		159.50	152.50			SAND&SHALE_2	Overburden Rock			
RA1 hyp_Oxfordian SR	5730	5750	20		160.00	159.50			SHALE_3	Source Rock	2.00	NewKinetic...	225.00
Basement	5750	5950	200		180.00	160.00			Granite	Underburden R...			
						180.00							

Boundary conditions of well RA-1

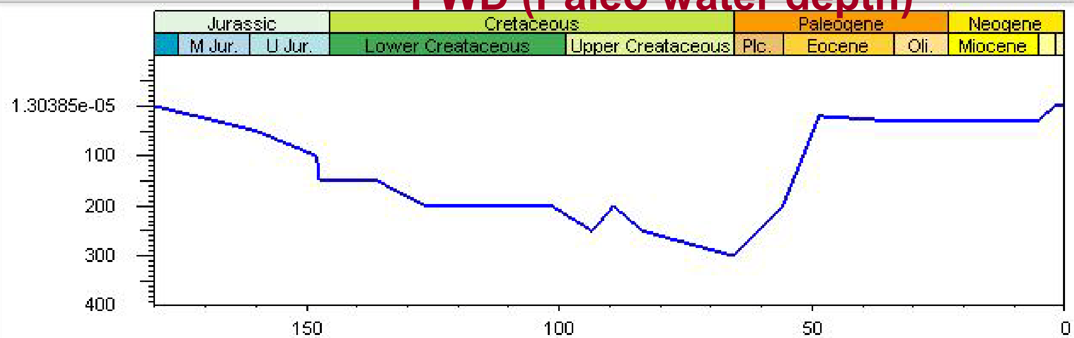
Boundary Conditions for RA1_3550_AAPG

Age [Ma]	PWD [m]
0.00	0
2.00	0
5.33	30
23.03	30
33.90	30
48.60	20
55.80	200
65.50	300
83.50	250
89.30	200
93.50	250
101.50	200
125.00	200
126.50	200
136.00	150
136.40	150
147.50	150
148.00	100
160.00	50
180.00	0

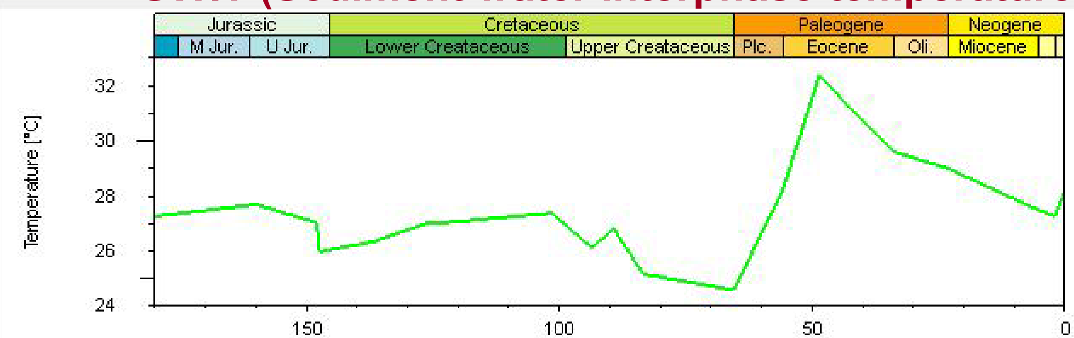
Age [Ma]	SWIT [°C]
0.00	28.20
2.00	27.28
5.33	27.50
23.03	29.00
33.90	29.62
48.60	32.37
55.80	28.24
65.50	24.59
83.50	25.18
89.30	26.84
93.50	26.12
101.50	27.38
125.00	27.00
126.50	27.00
136.00	26.41
136.40	26.37
147.50	25.98
148.00	27.03
160.00	27.70
180.00	27.27

Age [Ma]	Heat Flo nW/m
0.00	45.00
2.00	45.00
5.33	45.00
23.03	45.00
33.90	45.00
48.60	45.00
55.80	45.00
65.50	45.00
83.50	50.00
89.30	60.00
93.50	70.00
101.50	80.00
125.00	80.00
126.50	80.00
136.00	70.00
136.40	70.00
147.50	80.00
148.00	80.00
160.00	80.00
180.00	45.00

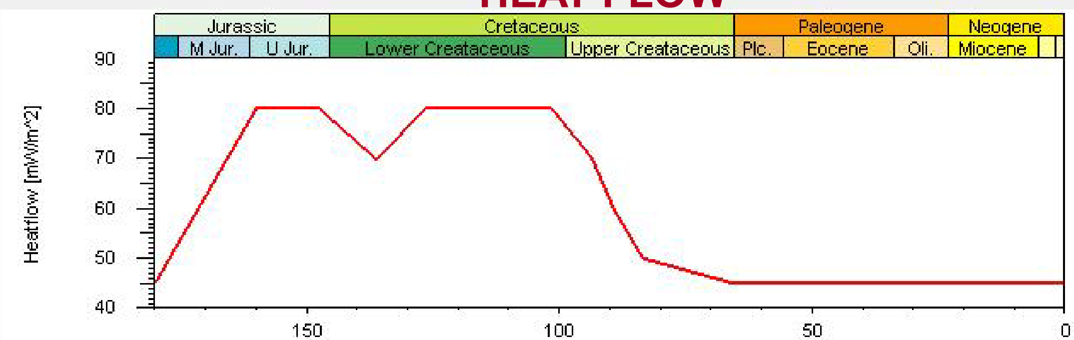
PWD (Paleo water depth)



