Petroleum Exploration Initiative

Interior Basin

Two Dimensional Basin Modelling of the Neoproterozoic Officer Basin of Western Australia to Calculate the Timing of Petroleum Charge

K. Ameed R. Ghori

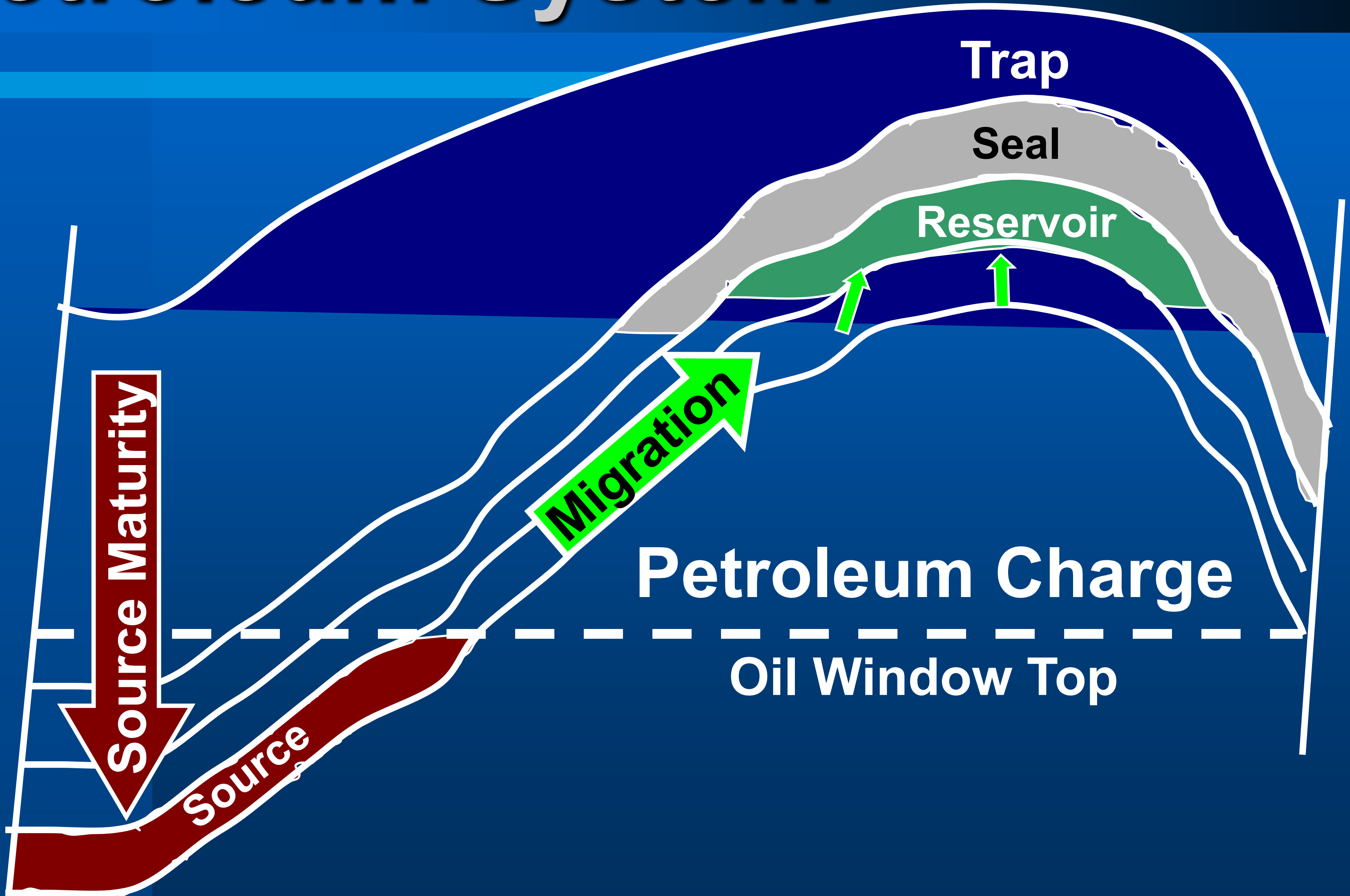
Presentation

- Petroleum prospectivity
  - Principles & Processes
  - Basin Modelling
- Objective of study
  - Location & Stratigraphy
  - Modelling
- Results & Conclusions

Prospectivity—Controlling Factors

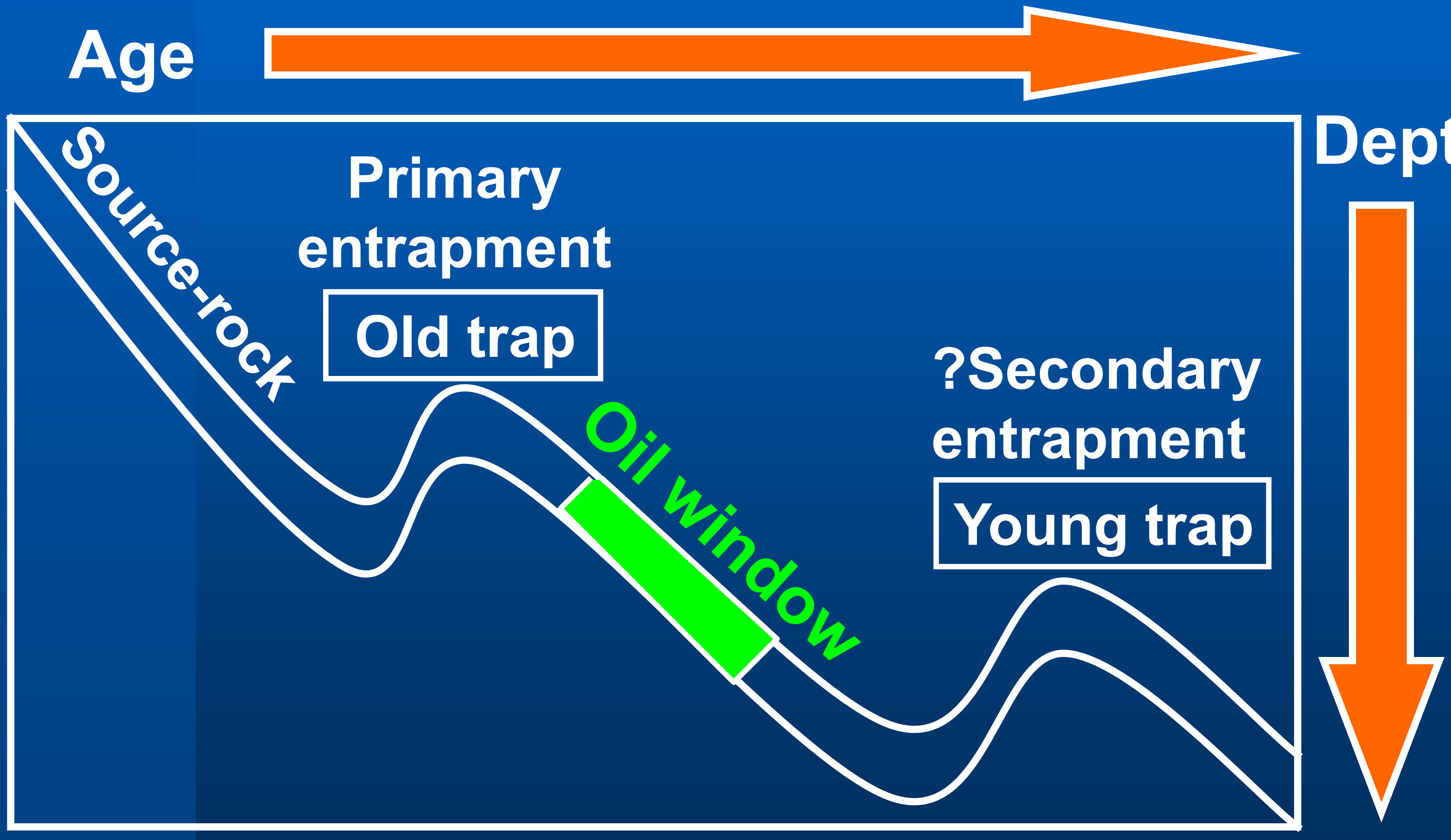
- Petroleum charge
  - source type & maturation, hydrocarbon expulsion, migration, & charge timing
- Trap
  - structure, reservoir & seal
- Preservation
  - thermal history & meteoric water invasion

Petroleum System

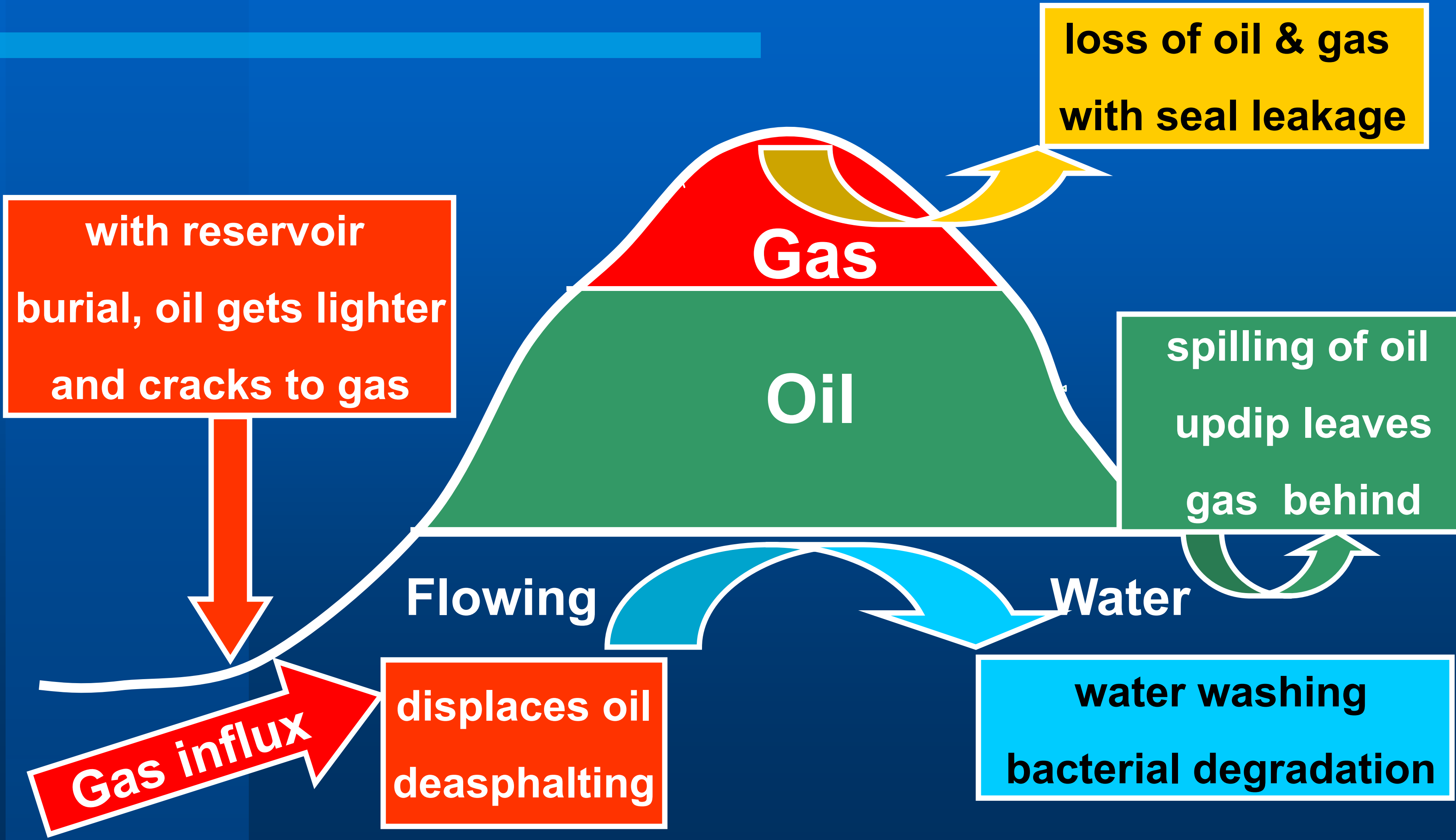


Ameed Ghori

Timing — Generation versus Trap



Petroleum Preservation



Ameed Ghori

Basin Modelling

- Most efficient tool to estimate timing of oil and gas generation
- Reconstruction of burial and thermal histories
- Integration of geophysics, geology and geochemistry

