THE 18th CONFERENCE OF SCIENCE AND TECHNOLOGY 2023
EARTH SCIENCE AND ENERGY RESOURCES WITH SUSTAINABLE DEVELOPMENT

BK TP.HCM GEOPET

45 GEOPET

Geochemical and petrological properties of the Neogene shale gas in the central Song Hong basin, Vietnam

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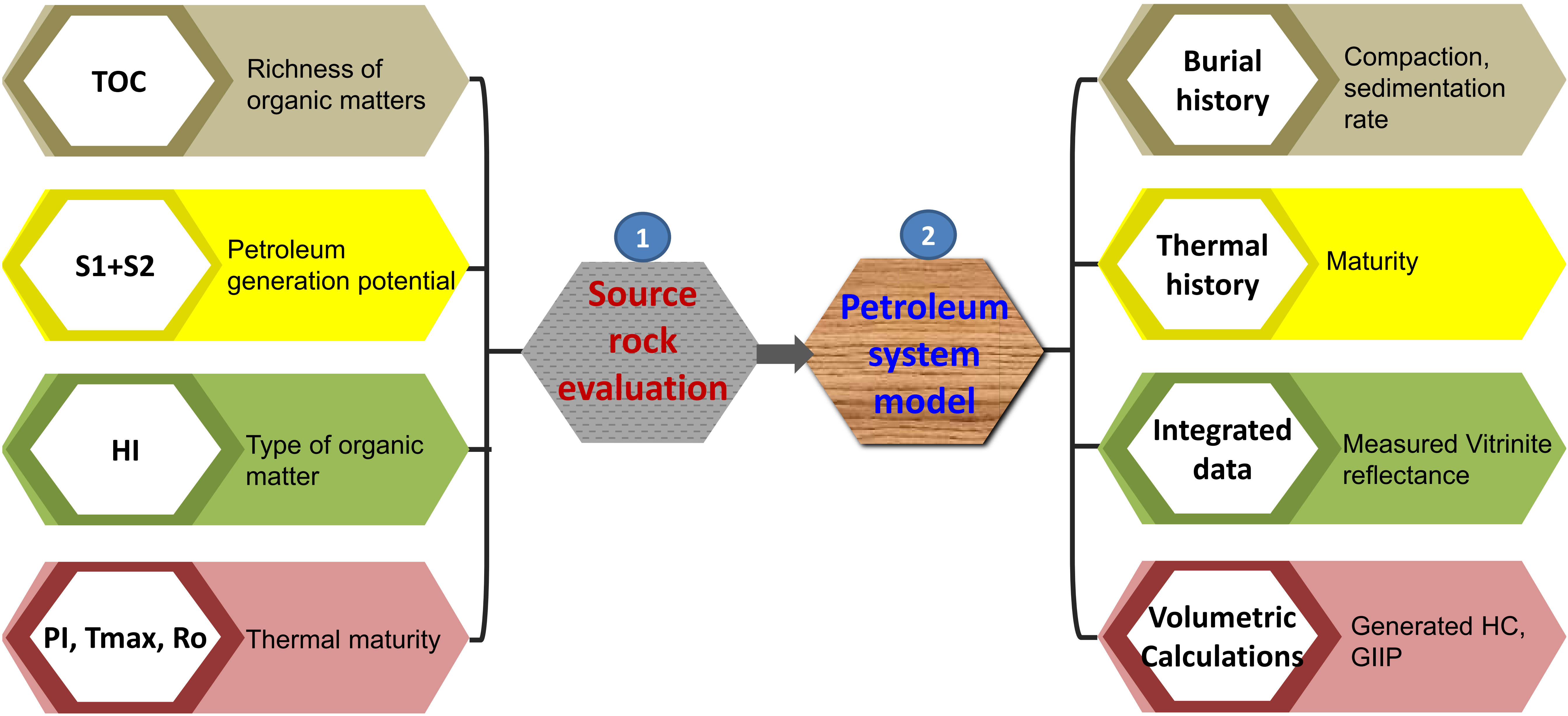
TOC
Richness of organic matters
S1+S2
Petroleum generation potential
HI
Type of organic matter
PI, Tmax, Ro
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Compaction, sedimentation rate
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Maturity
Integrated data
Measured Vitrinite reflectance
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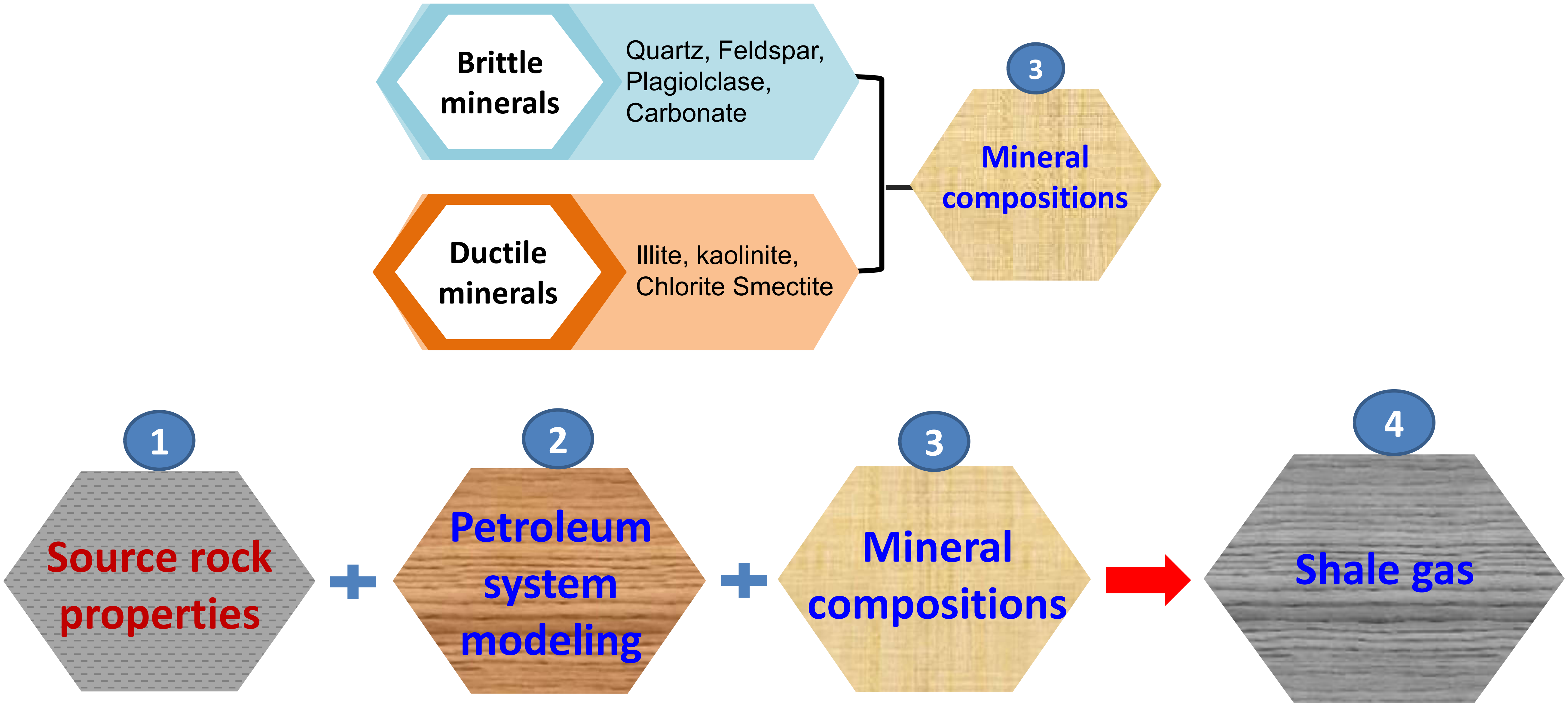
OBJECTIVES


Brittle minerals
Quartz, Feldspar, Plagiolclase, Carbonate
Ductile minerals
Illite, kaolinite, Chlorite Smectite
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Mineral compositions
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Source rock properties
+
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Petroleum system modeling
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Mineral compositions
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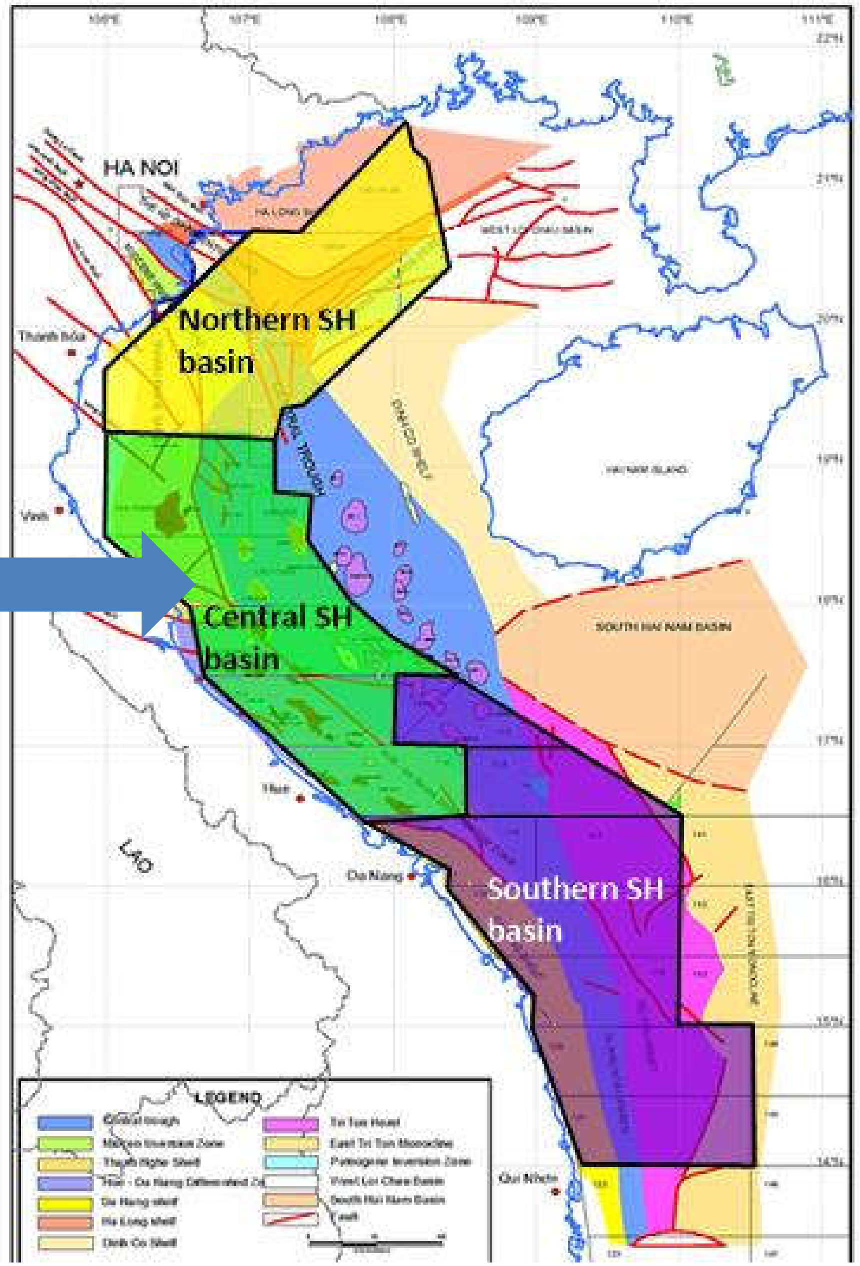
Shale gas