SWIT (Sediment water interphase temperature

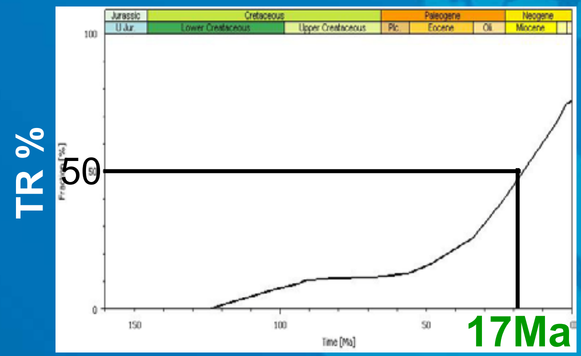


HEAT FLOW

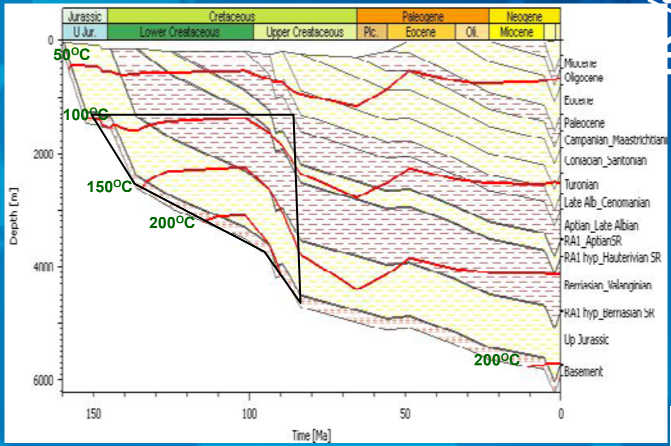


WELL RA-1
RAMNAD SUB BASIN

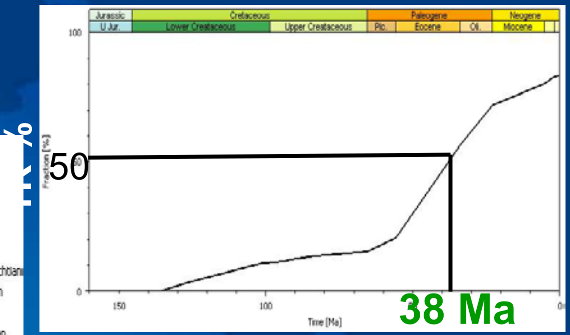
TRANSFORMATION RATIO – APTIAN SOURCE



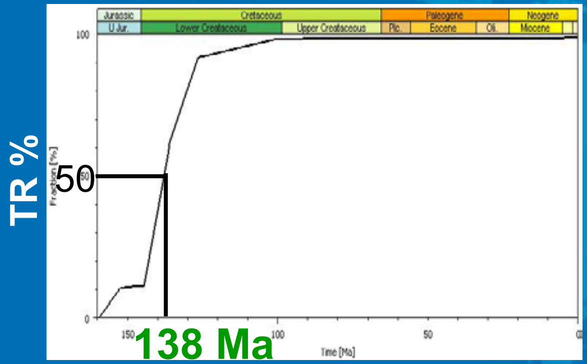
BURIAL HISTORY



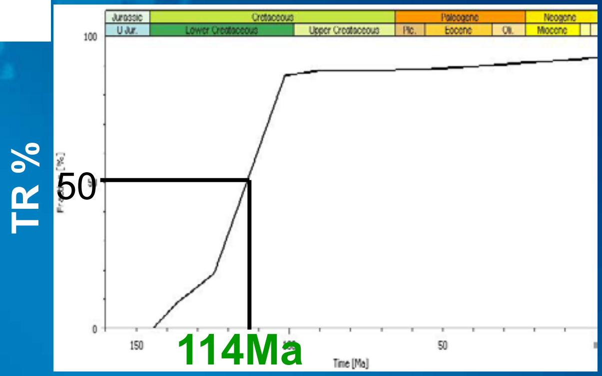
TRANSFORMATION RATIO – HAUTERIVIAN SOURCE *



TRANSFORMATION RATIO – OXFORDIAN SOURCE *



TRANSFORMATION RATIO – BERRIASIAN SOURCE *



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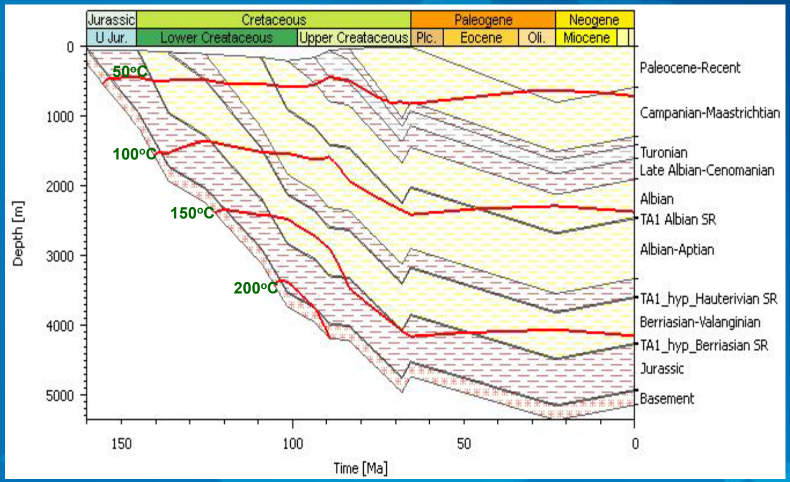
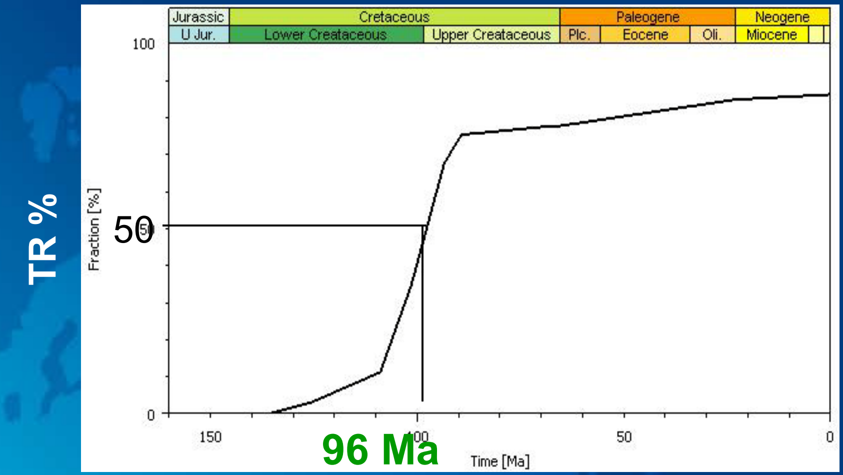
* **HYPOTHETICAL**