Modelling Type & Purpose

Single & multi-dimentional reconsturction of burial, thermal & fluid-flow history of a sedimentary basin

- **1-D**
  Single Location Hydrocarbon type & timing
- **2-D**
  Geological Section Evaluation of a Petroleum system
- **3-D**
  Basin Area Evaluation of a Petroleum system

Modelling Procedure

Step 1
Conceptual model

Time-stratigraphy
Rock units,
hiatuses & unconformities

Rock unit ages & lithologies
Erosion ages & thicknesses

Identification & characterization
of source, seal, carrier
and reservoir rocks

Modelling Procedure

Step 2
Calculation

Thermal maturity
porosity & permeability

Temperature, maturation &
hydrocarbon generation history

Modelling Procedure

Step 3
Optimization

Present temperatures
BHTs, RFTs, DSTs
& production test

Palaeotemperatures
VR, TAI, SCI, biomarkers & AFTA

Geochemical data
TOC, Rock-Eval, PGC,
extract & kerogen kinetics

Physical data
Porosity, permeabolity
pore pressure & mud weights

Ameed Ghori

Petroleum Prospectivity of Proterozoic

- Oil and gas accumulation will continue to be found in Proterozoic rocks worldwide:
  - where source rocks are organic-rich
  - kerogens not extensively dehydrogenated
  - reservoirs are well preserved.
- Thus these rocks should not be ignored as potential petroleum sources
  - (Hunt, 1996)

Proterozoic Petroleum System

- **Mesoproterozoic:**
  - McArthur & Urapungan Supersytems — 1.7–1.5 billion years, McArthur Basin
    - World's oldest oil from Urapunga 4 well

- **Neoproterozoic:**
  - Centralian Supersystem: Amadeus, Ngalia, Georgina, & Officer basins — 1.00 –0.54 billion years

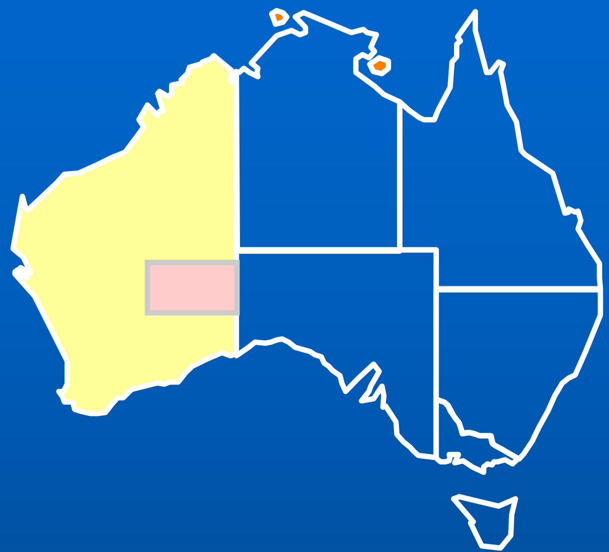
Proterozoic Amadeus Basin

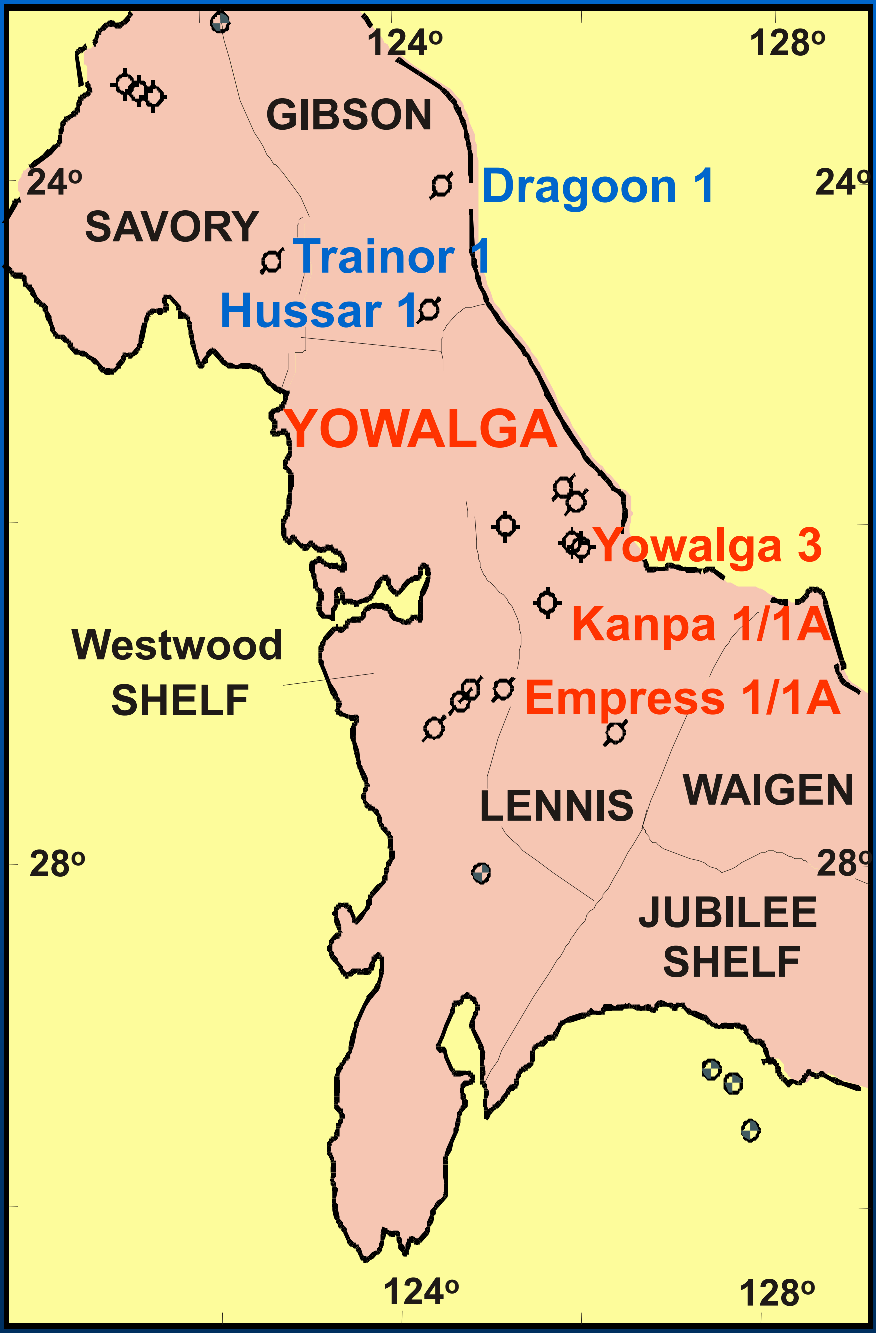
- Ooraminna 1, 1963
  - Gas Flow (12 MCFD), Areyonga Formation (~760 Ma)
- Dingo Gas Discovery, 1981
  - Arumbera Formation (5 MMCFD)
- Magee 1, 1992
  - Gas Flow (63.1 MCFD), Heavitree Quartzite (~ 870 Ma)

Objective

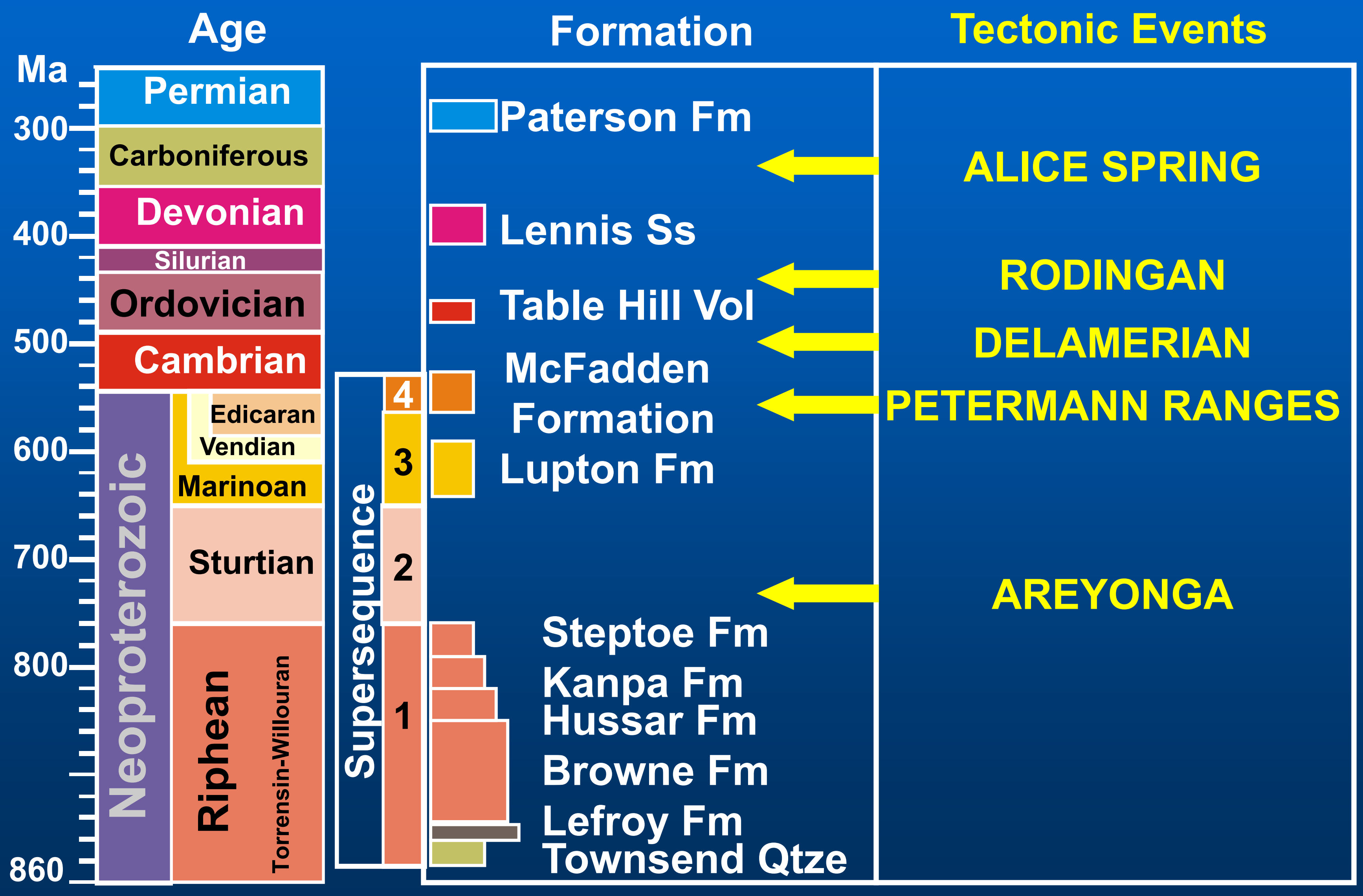
- The objective of this study was to reconstruct the maturation and hydrocarbon generation history to predict the timing of hydrocarbon charge to traps within the Yowalga Area of Officer Basin
- Because thermal maturity and its timing plays an important role in oil and gas generation, migration, accumulation and preservation