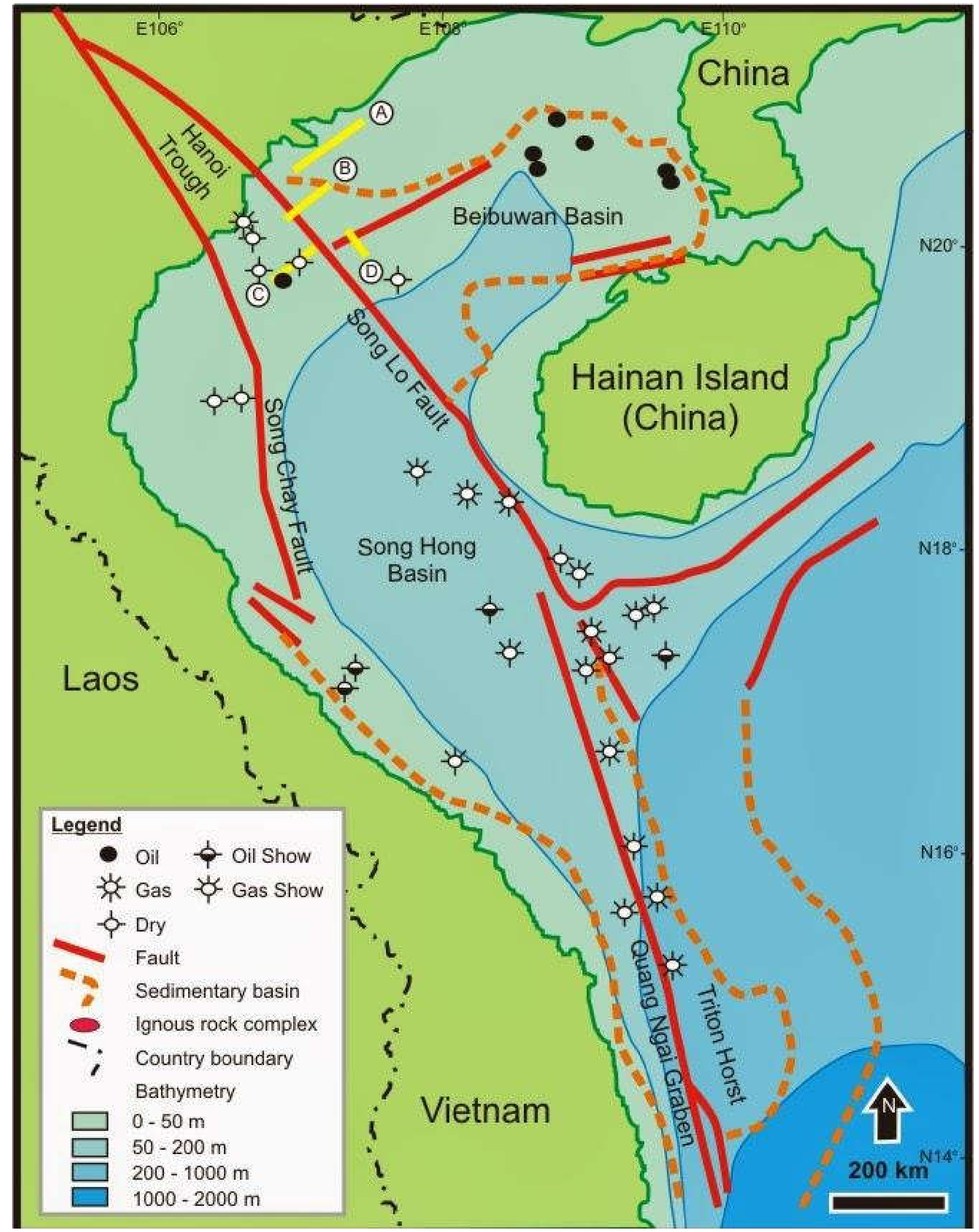
1. Introduction

- During last decades, sands, carbonates and fractured granites are considered the main conventional reservoirs in the petroleum systems in Vietnam;
- However, it needs to find solutions for increasing oil recovery because of the decrease of oil and gas reserves in the mature fields,
- It needs to look for new fields in deep-water areas (Phu Khanh, Tu Chinh-Vung May, Hoang Sa-Truong sa basins) because of having not many new fields in the early exploration stage or in shallow water areas;
- Therefore, unconventional reservoirs are new findings for more petroleum from mature fields and wildcat areas;
- The presence of shale gas in the central Song Hong basin is a new finding for unconventional petroleum system in the sedimentary basins in Vietnam