WELL TA-1
TANJORE SUB BASIN

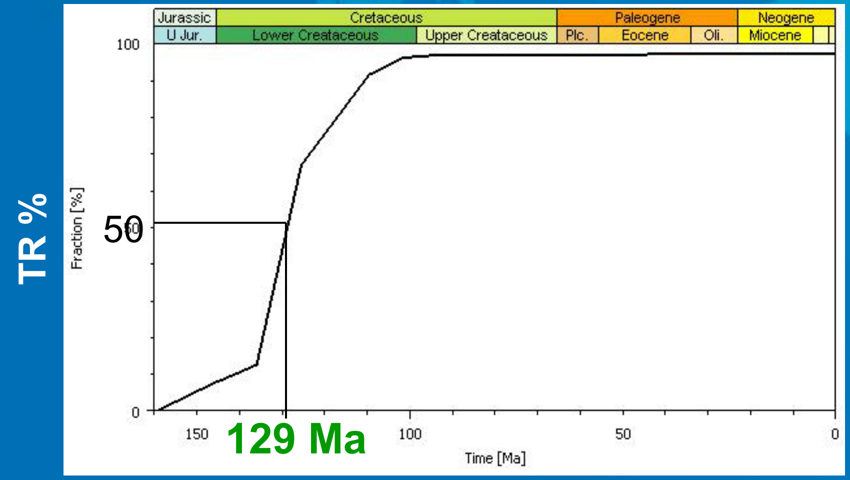
BURIAL HISTORY



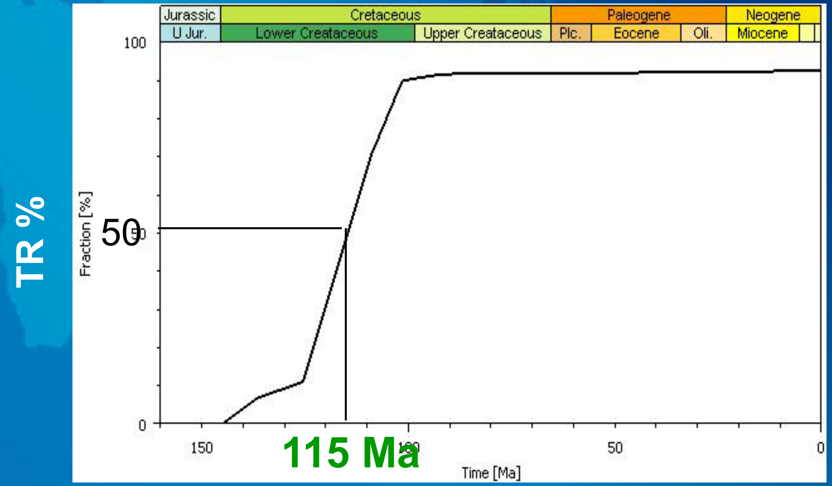
TRANSFORMATION RATIO – HAUTERIVIAN SOURCE



TRANSFORMATION RATIO – OXFORDIAN SOURCE *



TRANSFORMATION RATIO – BERRIASIAN SOURCE *



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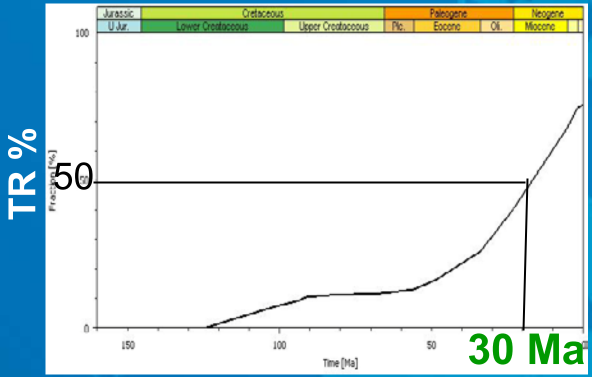
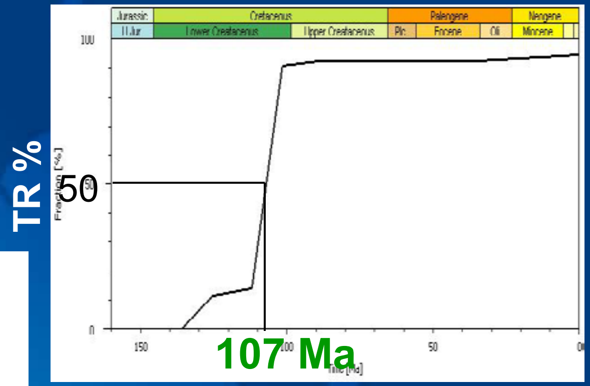
* **HYPOTHETICAL**