Officer Basin, Sub-basin & Well Locations





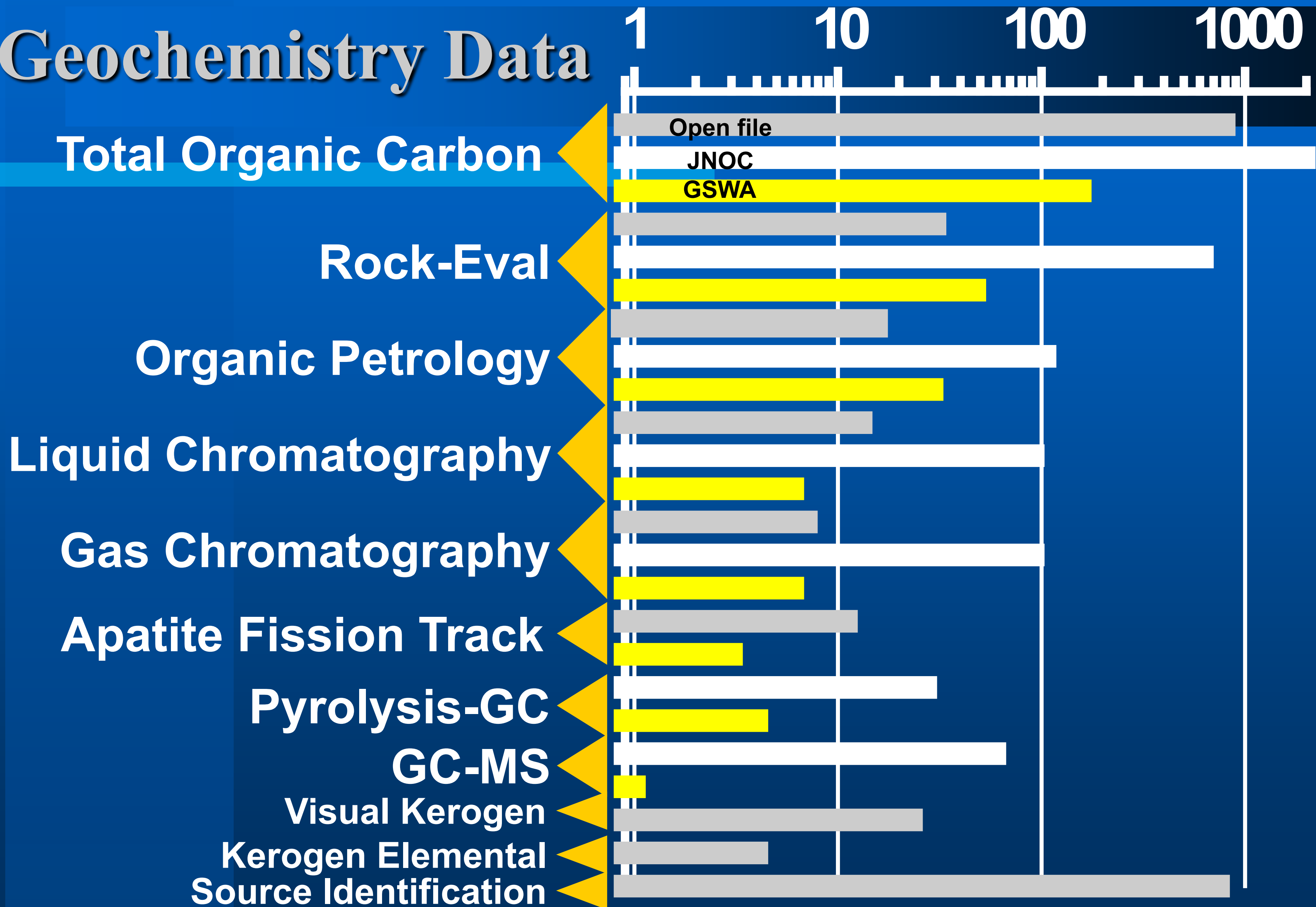
Officer Basin — Stratigraphy



Petroleum Exploration

- Phase 1 - 1965-66
  - 5 Shallow wells by Hunt Group
- Phase 2: 1980-84
  - 5 deep wells by Shell & Eagle Group
- Phase 3: 1995- Present
  - 3 wells by GSWA; 3 wells by Amadeus and analysis by JNOC

Geochemistry Data



Ameed Ghori

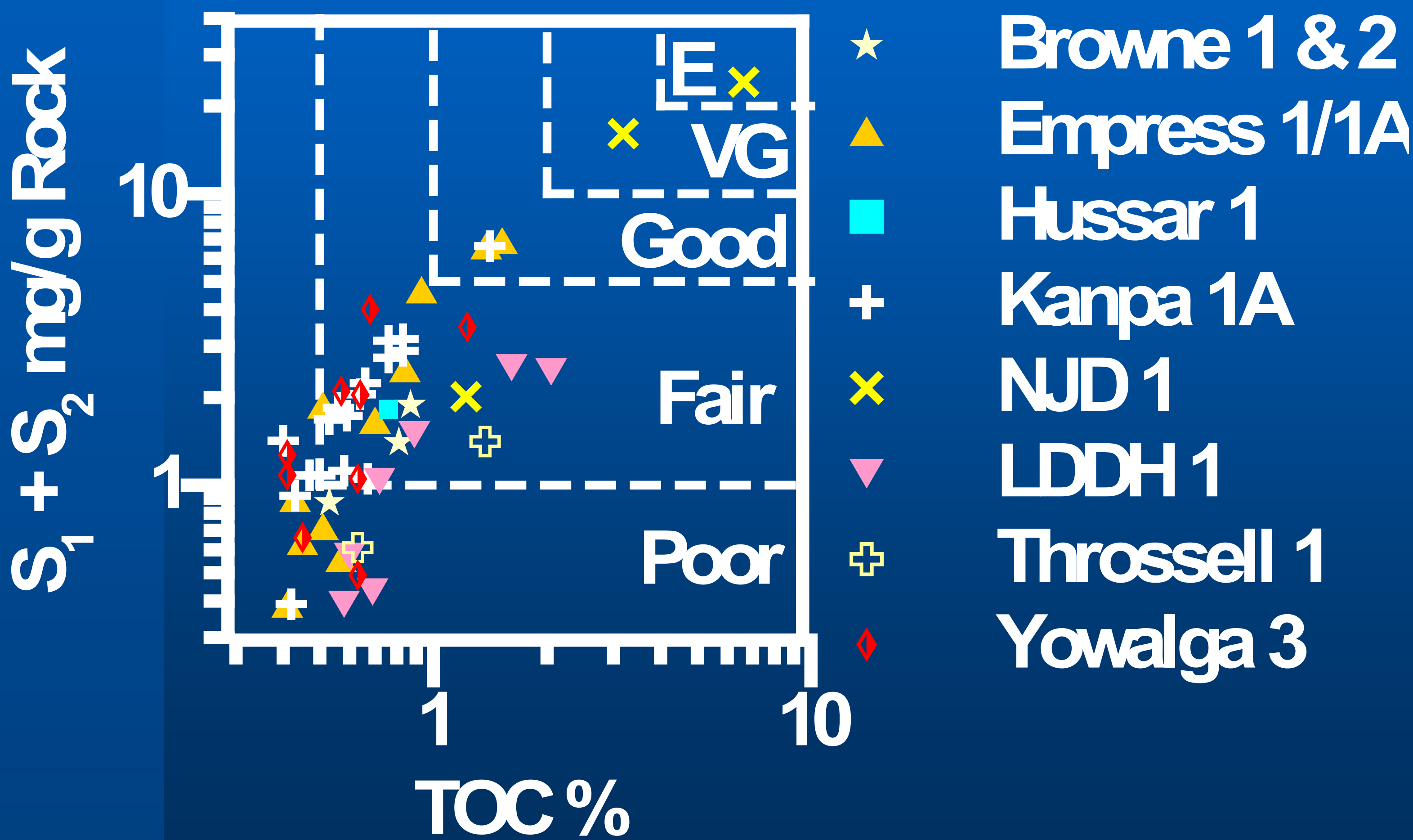
Source Rocks

- Thin but excellent to fair source-beds have been identified in Brown 1 & 2, Empress 1/1A, Hussar 1, Kanpa 1A, LDDH 1, NJD 1, Throssell 1 & Yowalga 3

Following 5 slides will show:

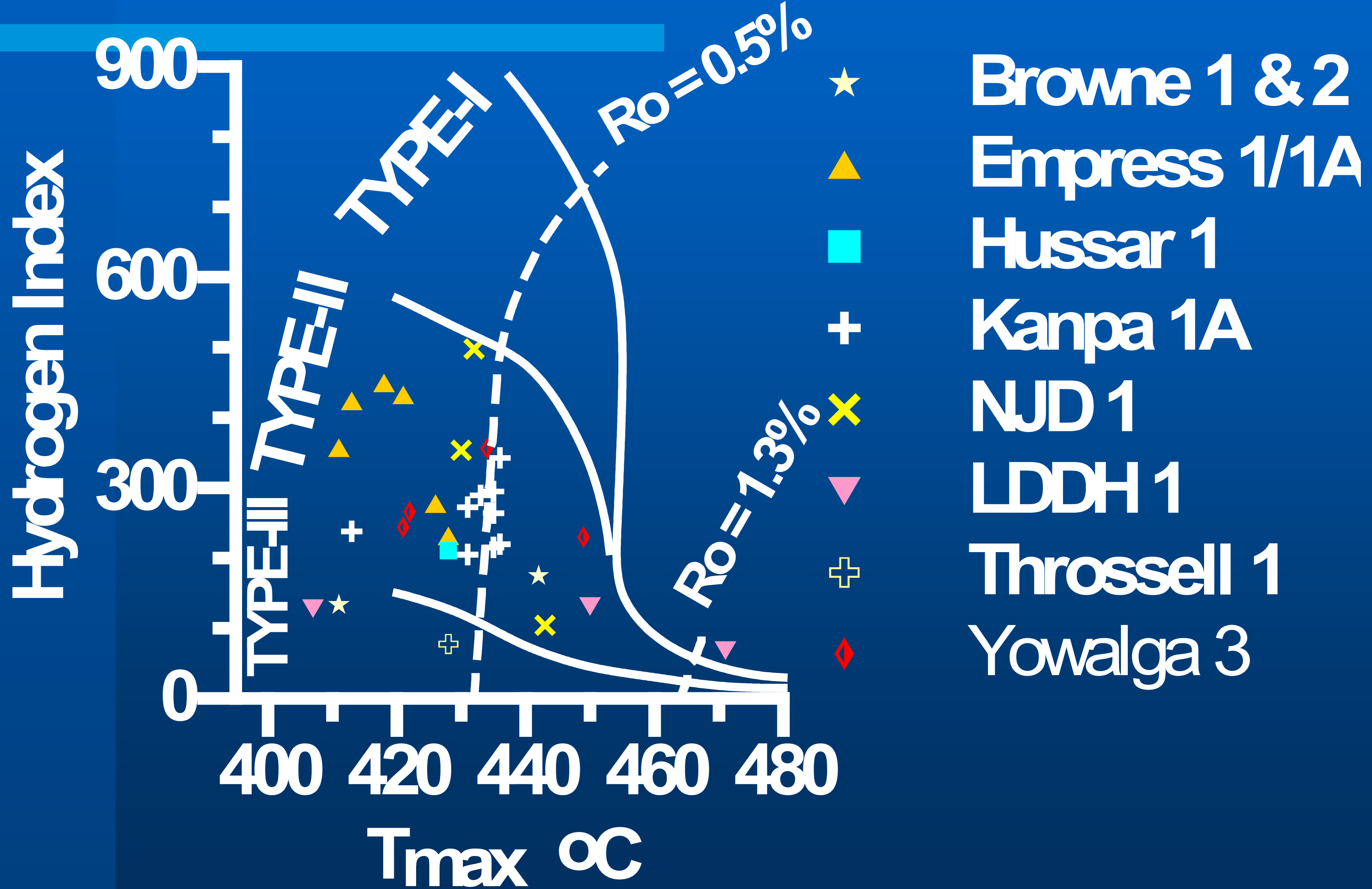
- Generating Potential
- Kerogen type
- Source rock intervals in 3 key wells