2. Geological settings

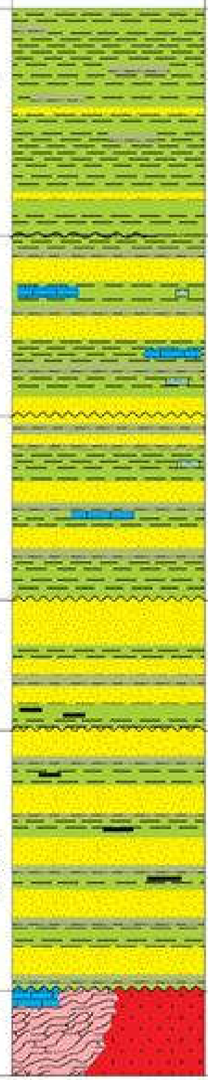
Study area



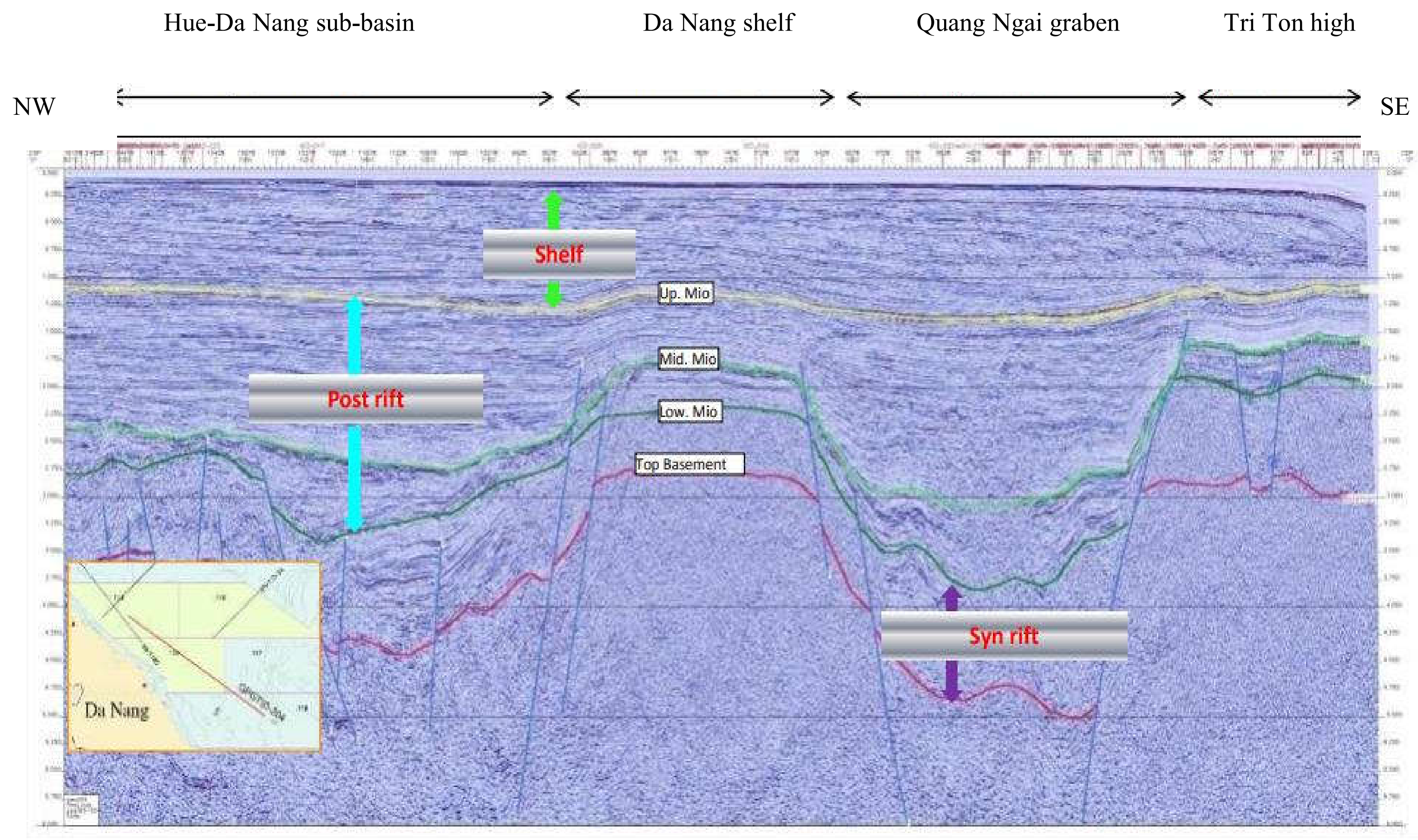


2. Geological settings

Era	Period	Epoch	Sub-Ep.	Fm.	Lithology	h (m)	Lithology	Dep. Envi.	
Cenozoic	Quaternary			Biển Đông		400 - 3,100	Mainly shales with thin sandstones	Coastal plain, shallow marine	Subsidence
	Neogene	Pliocene							
		Miocene	Upper	Quang Ngai		500 - 1,800	Claystones, carbonaceous claystones, siltstones, interbedded sandstones, occ. limstones	Coastal plain, inner shelf	Post-Rift
			Middle	Tri Ton		300 - 2,000			
			Lower	Song Huong		100 - 1,300	Sands, silts, cl, occ. limestones		
	Paleogene	Oligocene		Bach Tri		100 - 1,100	Upper part: sands, silts, cl. Lower part: sands, silts, cl., occ. coal	Deltaic, inner shelf	Syn-Rift
Pre-Tertiary				Mong			Granite, shales, carbonate?		



Sand · Silt · Clay · Cal cl. · Lime · Metamorphic rock · Bsmt



Stratigraphy column and geological cross-section of the central Song Hong basin

3. Data and Anatytical Methods

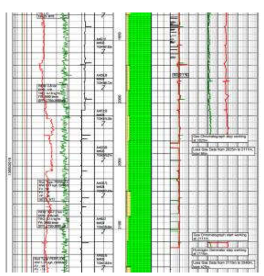
Samples and Data

36 shale samples:

TOC-Rock Eval pyrolysis, Vitrinite Reflectance

20 cutting samples:

X-ray Diffraction: whole rock fraction and clay minerals



Data

Well logs, geothermal gradient, analysis results

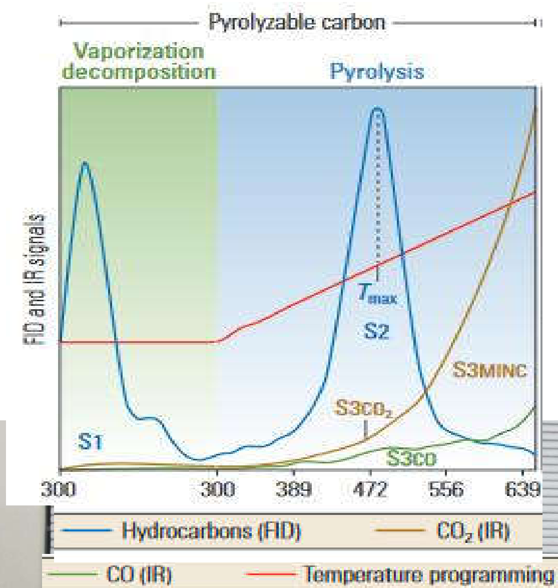
3. Data and Anatytical Methods

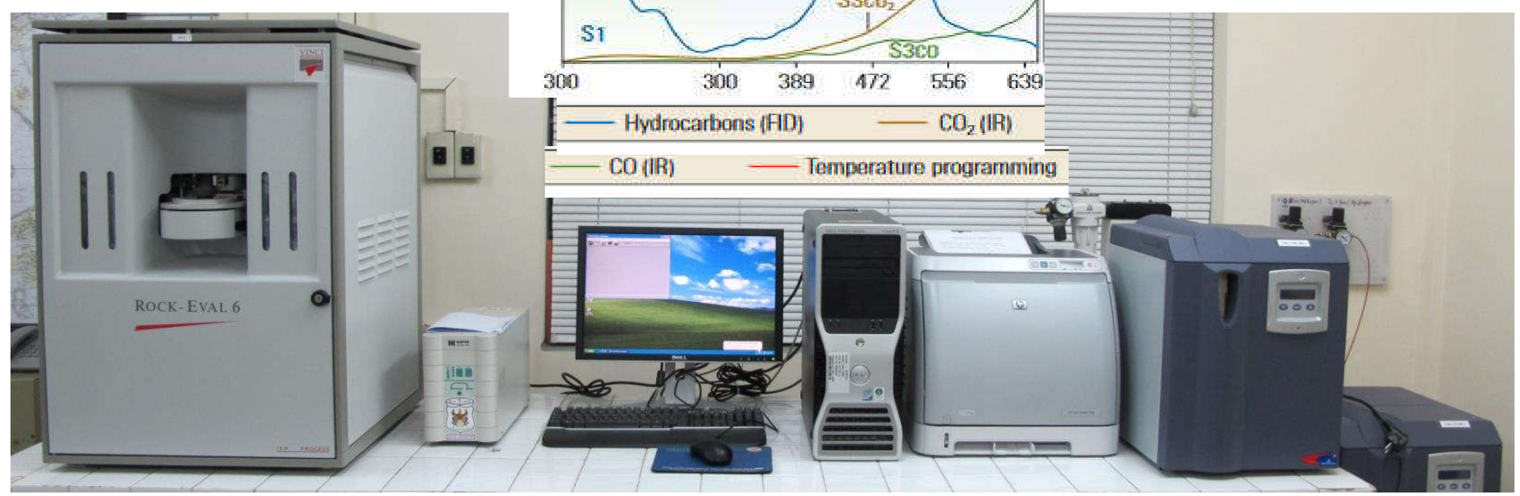
1. Rock-Eval pyrolysis

Quantity	TOC (wt. %)	S1 (mg g)	S2 (mg g)
Poor	<0.5	<0.5	<2.5
Fair	0.5-1.0	0.5-1	2.5-5
Good	1-2	1-2	5-10
Very good	2-4	2-4	10-20
Excellent	>4	>4	>20

Quality	HI (mg/g)	Kerogen type
Non HC	<50	IV
Gas	50-200	III
Gas and oil	200-300	II/III
Oil	300-600	II
Oil	>600	I

- Organic richness
  - TOC
- Kerogen type
  - HI
- HC generation potential
  - S1, S2
- Thermal maturity
  - PI
  - Tmax