WELL NP-1
NAGAPATTINAM SUB BASIN

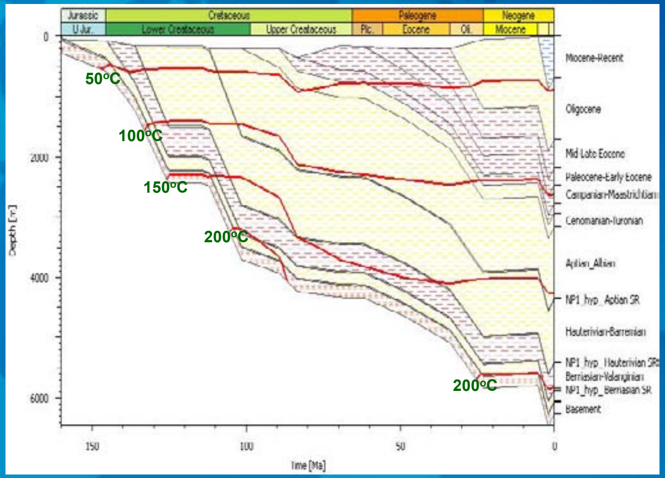
TRANSFORMATION RATIO – APTIAN SOURCE *



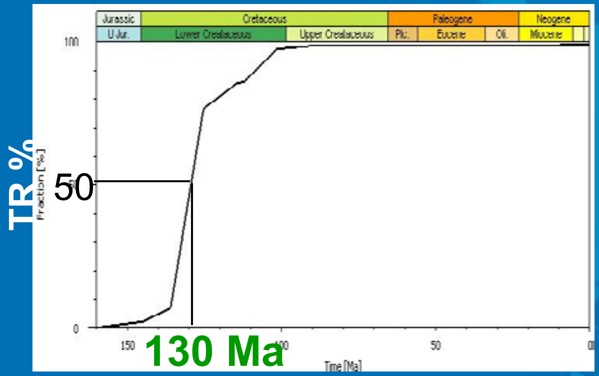
TRANSFORMATION RATIO – HAUTERIVIAN SOURCE *



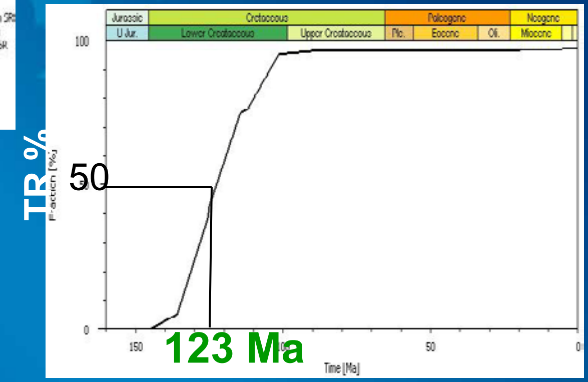
BURIAL HISTORY



TRANSFORMATION RATIO – OXFORDIAN SOURCE *



TRANSFORMATION RATIO – BERRIASIAN SOURCE *



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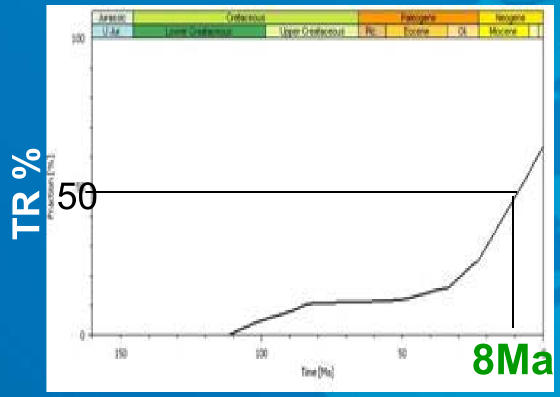
ONGC INDIA

* **HYPOTHETICAL**

WELL TR-1
TRANQUEBAR SUB BASIN

TRANSFORMATION RATIO – APTIAN SOURCE



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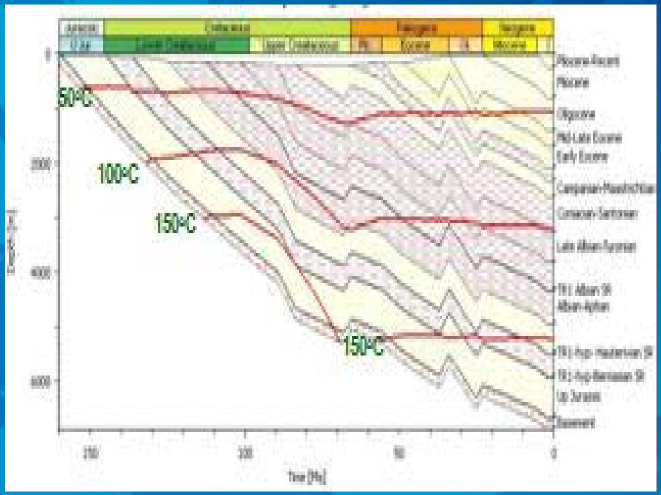

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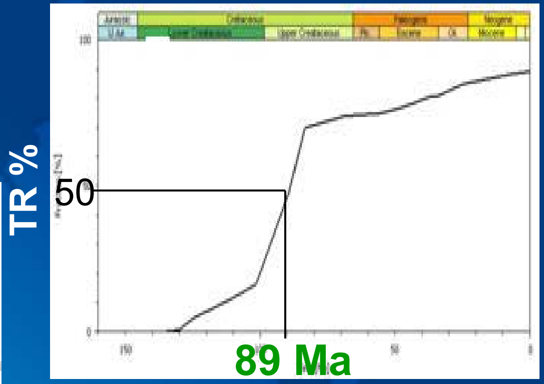