Petroleum Generating Potential

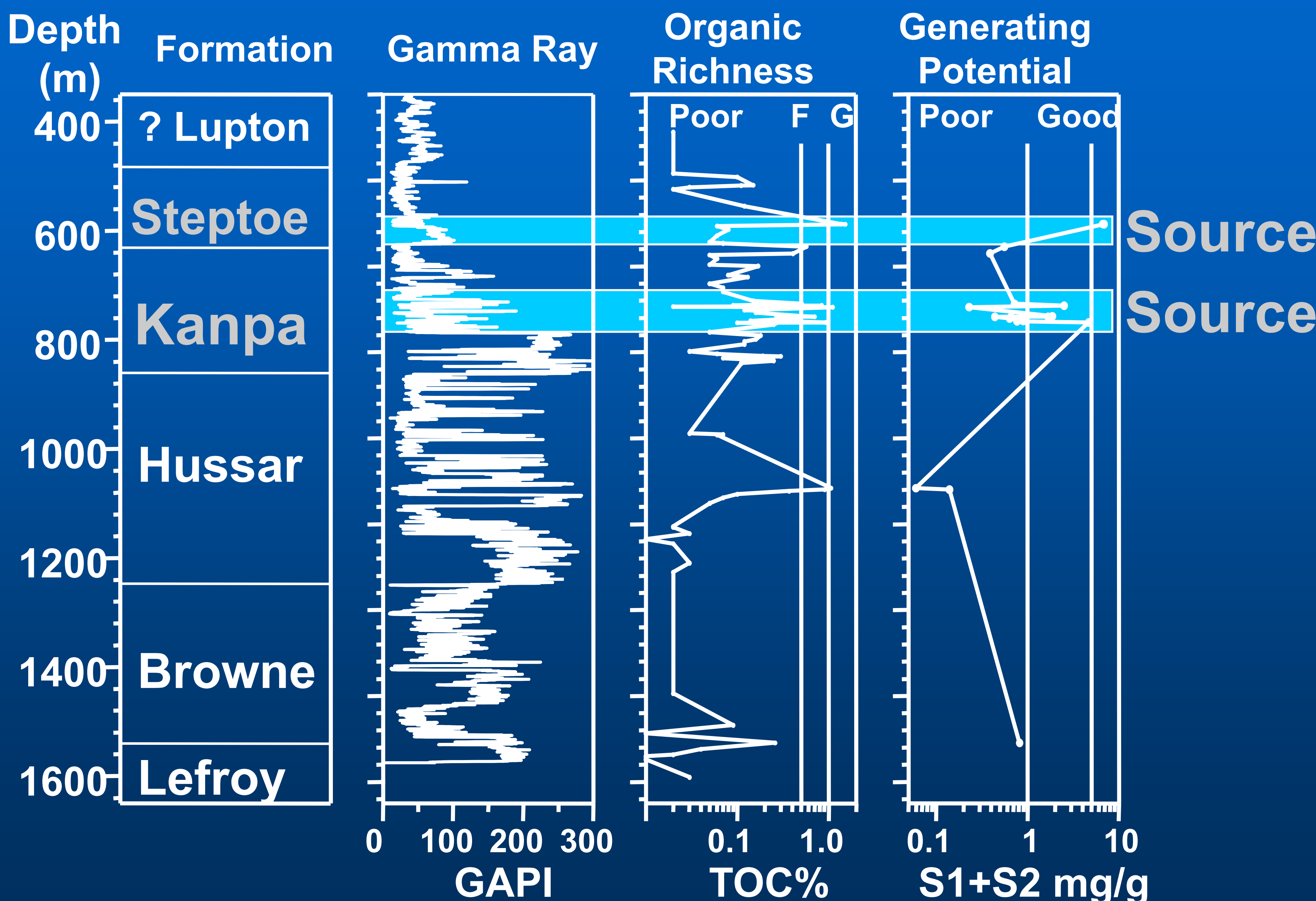


Ameed Ghori

Rock-Eval Kerogen Typing

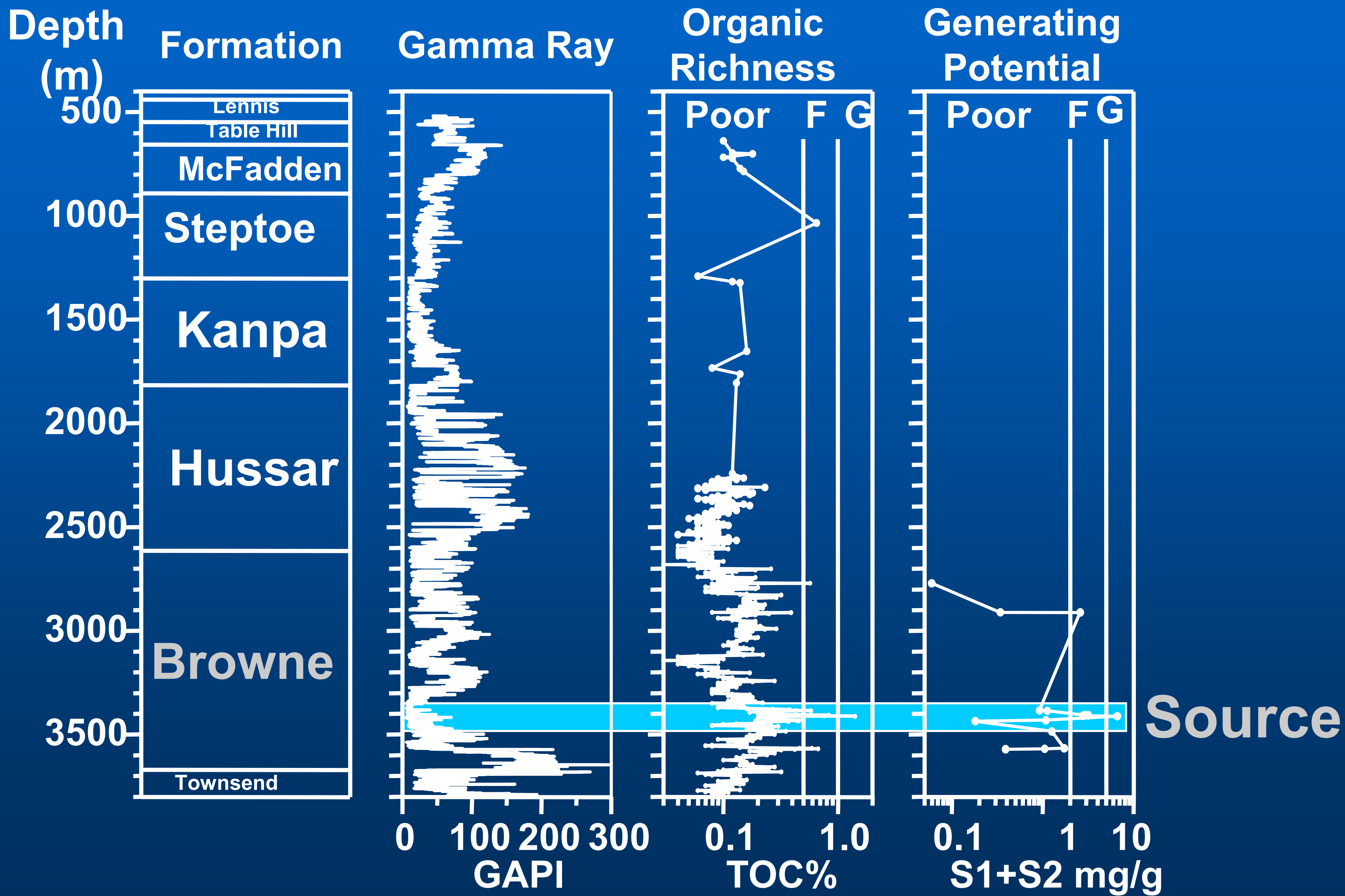


Empress 1A



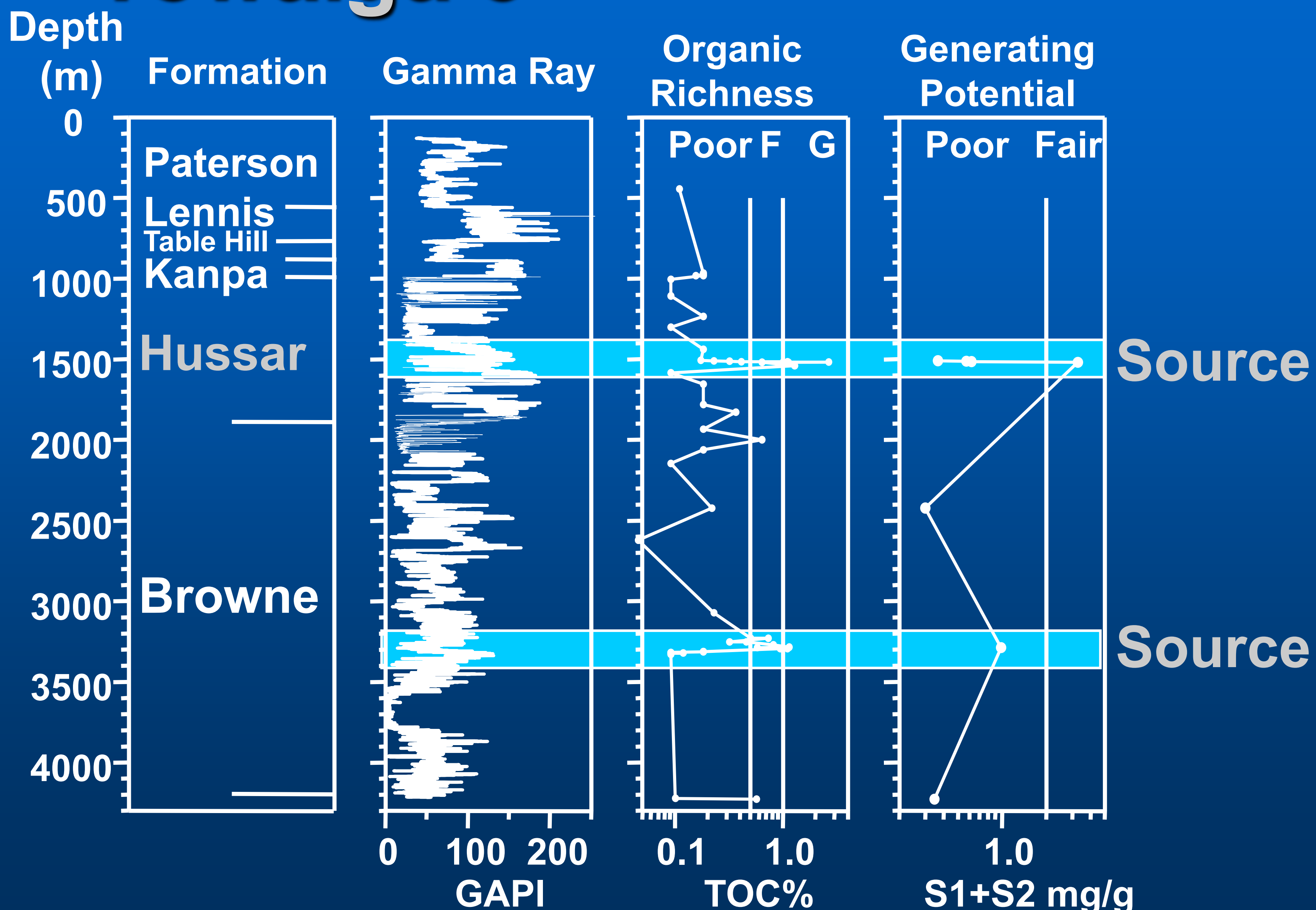
Depth (m)
Formation
Gamma Ray
Organic Richness
Generating Potential
400
600
800
1000
1200
1400
1600
? Lupton
Steptoe
Kanpa
Hussar
Browne
Lefroy
Poor
F
G
Poor
Good
Source
Source
0
100
200
300
GAPI
0.1
1.0
TOC%
0.1
1
10
S1+S2 mg/g

Kanpa 1A



Depth (m)
Formation
Gamma Ray
Organic Richness
Generating Potential
500
1000
1500
2000
2500
3000
3500
Lennis
Table Hill
McFadden
Steptoe
Kanpa
Hussar
Browne
Townsend
Poor
F
G
Poor
F
G
Source
0
100
200
300
GAPI
0.1
1.0
TOC%
0.1
1
10
S1+S2 mg/g

Yowalga 3



Depth (m)
Formation
Gamma Ray
Organic Richness
Generating Potential
0
500
1000
1500
2000
2500
3000
3500
4000
Paterson
Lennis
Table Hill
Kanpa
Hussar
Browne
Poor F G
Poor Fair
Source
Source
0 100 200
GAPI
0.1 1.0
TOC%
1.0
S1+S2 mg/g

Modelling, 4 Wells & 6 Seismic Locations

- Step 1: 1-D modelling of a single well location to Develop and constraint burial and thermal histories
- Step 2: 1-D modelling of multi-well locations to evaluate geographic maturity variation
- Step 3: 2-D modelling of a geological cross section to evaluate maturation timing across the region