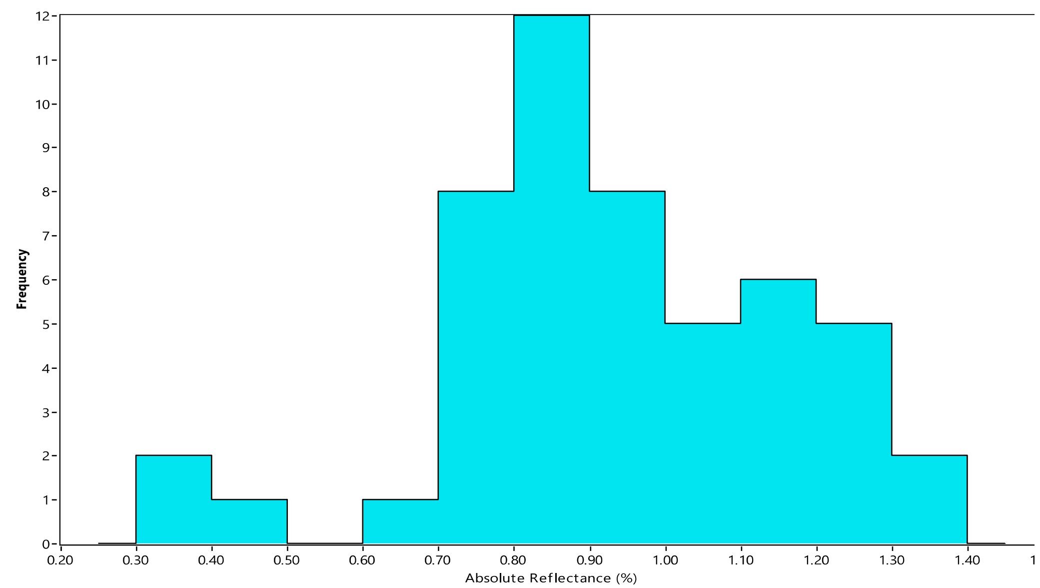


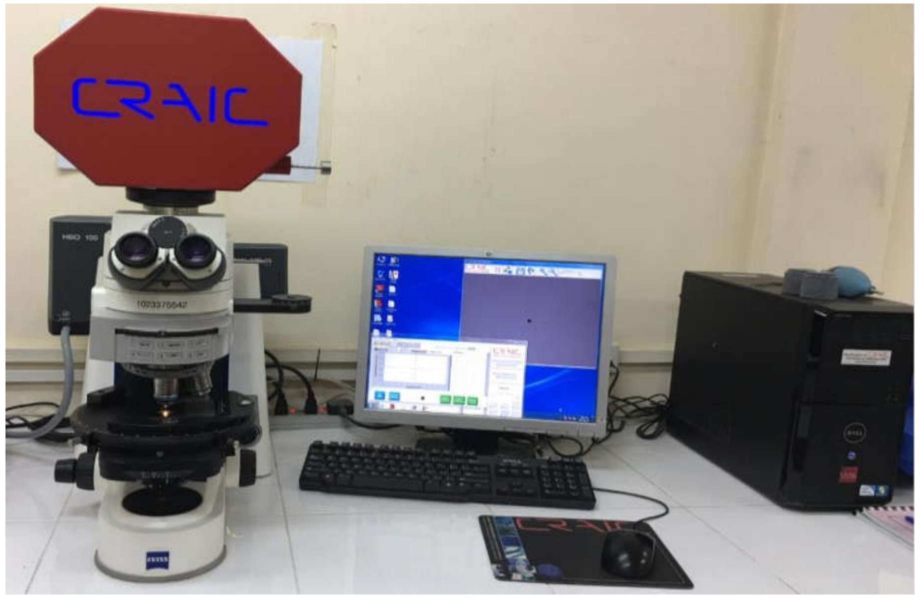


3. Data and Anatytical Methods

2. Vitrinite Reflectance (% Ro)

Level of maturation	Ro (%)	Tmax (°C)	PI
Immature	0.2-0.55	<435	<0.10
Marginal mature	0.55-0.60	-	-
Mature Early mature	0.60-0.65	435-445	0.10-0.25
Peak mature	0.65-0.90	445-450	0.25-0.40
Late mature	0.90-1.35	450-470	>0.40
Post mature	>1.35	>470	-

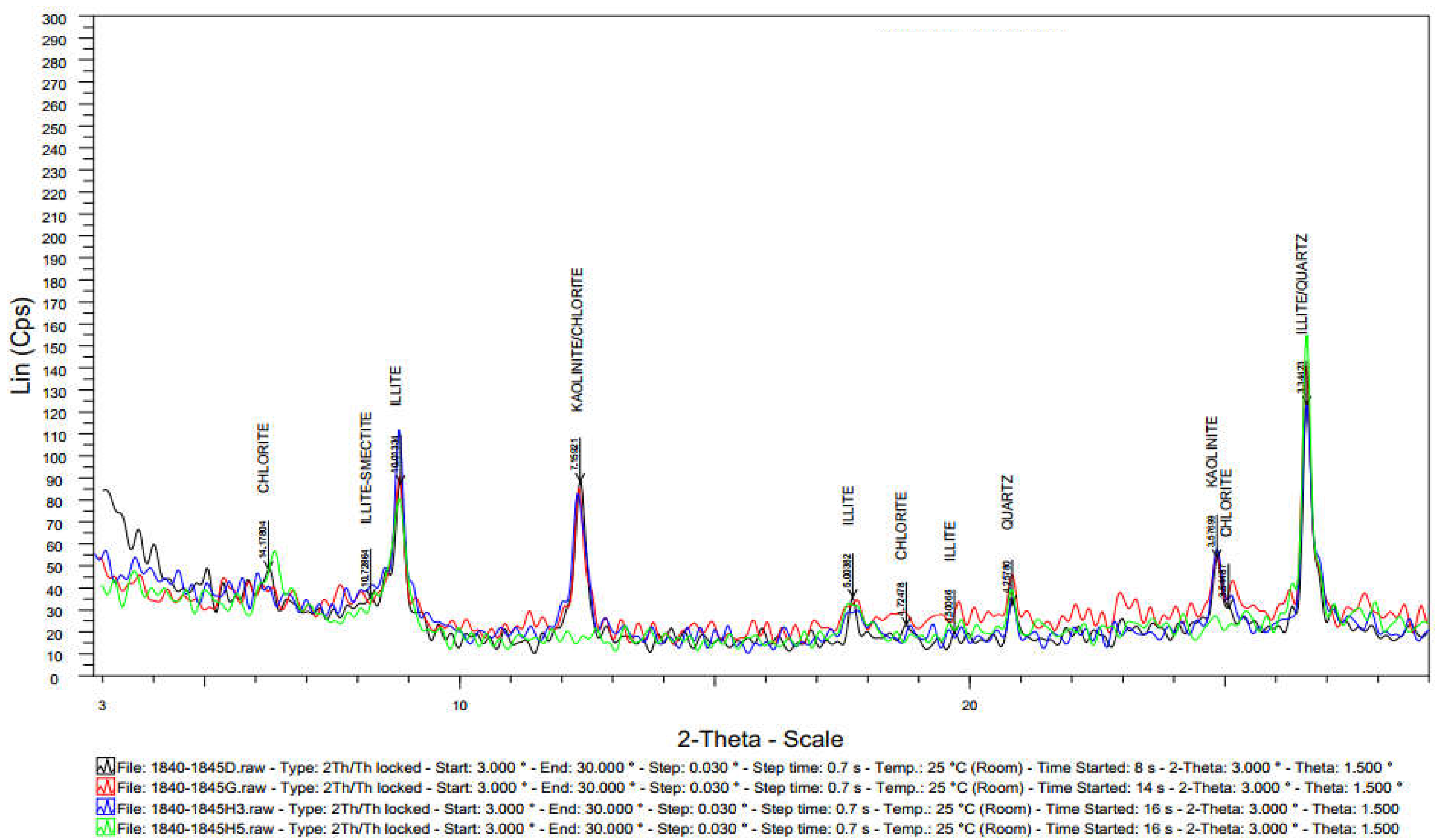




3. Data and Anatytical Methods

3. X-Ray Diffraction

- **Brittle minerals:** Quartz, Feldspar, Plagioclase, Carbonate (>40%)
- **Ductile minerals:** Illite, Kaolinite, Chlorite, Smectite



3. Data and Anatytical Methods

4. Petroleum system modeling

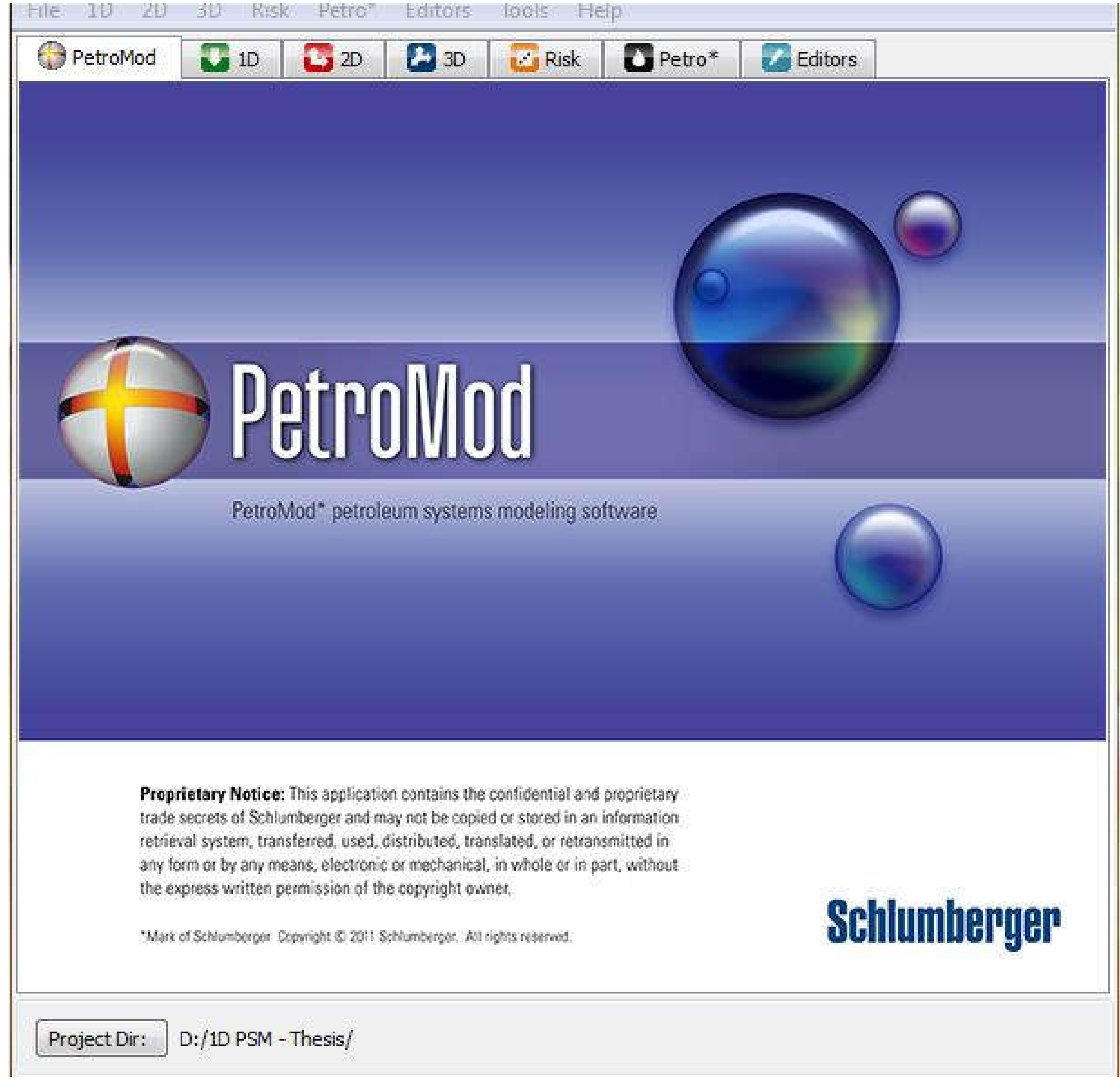
Petroleum system modeling

Software

Petromod 1D from Schlumberger Co.