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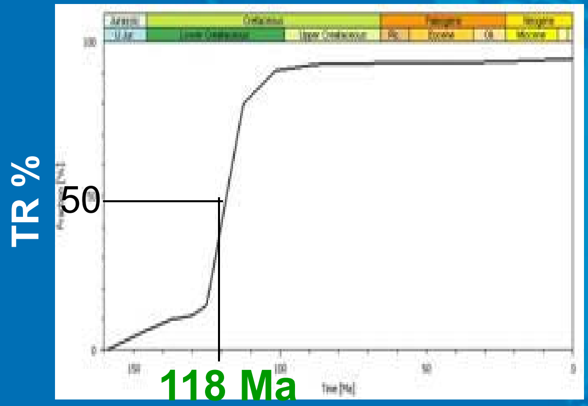
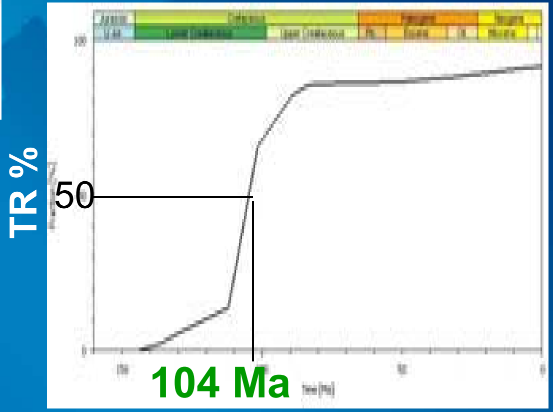


TRANSFORMATION RATIO BERRIASIAN SOURCE*



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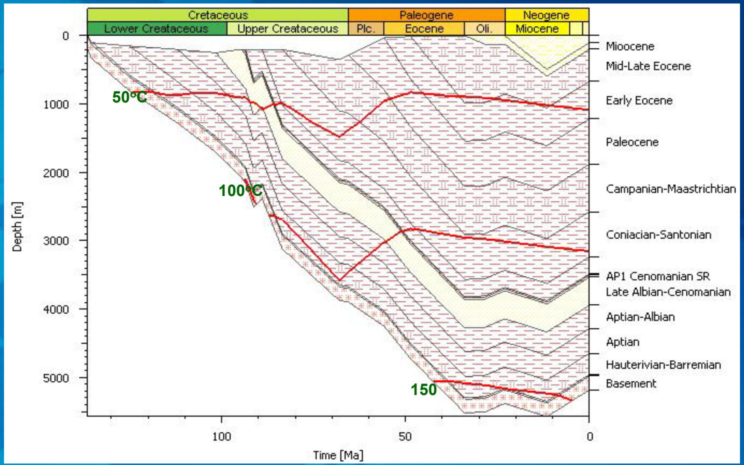
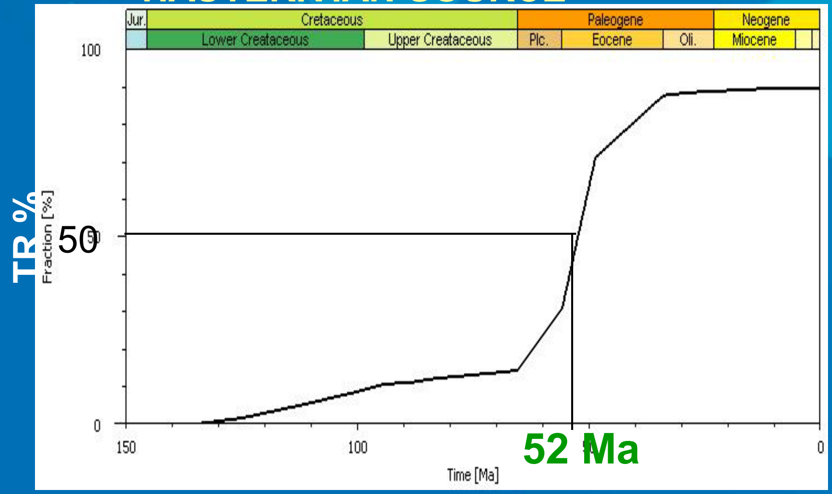
* **HYPOTHETICAL**

WELL AP-1
ARIYALUR PONDICHERRY

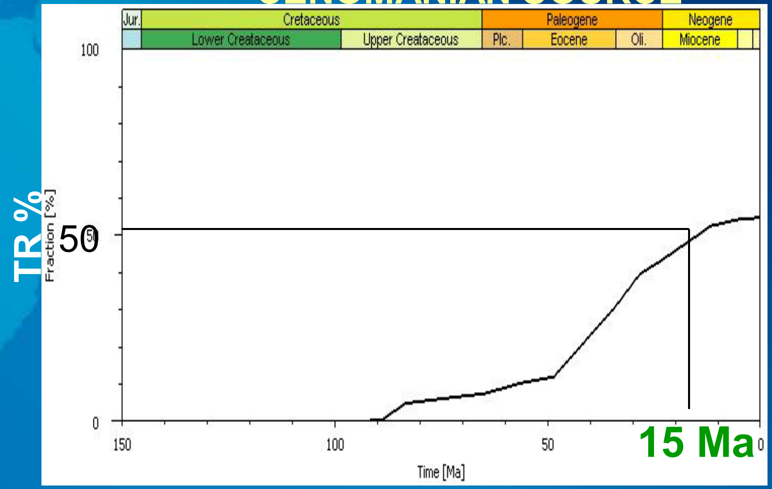
BURIAL HISTORY



TRANSFORMATION RATIO – HAUTERIVIAN SOURCE *



TRANSFORMATION RATIO – CENOMANIAN SOURCE



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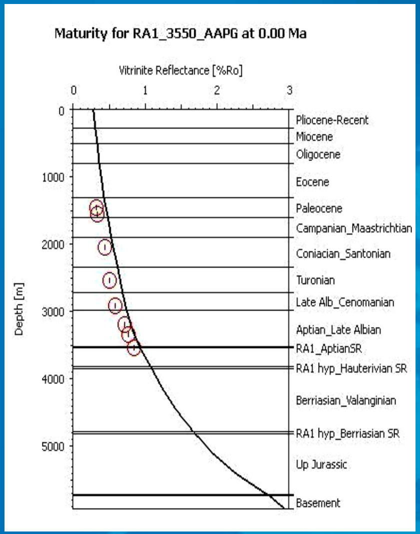
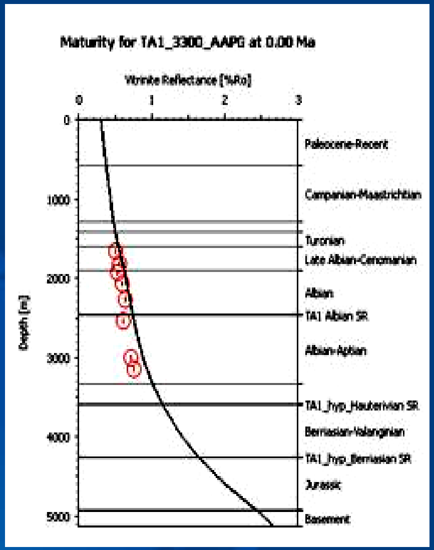
* **HYPOTHETICAL**