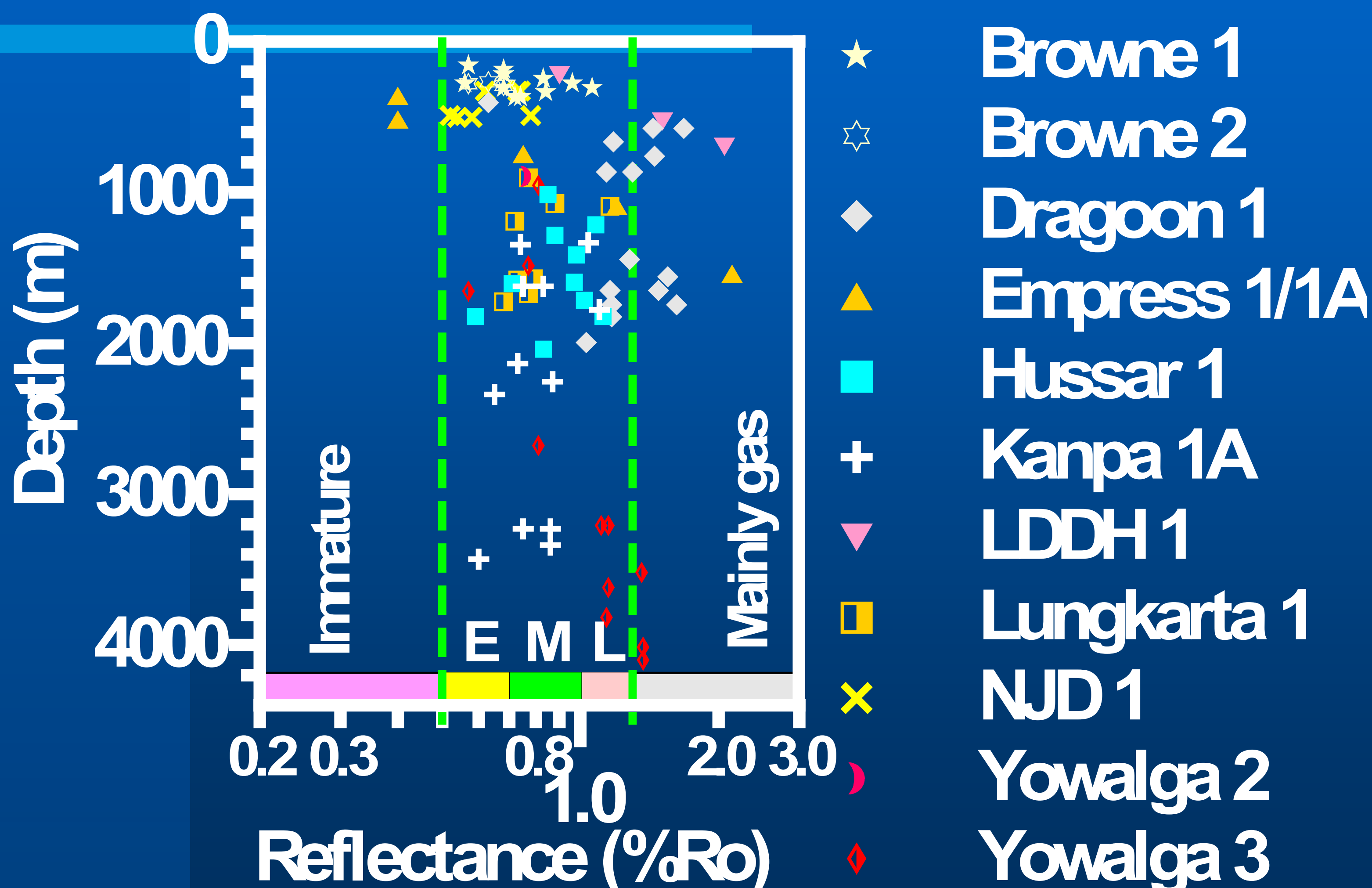
Maturity Calibration

- Time-Stratigraphy & Lithology — Wells
- Present-day temperature — BHT
- Equivalent %Ro — Lamalginite
- Rock-Eval Parameter — T_{max}
- Palaeotemperatures — AFTA

Modelling Parameters

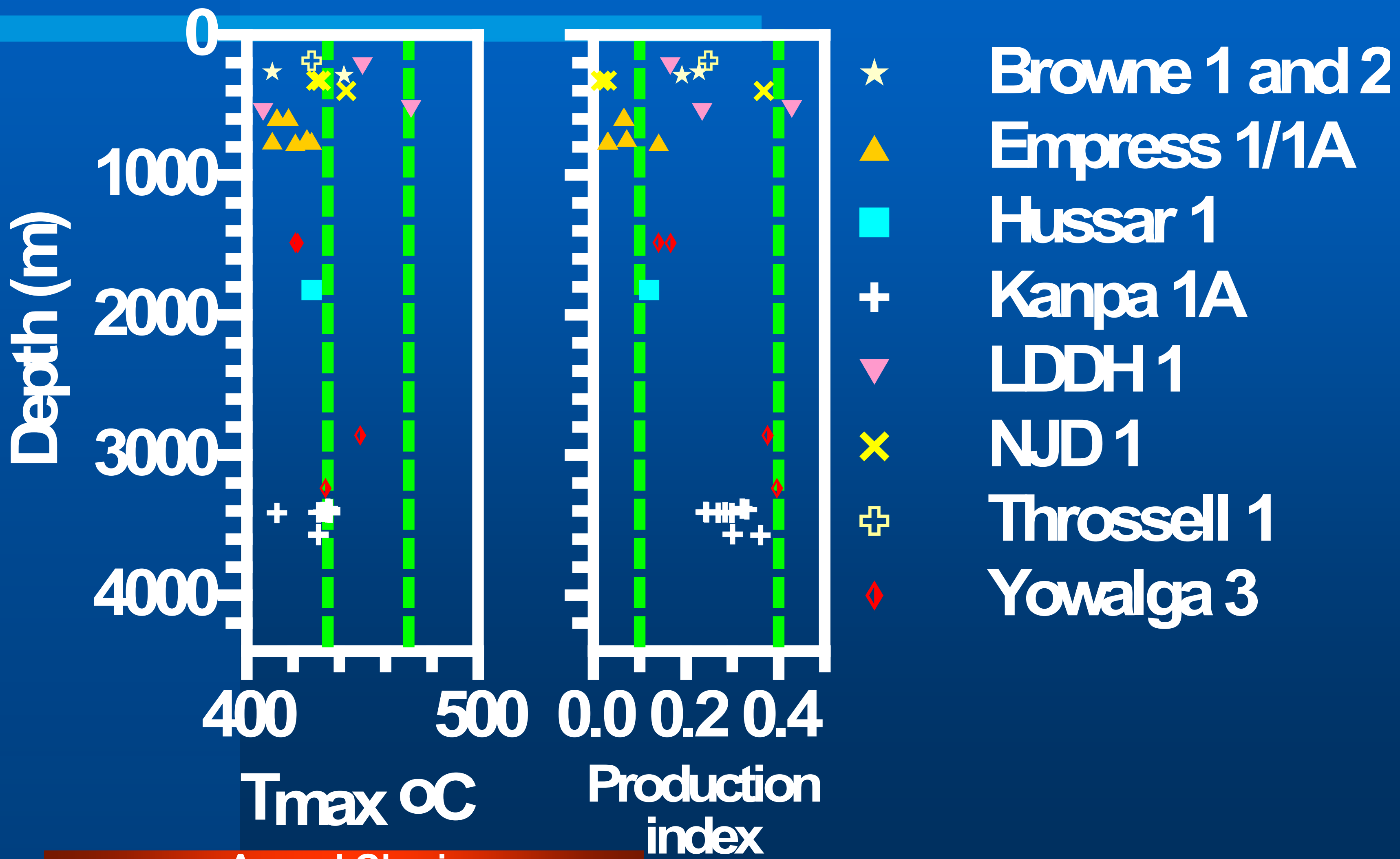
- Present-day temperature: 25°C
- Heat flow: Transient
- Compaction: Bmod 2-D fluid flow
- Maturity calculation: LLNL
- Kerogen kinetics: 1% type II