Data input

Well logs, sample analysis results, seismic, published data



4. Results and Discussion

1. Source rock properties

Hydrocarbon generation potential

Quantity of OM (TOC, wt.%)

- **Pliocene**
  <0.5 %: Low
- **Upper Miocene**
  0.19-0.24%: Low
  0.56-0.79%: Moderate

Quality of OM (S2, mgHC/g rock)

- **Pliocene**
  < 2.5 mg/g: Poor
- **Upper Miocene**
  0.37-0.43 mg/g: Poor
  0.67-2.05 mg/g: Fair

Kerogen type

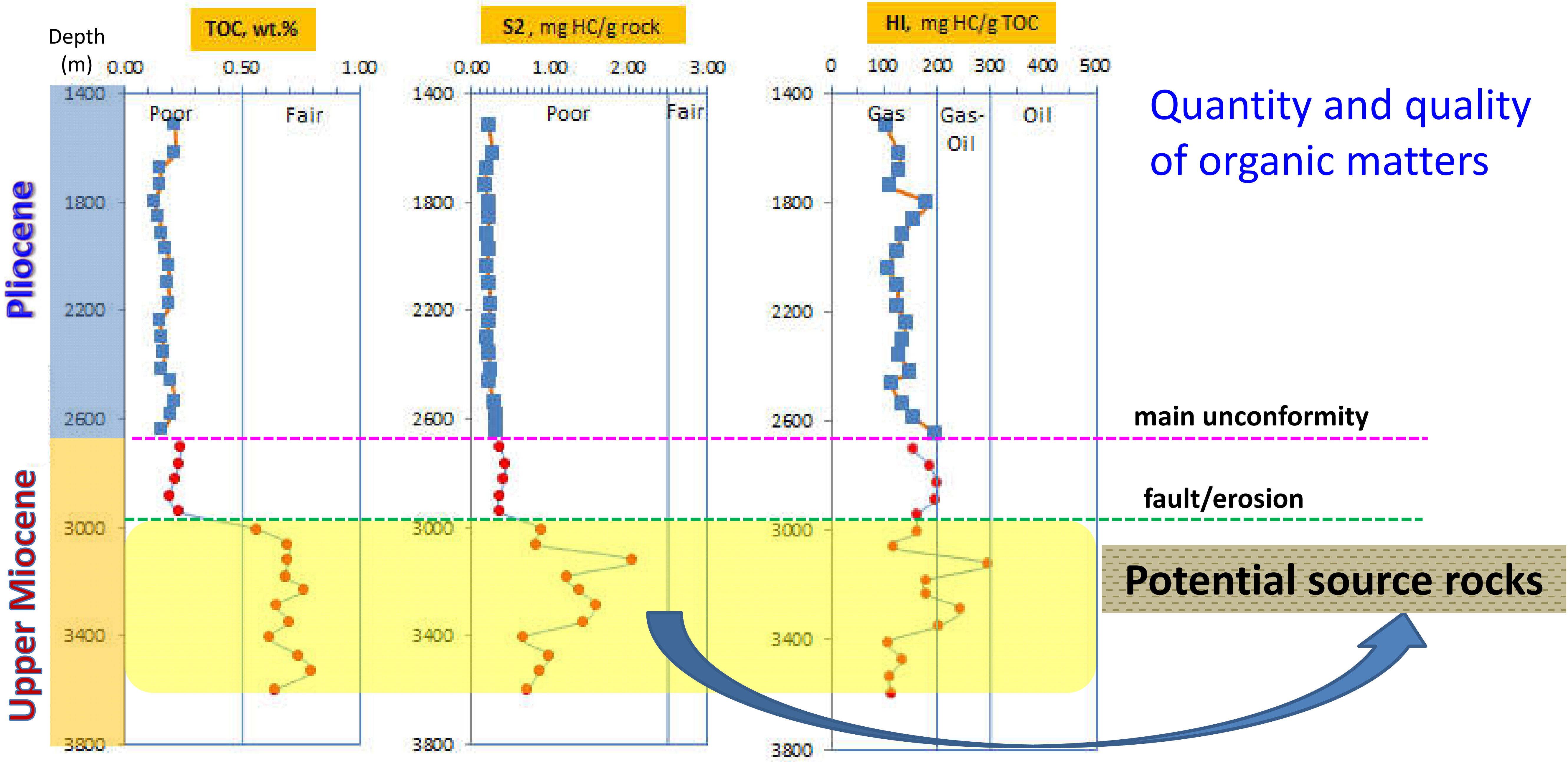
- **Pliocene**
  103-196 mg/g: III
- **Upper Miocene**
  155-199 mg/g: III
  109-296 mg/g: III/II

Lithologies:

- **Pliocene:** 90-100 % shales interbedded with sands
- **Miocene:** 40-100 % shales, interbedded with sands, silts