Calibration With VRo Data

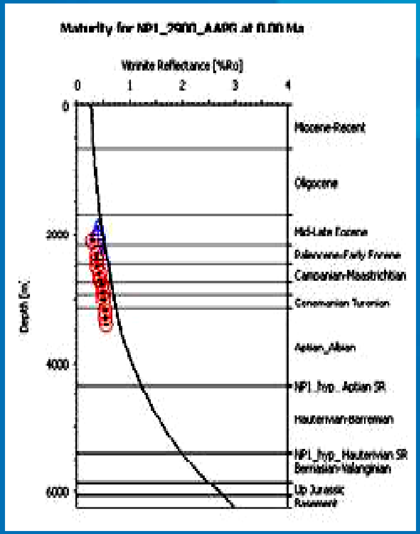
RA-1



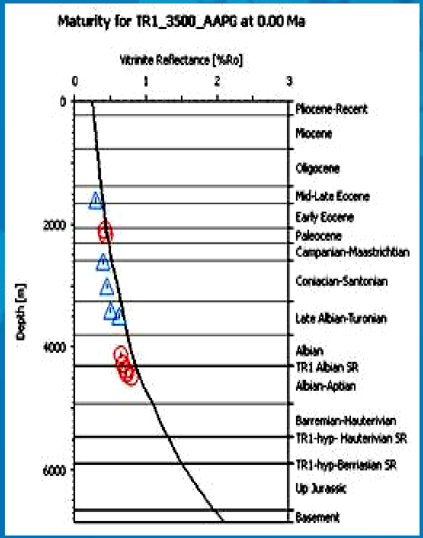
TN-1



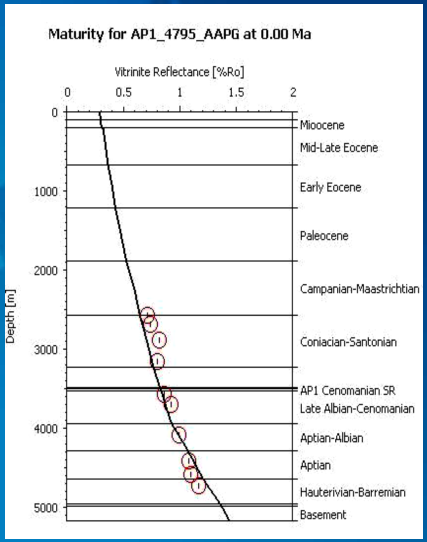
NP-1



TR-1

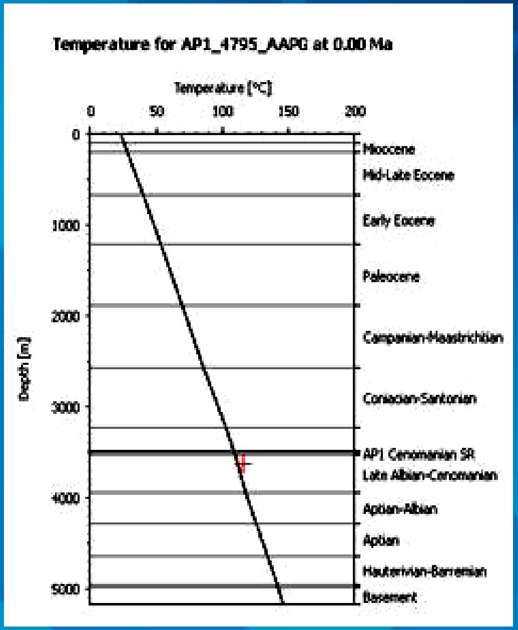


AP-1

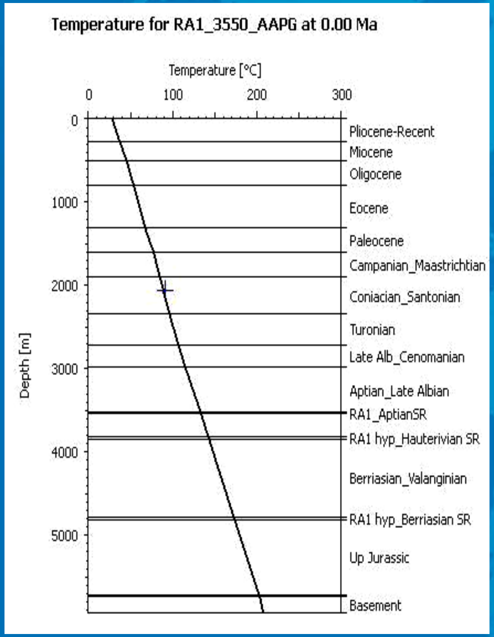


CALIBRATION WITH BOTTOM HOLE TEMPERATURE

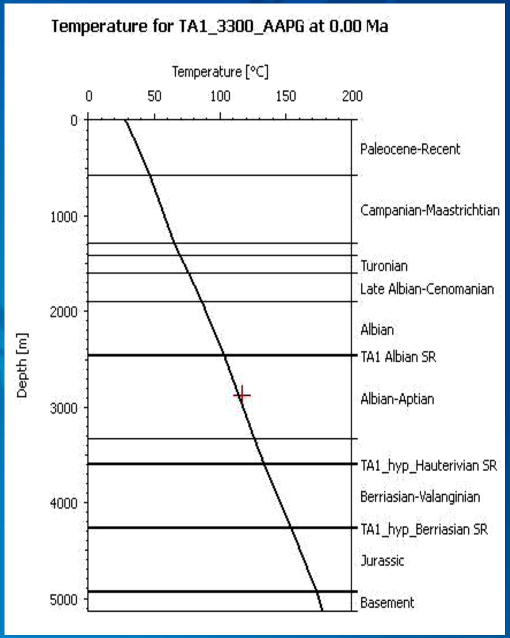
AP-1



RA-1

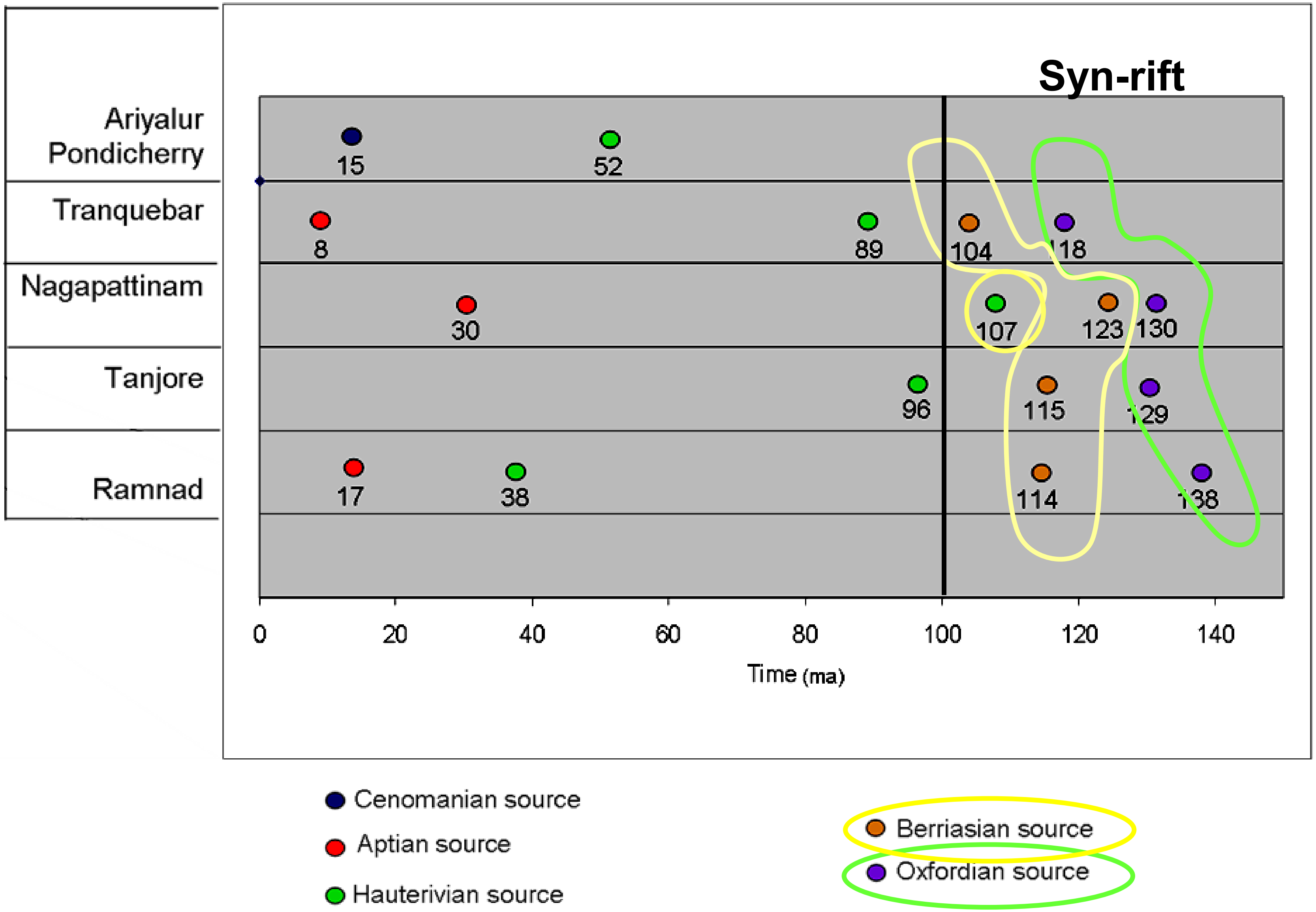


TA-1

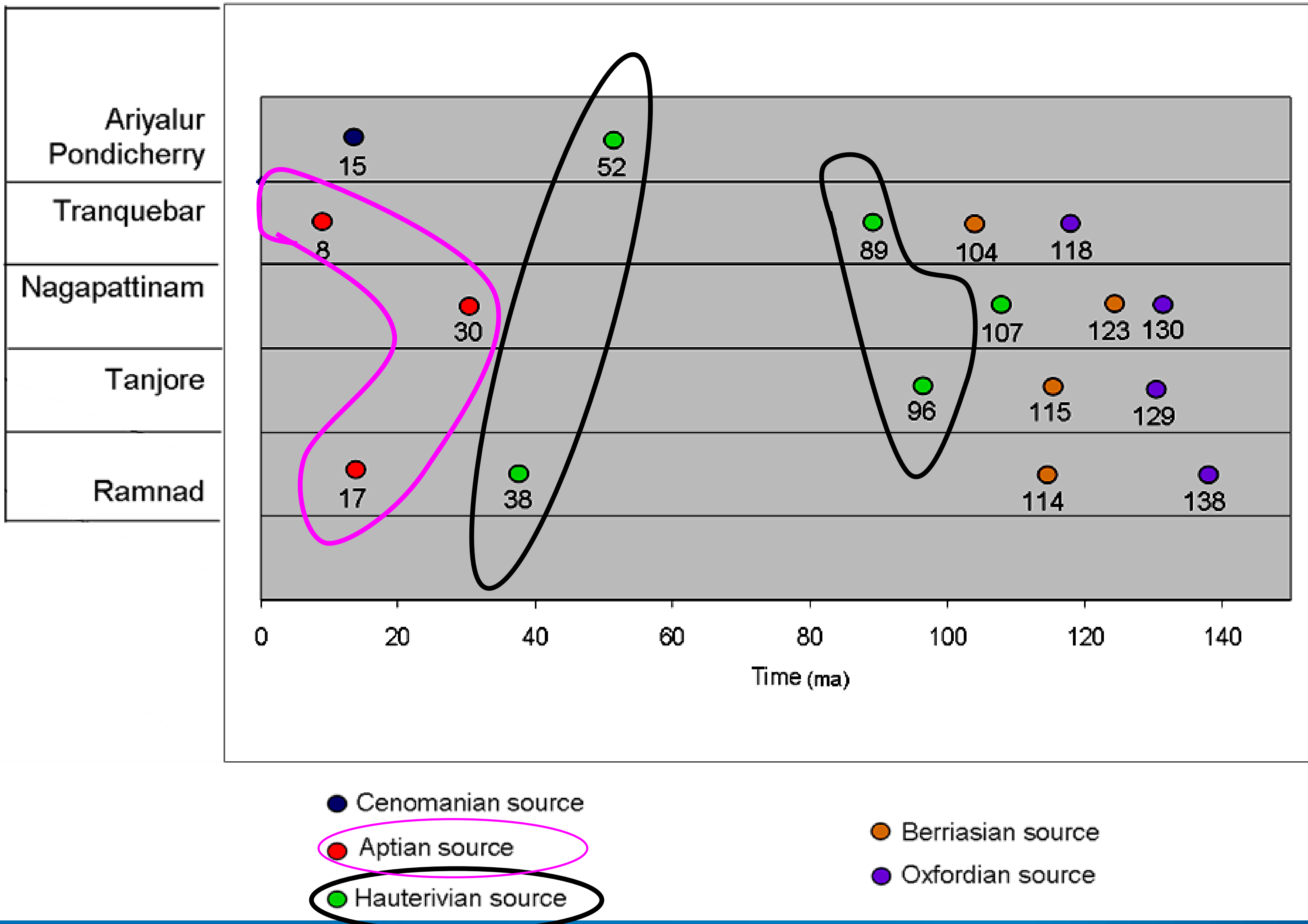


Comparison of Critical Moments for two kinetic variants		
AGE	New Kinetic	Pepper & Corvi (1995)_TIIIH(DE)
AP1-Cenomanian	15	Not Reached
TR1-Aptian	8	Not Reached
NP1-Aptian	30	24
RA1-Aptian	17	Not Reached
AP1-Hauterivian	52	45
TR1-Hauterivian	89	46
NP1-Hauterivian	107	106
TA1- Hauterivian	96	68
RA1- Hauterivian	38	14
TR1-Berriasian	104	95
RA1-Berriasian	114	109
TA1-Berriasian	115	108
NP1-Berriasian	123	112
TR1-Oxfordian	118	114
NP1-Oxfordian	130	125
TA1-Oxfordian	129	121
RA1-Oxfordian	138	133

DISTRIBUTION OF CRITICAL MOMENTS WITH TIME IN CAUVERY BASIN