Maturity — Organic Petrology



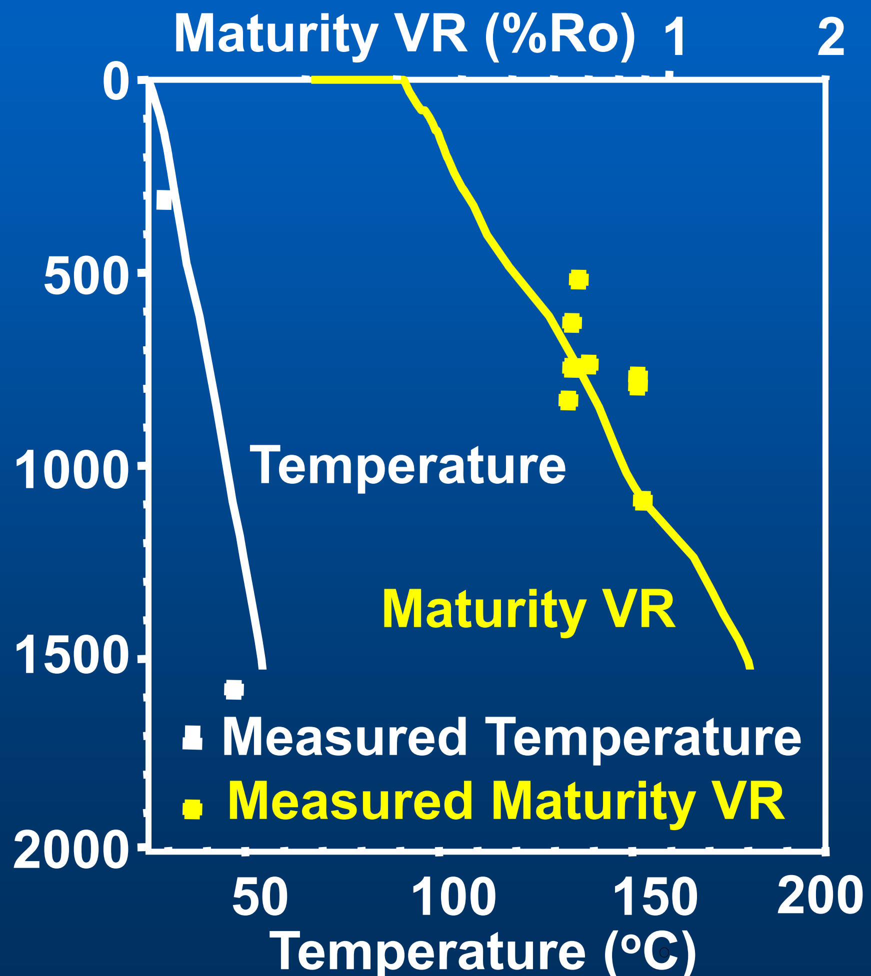
Ameed Ghori

Maturity — Rock-Eval Pyrolysis



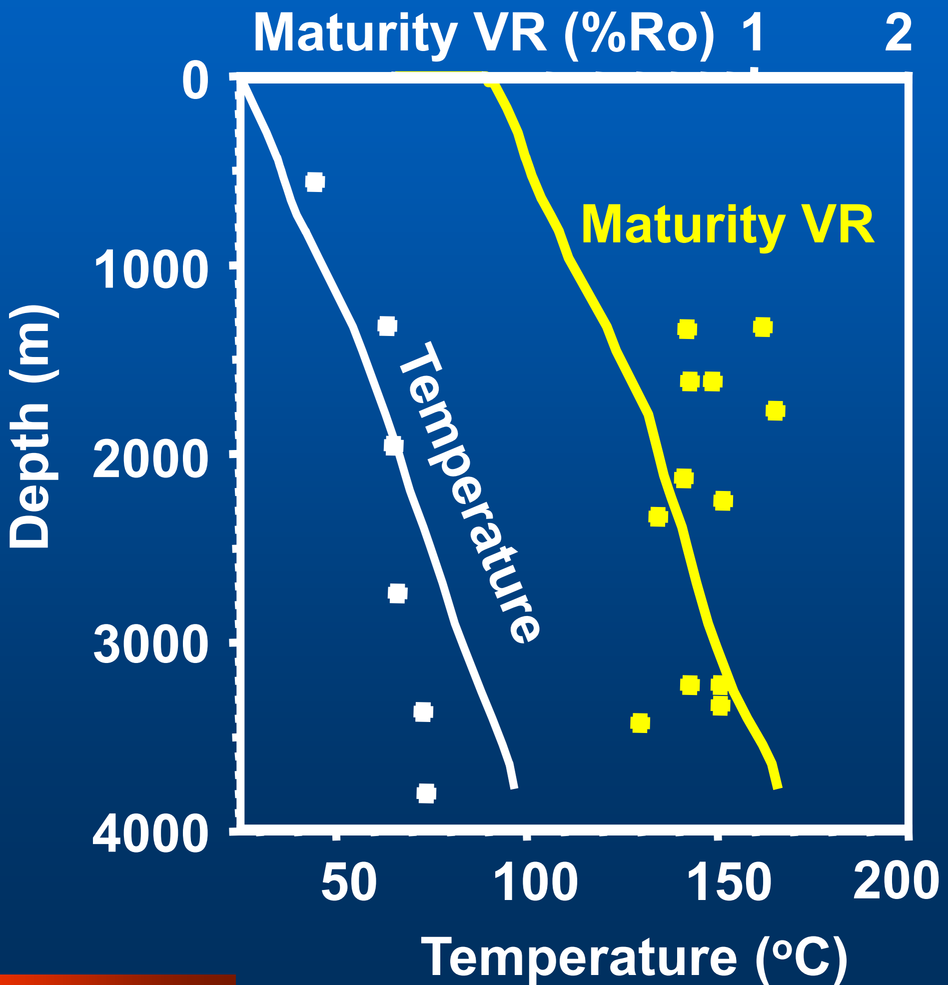
Ameed Ghori

Empress 1/1A — Calibration

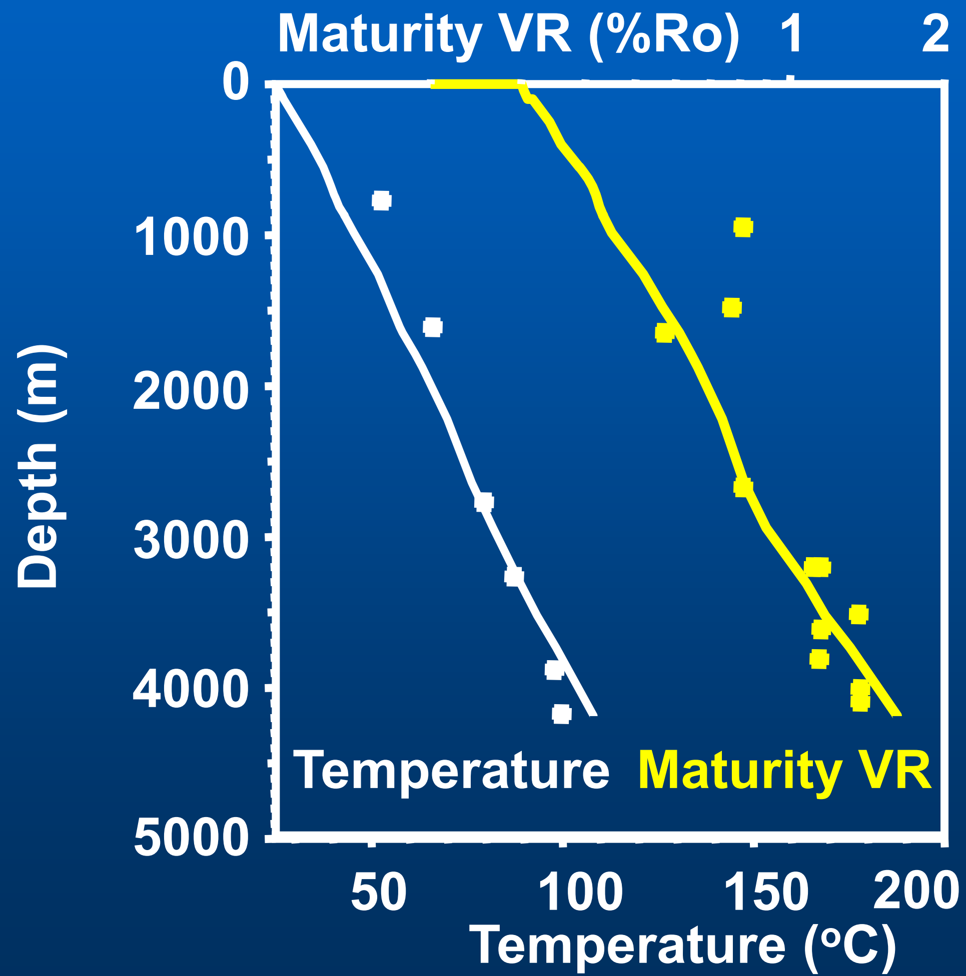


Ameed Ghori

Kanpa 1A — Calibration

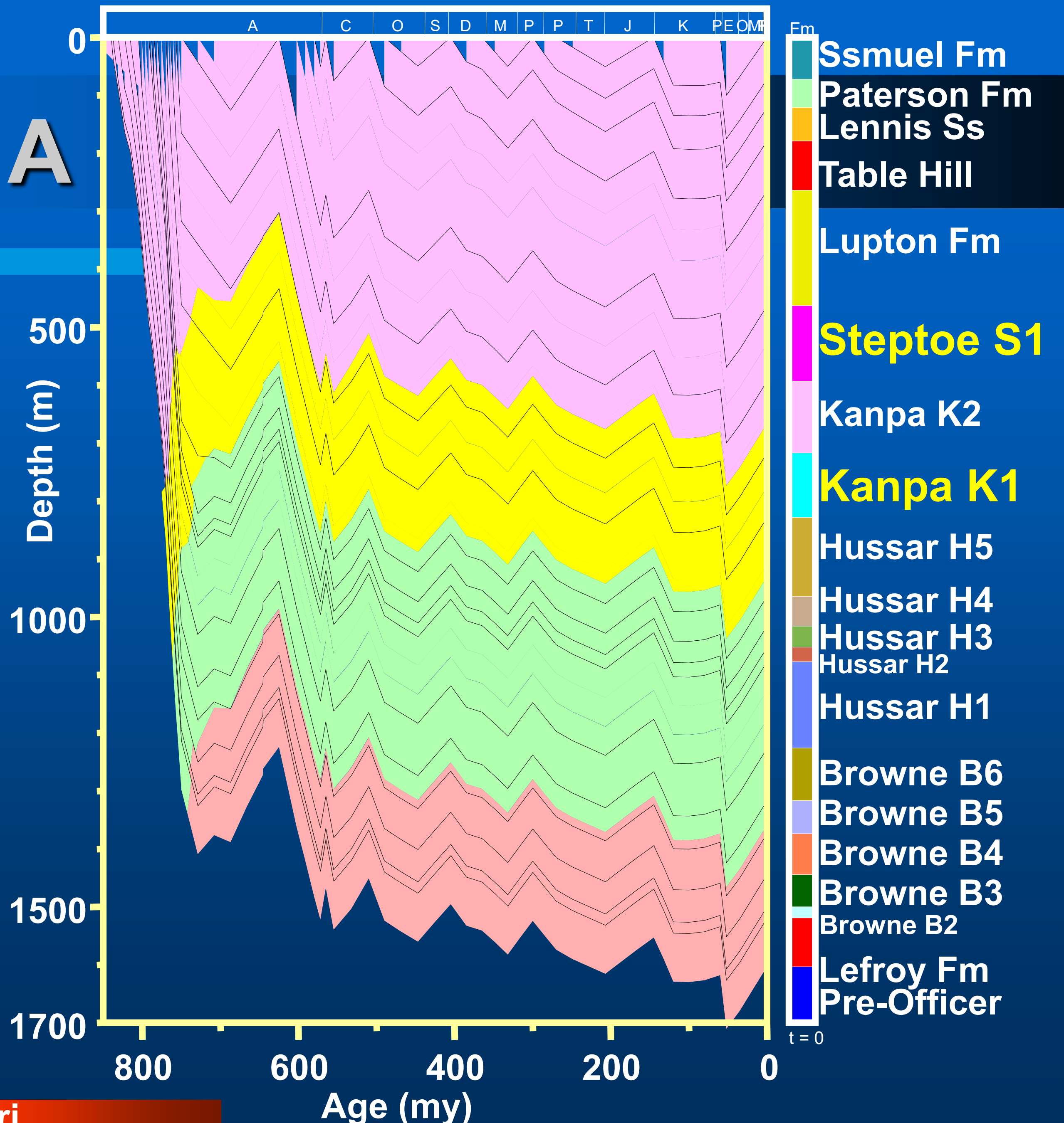


Yowalga 3 — Calibration



Empress 1A

Burial & Maturation History



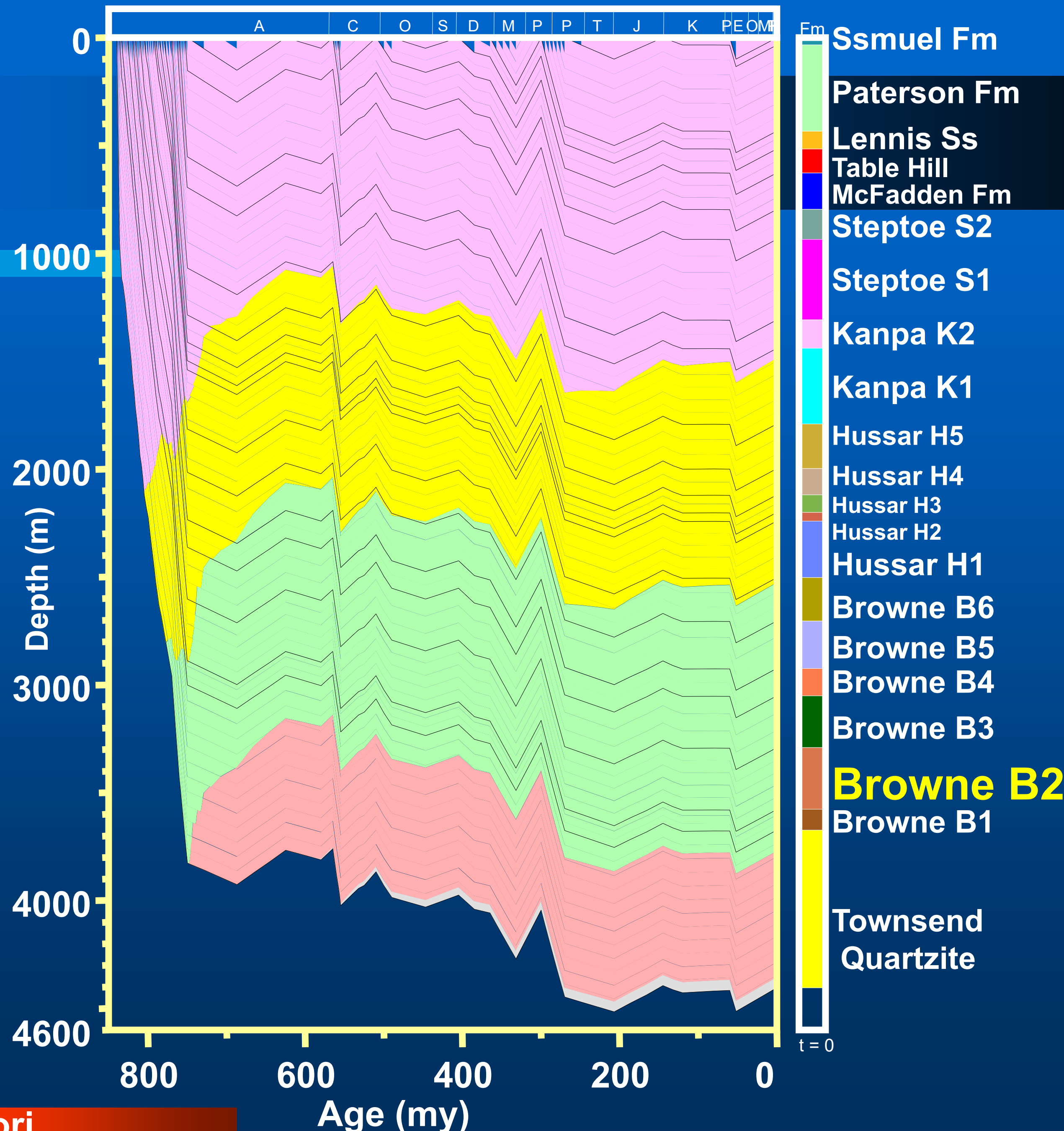
Maturity VR (%Ro)