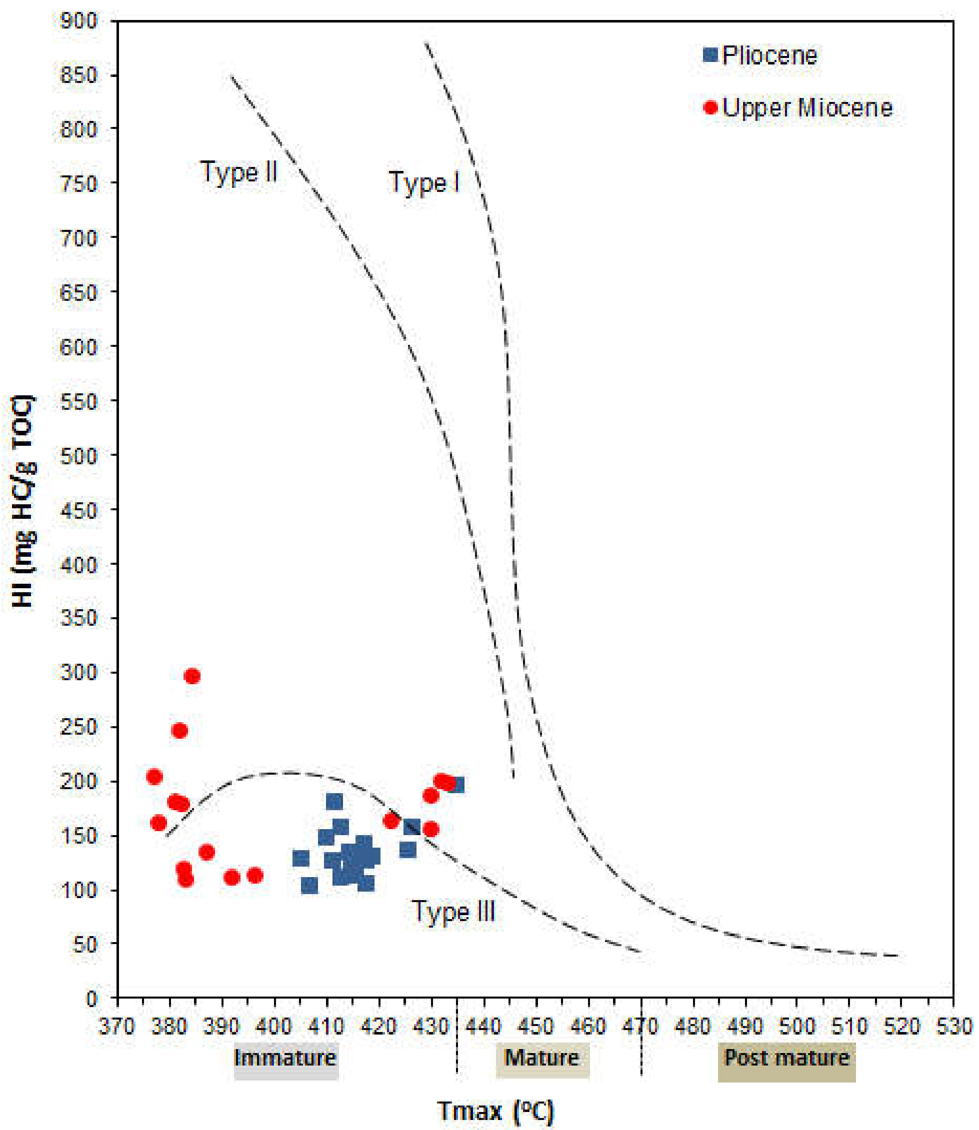
4. Results and Discussion

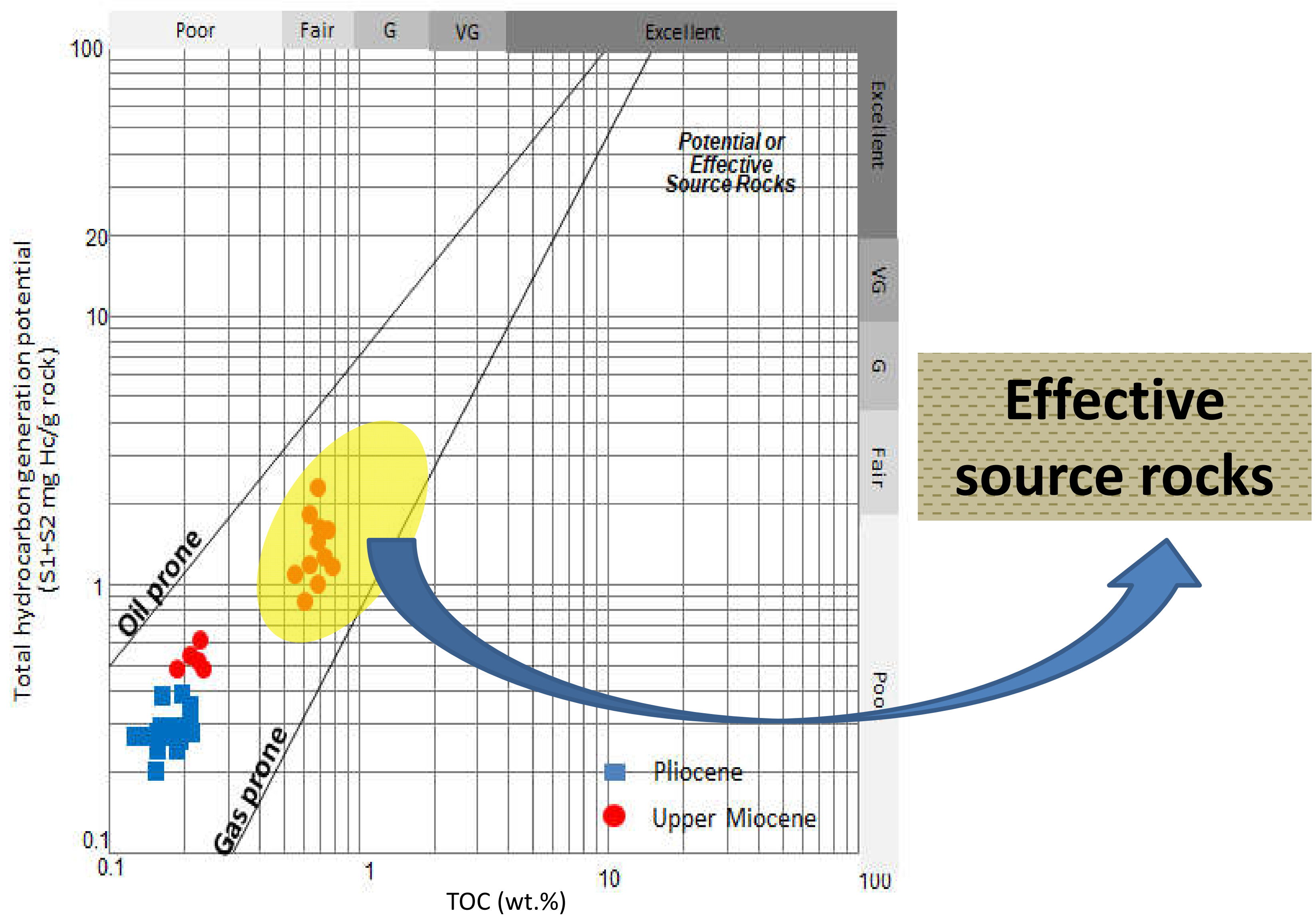
Quantity and quality of organic matters



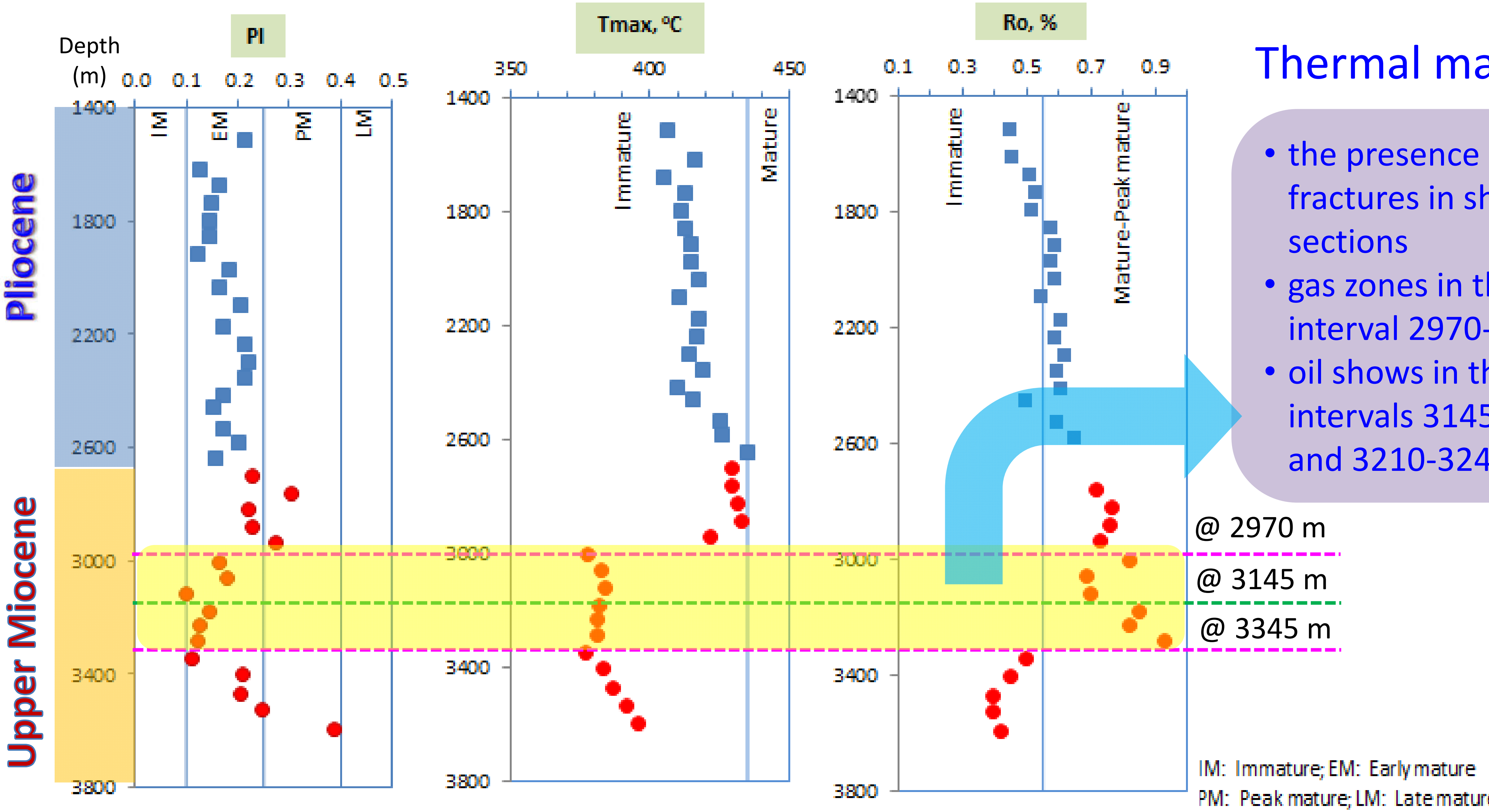
4. Results and Discussion

Kerogen type and HC generation potential





4. Results and Discussion



Thermal maturity

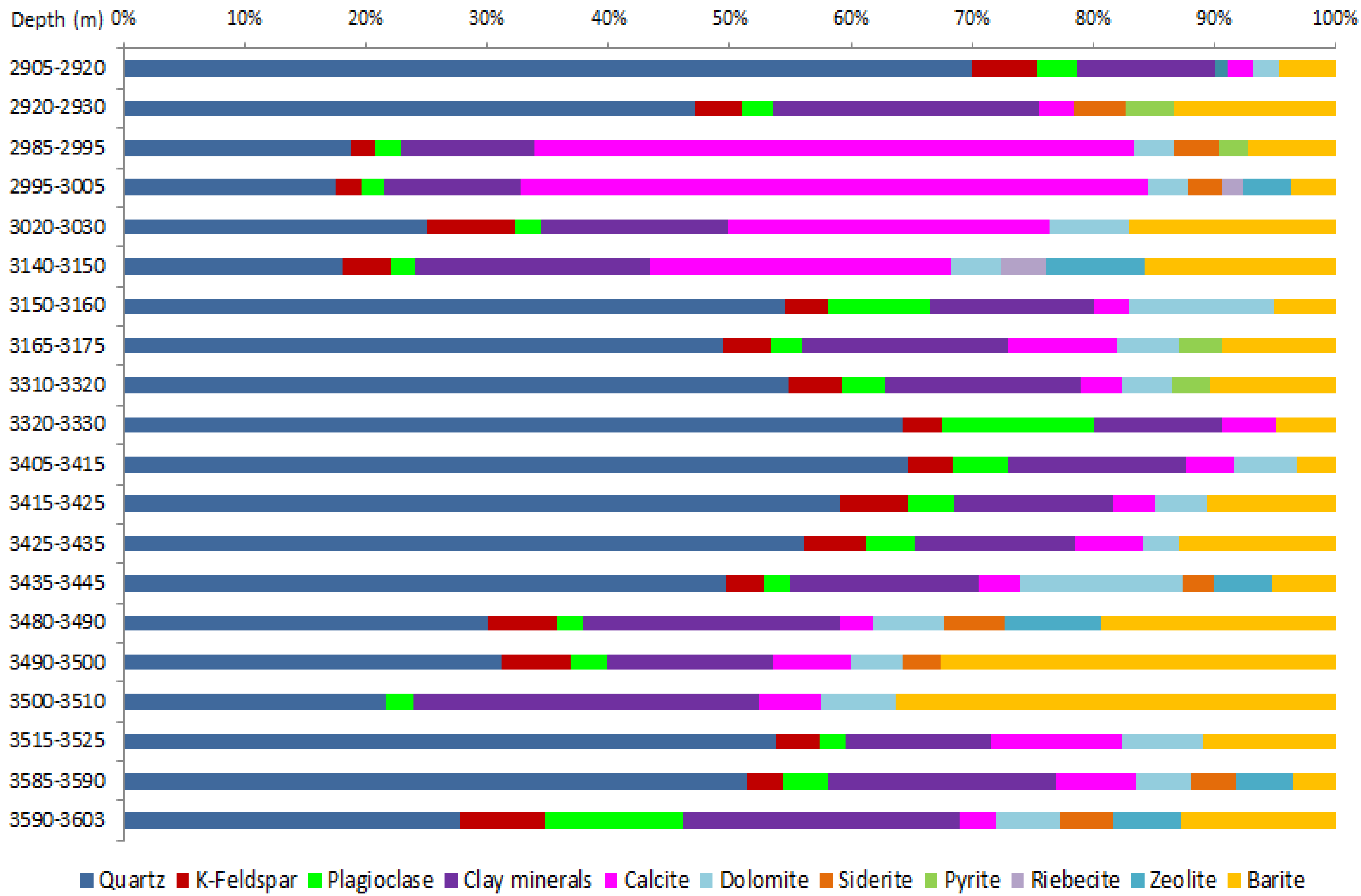
- the presence of fractures in shale sections
- gas zones in the interval 2970-3345m
- oil shows in the intervals 3145-3180m and 3210-3240m