DISTRIBUTION OF CRITICAL MOMENTS WITH TIME IN CAUVERY BASIN



Results

- Peak generation of Oxfordian and Berriasian sources (hypothetical) was attained within Lower Cretaceous (syn rift) in the basin.
- Hauterivian source rocks in Nagapattinam sub basin attained peak generation during Aptian age

Peak generation of source rocks within syn rift period

Sub basin	Source rock				
	Oxfordian	Berriasian	Hauterevian	Aptian	Cenomanian
ARIYALUR PONDICHERRY					
TRANQUEBAR					
NAGAPATTINAM					
TANJORE					
RAMNAD					

Results

- Peak generation of Oxfordian and Berriasian sources was attained within Lower Cretaceous (syn rift) in the basin.
- Hauterivian source rocks in Nagapattinam sub basin attained peak generation during Aptian age (syn rift)
- Hauterivian source rocks in Tanjore and Tranquebar sub basins attained peak generation in early part of Upper Cretaceous. Ramnad and Ariyalur-Pondicherry sub basins the equivalent source facies matured much later (Eocene)
- Aptian and Cenomanian sources attained peak generation during Oligocene and Younger

Peak generation of source rocks in post rift period

Sub basin	Source rock				
	Oxfordian	Berriasian	Hauterevian	Aptian	Cenomanian
ARIYALUR PONDICHERRY					
TRANQUEBAR					
NAGAPATTINAM					
TANJORE					
RAMNAD					

Conclusions

- As major source facies attain peak generation within syn-rift period, syn-rift reservoirs of Ramnad, Tanjore, Nagapattinam and Tranquebar sub basins are potential targets.
- Hydrocarbons expelled from early maturation of Oxfordian and Berriasian sources are likely to charge syn-rift reservoirs in these sub basins.
- Maturation of Hauterivian source rocks during Aptian could also charge the syn-rift reservoirs in Nagapattinam sub basin.
- With high probability for the presence of other elements required for existence of petroleum system, in analogy with other rift basins -
- Hydrocarbon accummulations could occur in syn-rift reservoirs of Cauvery Basin. Exploration targeting these reservoirs needs an API with deliberate focus in the depth range 3500 to 5500m (syn rift sequences).