- Immature (oil)
- Early Mature (oil)
- Mid Mature (oil)
- Late Mature (oil)
- Mainly Gas

Ameed Ghori

Kanpa 1A

Burial & Maturation History



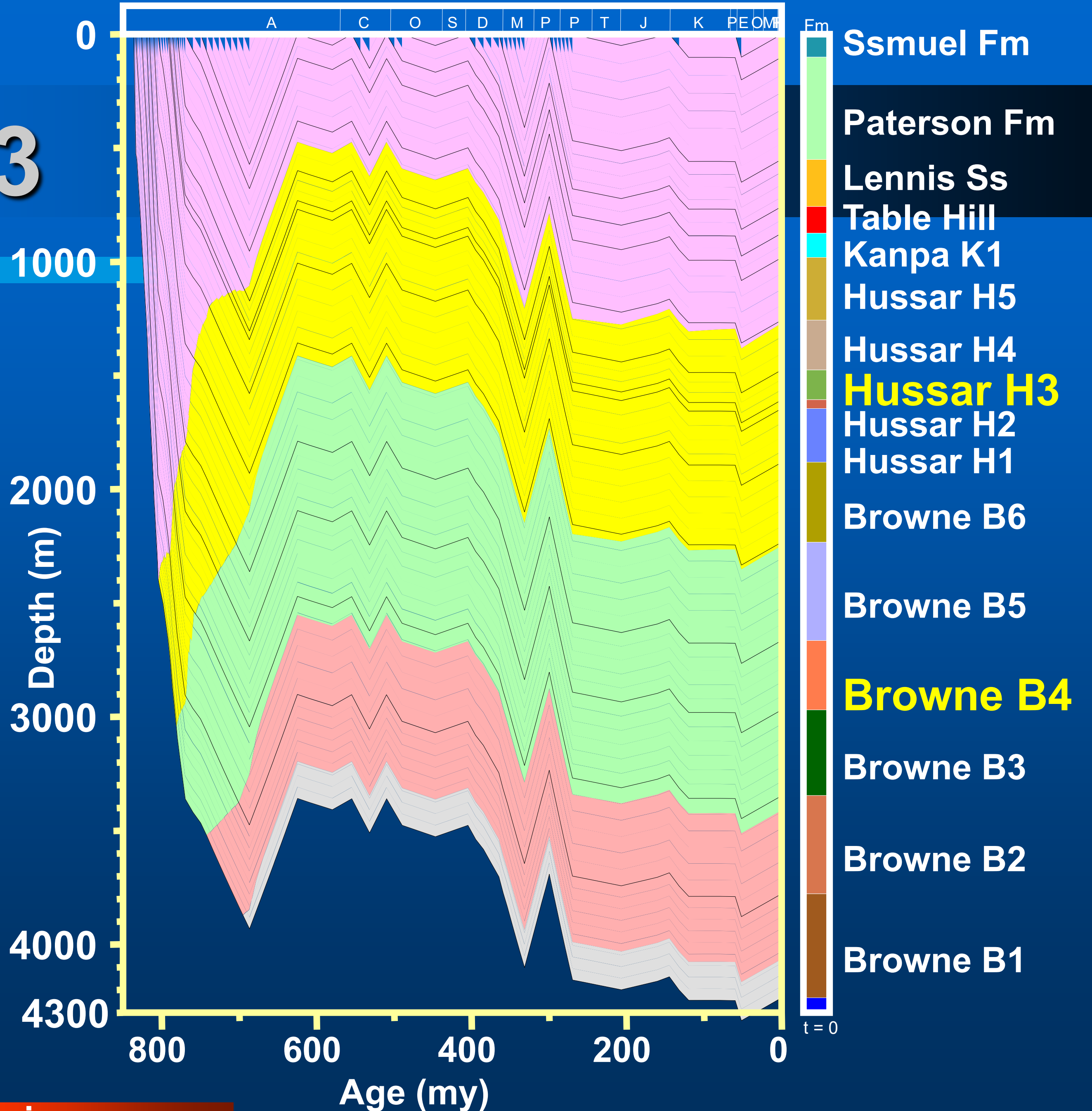
Maturity VR (%Ro)

- Immature (oil)
- Early Mature (oil)
- Mid Mature (oil)
- Late Mature (oil)
- Mainly Gas

Ameed Ghori

Yowalga 3

Burial & Maturation History



Maturity VR (%Ro)

- Immature (oil)
- Early Mature (oil)
- Mid Mature (oil)
- Late Mature (oil)
- Mainly Gas

Ameed Ghori

Geographic Maturity Variation

- Maturity at the top of source rock containing units:
  - Brown Formation - B2 horizon
  - Brown Formation - B4 horizon
  - Hussar Formation - H3 horizon
  - Kanpa Formation - K1 horizon
  - Steptoe Formation - S1 horizon

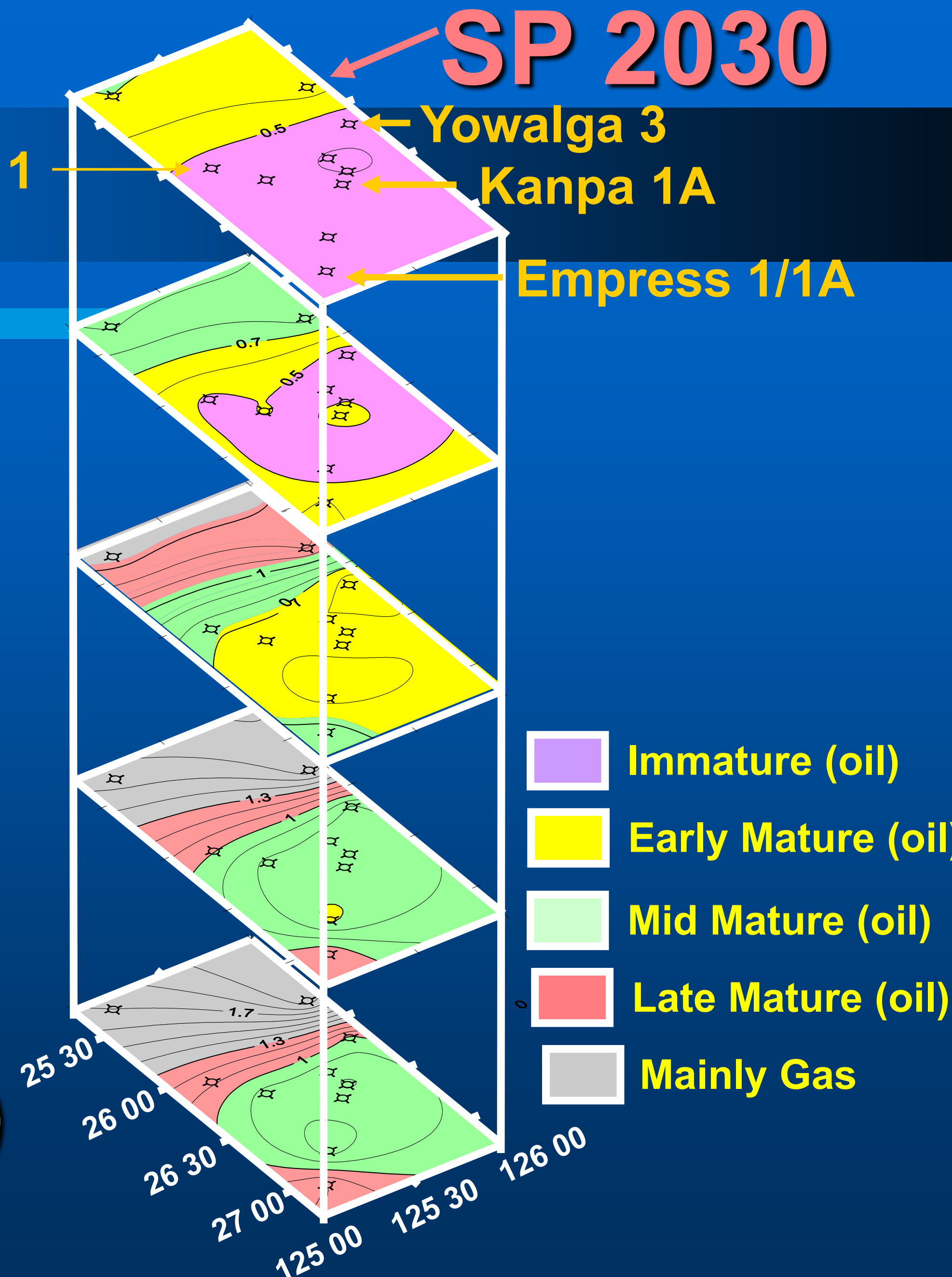
Steptoe – S1 Horizon

Kanpa – K1 Horizon

Hussar – H3 Horizon

Brown – B4 Horizon

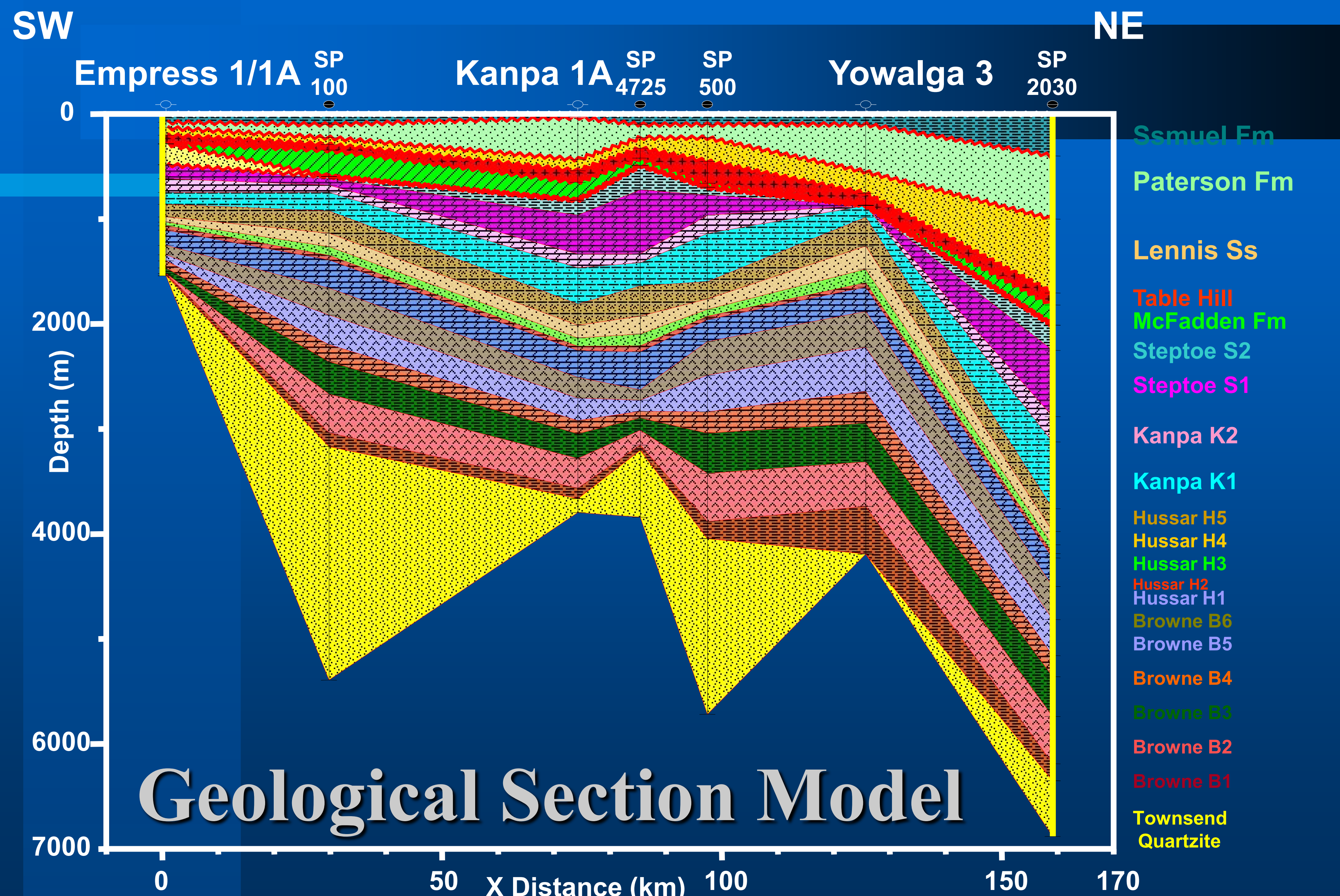
Brown – B2 Horizon



Maturity (%Ro)