4. Results and Discussion

2. Mineral compositions

Brittle minerals:

Quartz + Feldspar + Plagioclase + Carbonate > 40 %



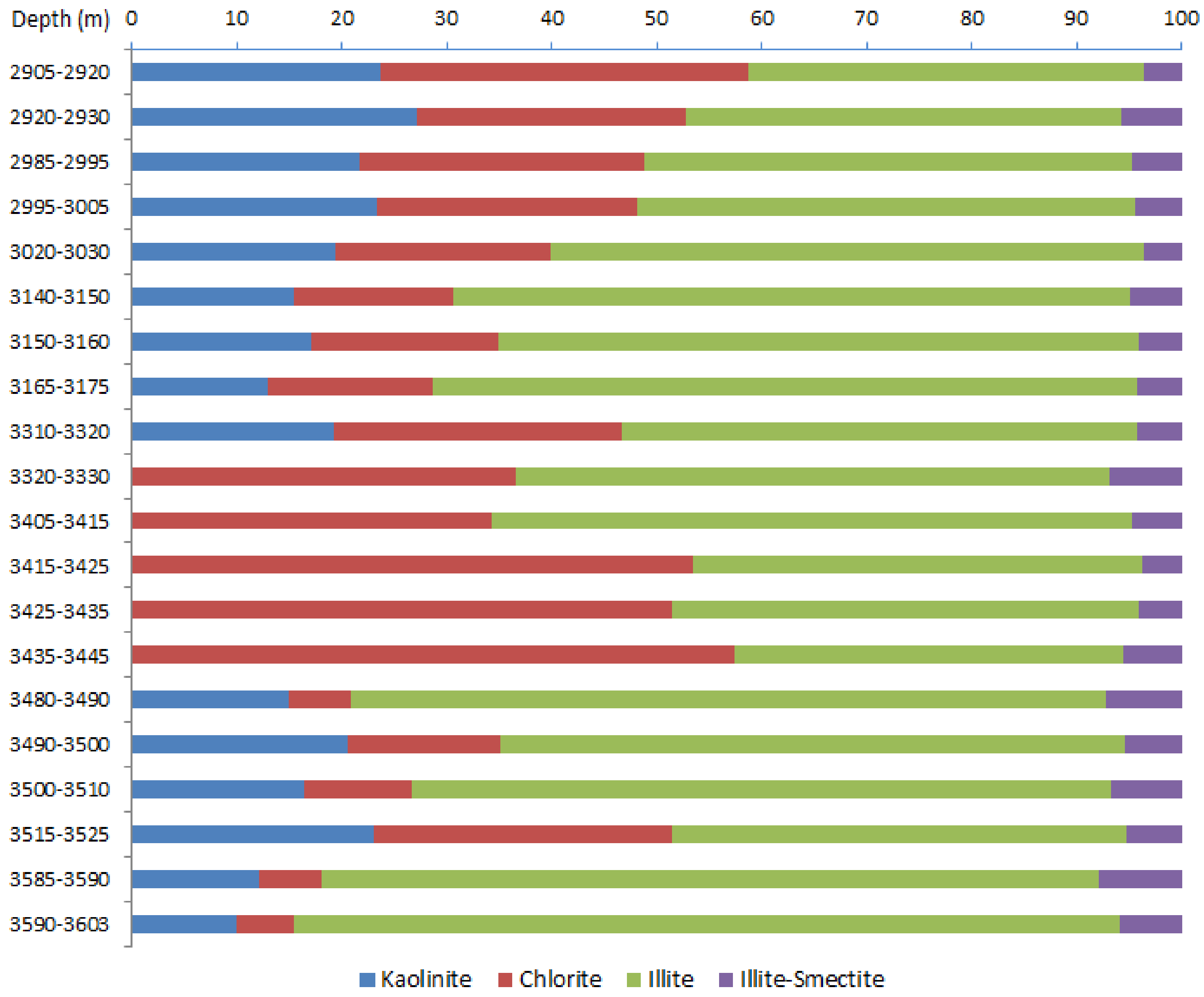
4. Results and Discussion

2. Mineral compositions

Ductile minerals:

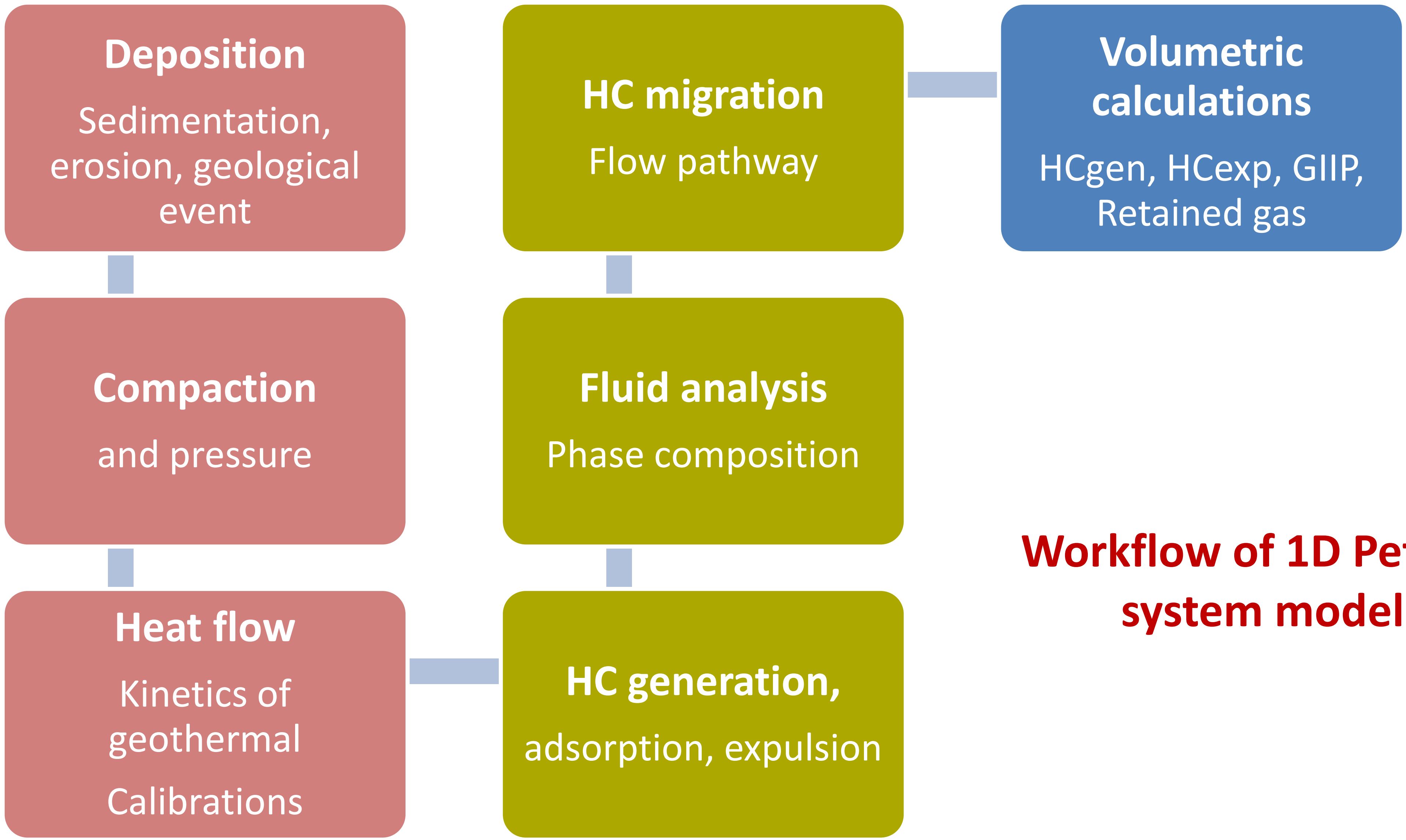
Illite + Kaolinite + Cholrite + Smectite < 30 %