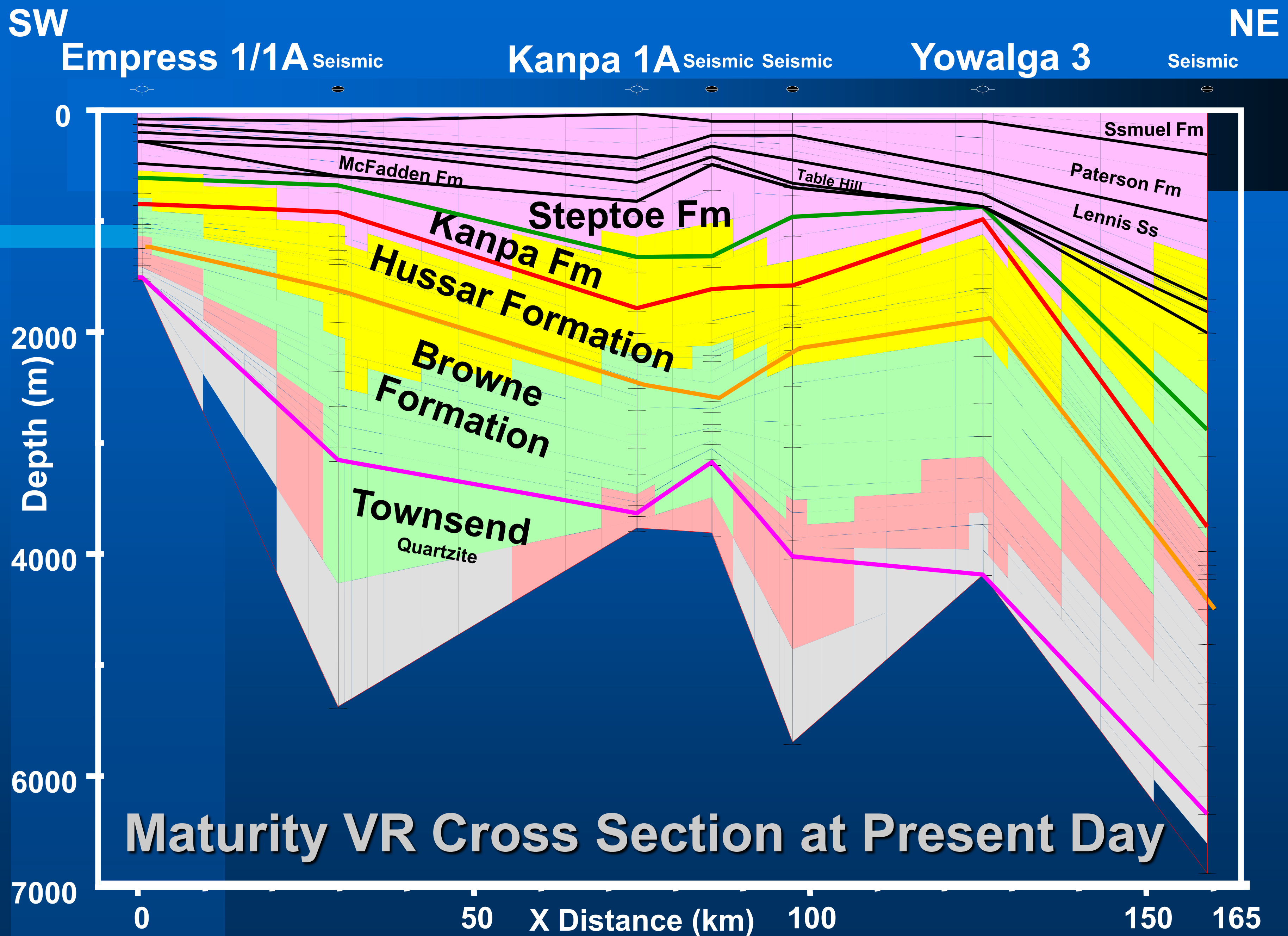
SP 2030

Ameed Ghori



SW
NE
Empress 1/1A
SP 100
Kanpa 1A
SP 4725
SP 500
Yowalga 3
SP 2030
0
2000
4000
6000
7000
Depth (m)
0
50
100
150
170
X Distance (km)
Ssmuel Fm
Paterson Fm
Lennis Ss
Table Hill
McFadden Fm
Steptoe S2
Steptoe S1
Kanpa K2
Kanpa K1
Hussar H5
Hussar H4
Hussar H3
Hussar H2
Hussar H1
Browne B6
Browne B5
Browne B4
Browne B3
Browne B2
Browne B1
Townsend Quartzite
Geological Section Model

Ameed Ghori



Maturity VR Cross Section at Present Day

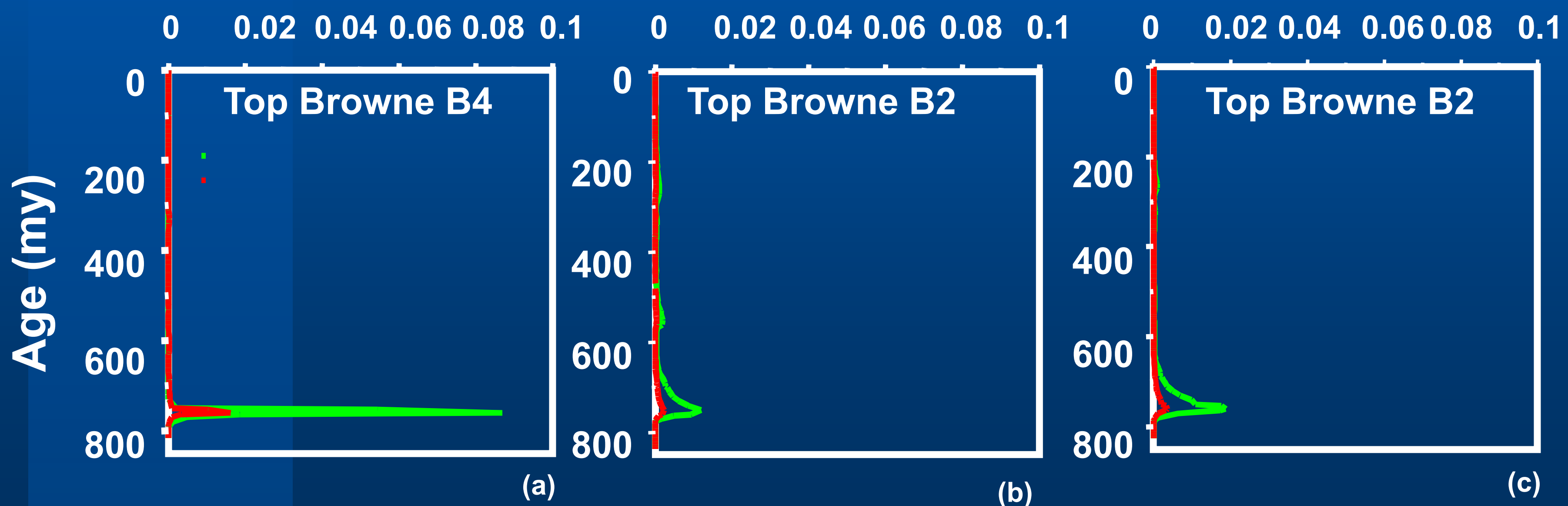
Ameed Ghori

Petroleum Generation Timing

Browne Formation

Empress 1/1A Kanpa 1A Yowalga 3

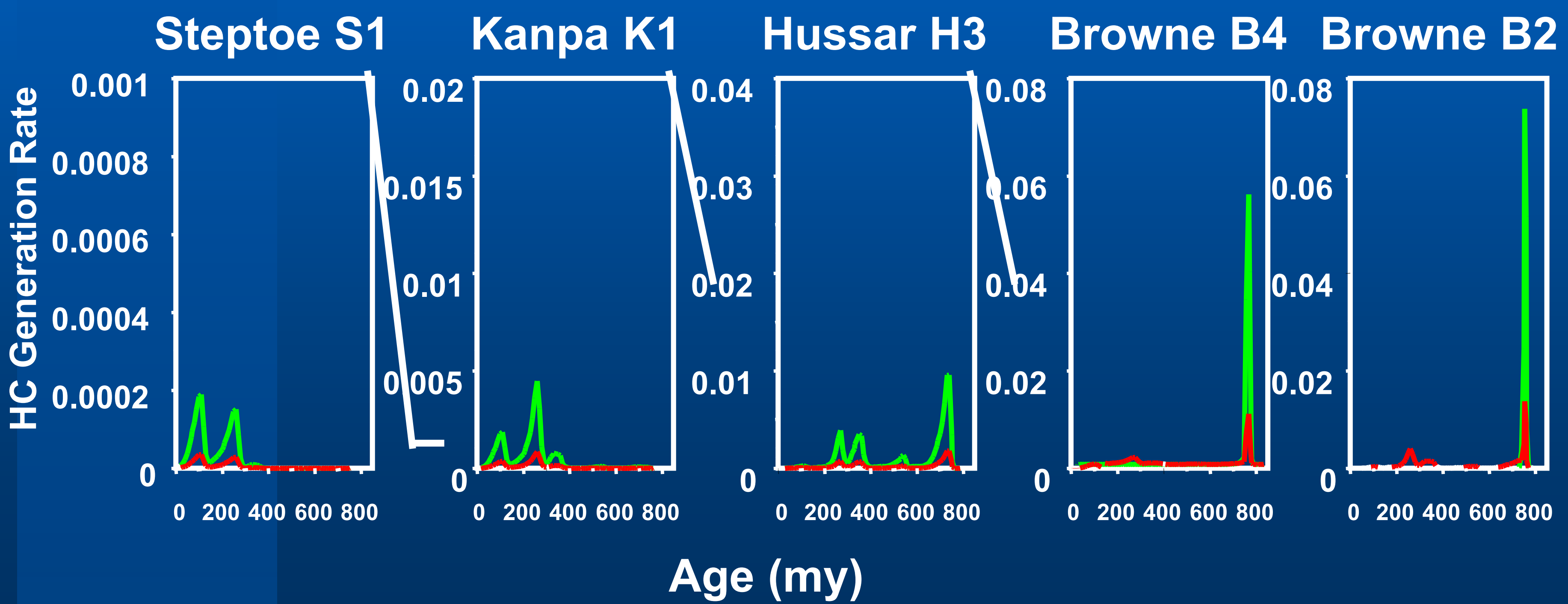
HC Generation /Pot HC Rate (g/g pot HC*my)



Ameed Ghori

Petroleum Generation Timing

At Seismic Location SP 2030 Line T80–11



Ameed Ghori

Conclusions — 1

- Thin beds with excellent to fair oil generating potential indicate the development of organic rich facies

- Minor oil & numerous bitumen shows indicate the existence of petroleum system within the Neoproterozoic of the western Officer Basin

Conclusions — 2

- Optimum hydrocarbon generation within the Browne Formation was reached and exhausted during the Neoproterozoic
- Younger Hussar, Kanpa & Steptoe Formations were not reached to optimum hydrocarbon generation rate during the Neoproterozoic
- Their generation rate varied during the geological evolution of the basin

Conclusions — 3

- Thick effective source rock units and commercially viable petroleum system can not be identified from the available dataset but verify and provide incentive to explore more, because:
  - Significant part of the Neoproterozoic is presently within the oil window
  - Thin but good quality oil source-beds
  - Minor but numerous hydrocarbons shows

Thanks