→ **Illite-type**



4. Results and Discussion

3. Petroleum system modeling



Workflow of 1D Petroleum system modeling

4. Results and Discussion

3. Petroleum system modeling

Basic elements of PSM

Age assigment:
- Stratigraphy column

Paleo geometries:
- Water depth
- Erosions
- Salt/shale diapirs
- Thickness

Boundary conditions:
- SWI-Temperature (SWIT)
- Heat flow

Facies and parameters:
- Facies definitions
- TOC, HI
- Rock composition

4. Results and Discussion

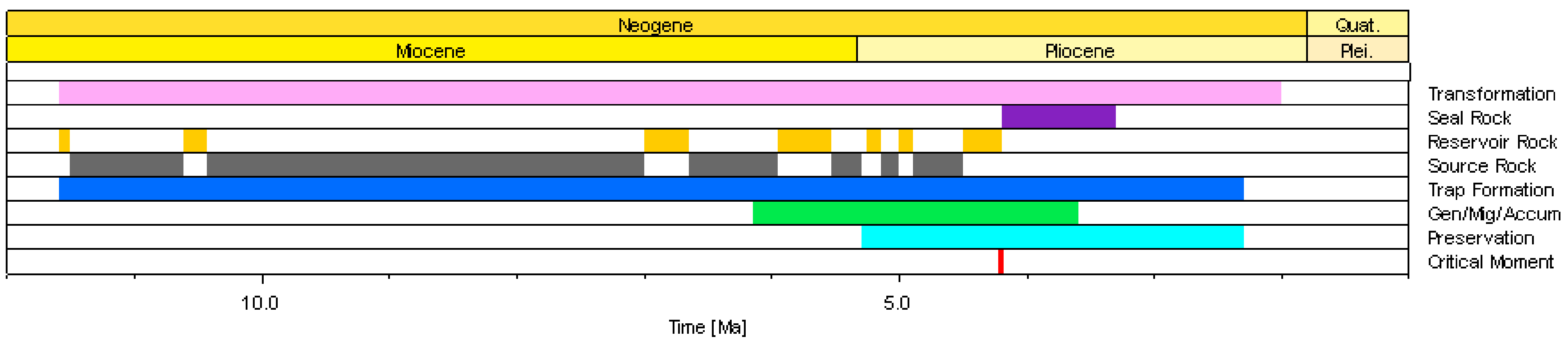
3. Petroleum system modeling

Formation	Pliocene	Upper Miocene
Age (Ma)	5.6-2.6	11.6-5.6
Depth (m)	50-2,651	2,651-3,603
Thickness of shale (m)	1,210	762
Thickness of erosion (m) Depth of erosion (m)	12 2,651	|
Boundary conditions:		
PWD (m)	50	20
SWIT (°C)	20.2	20.9
HF (mW/m²)	67	75

Input parameters used for 1D Petroleum system modeling

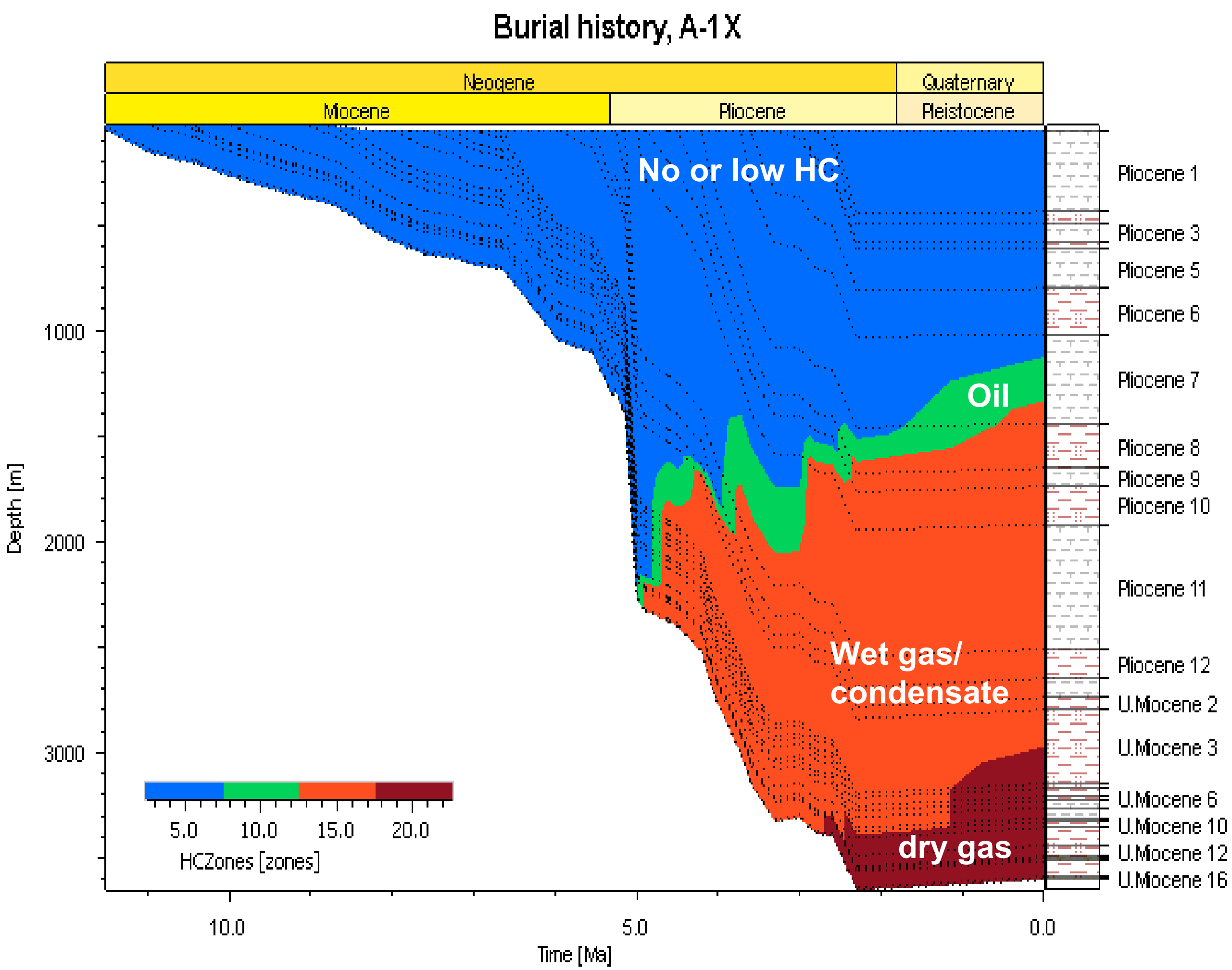
*HF= thermal conductivity of rock * geothermal gradient*
Parameters of McKenzie model: ß mantle=3 and ß crust=1.9; T_{swi} = 25.52 °C; T_b= 1333°C; hc=30 km; hm=95 km; t_s=23 Ma

Petroleum system event chart, A-1X

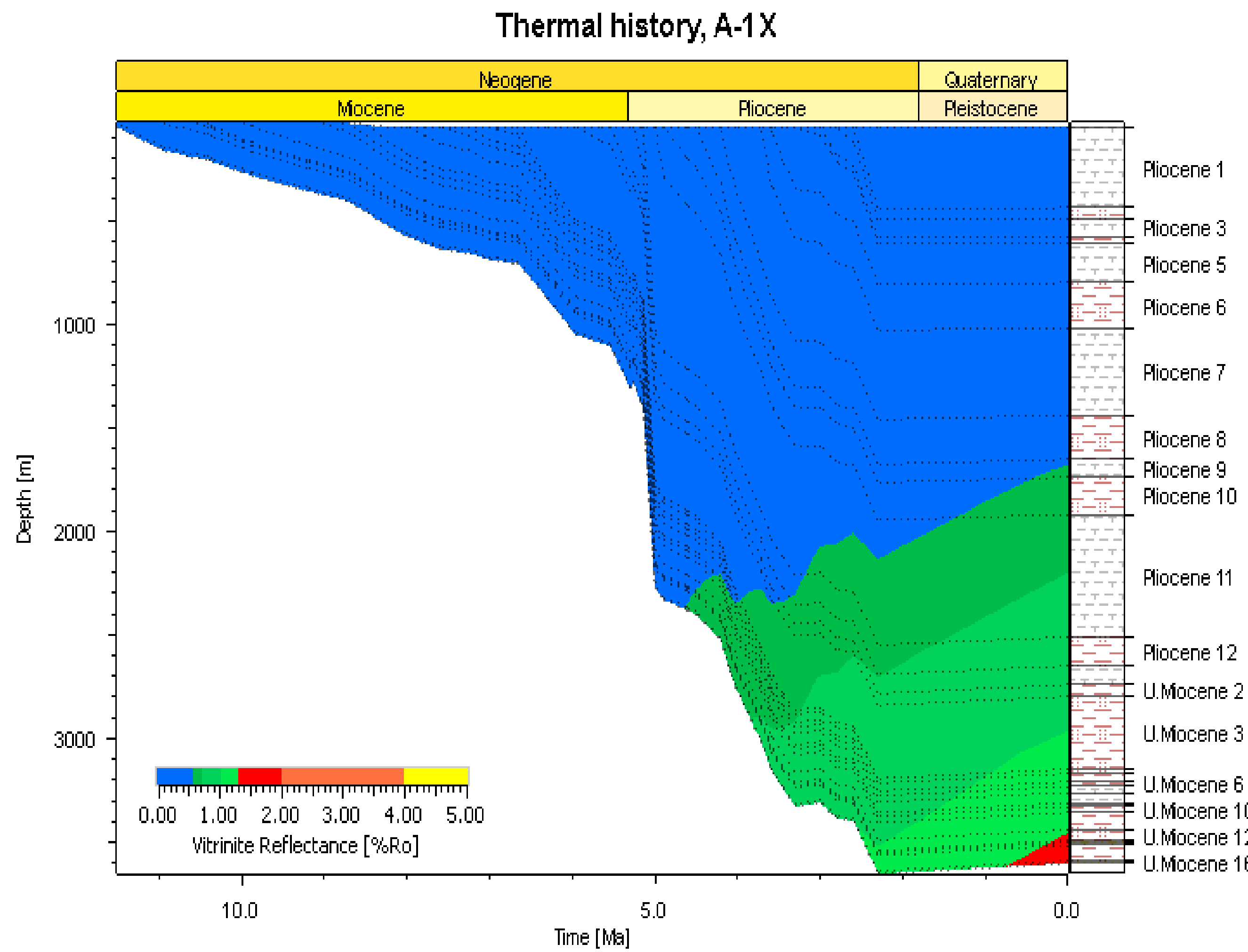


4. Results and Discussion

Burial history

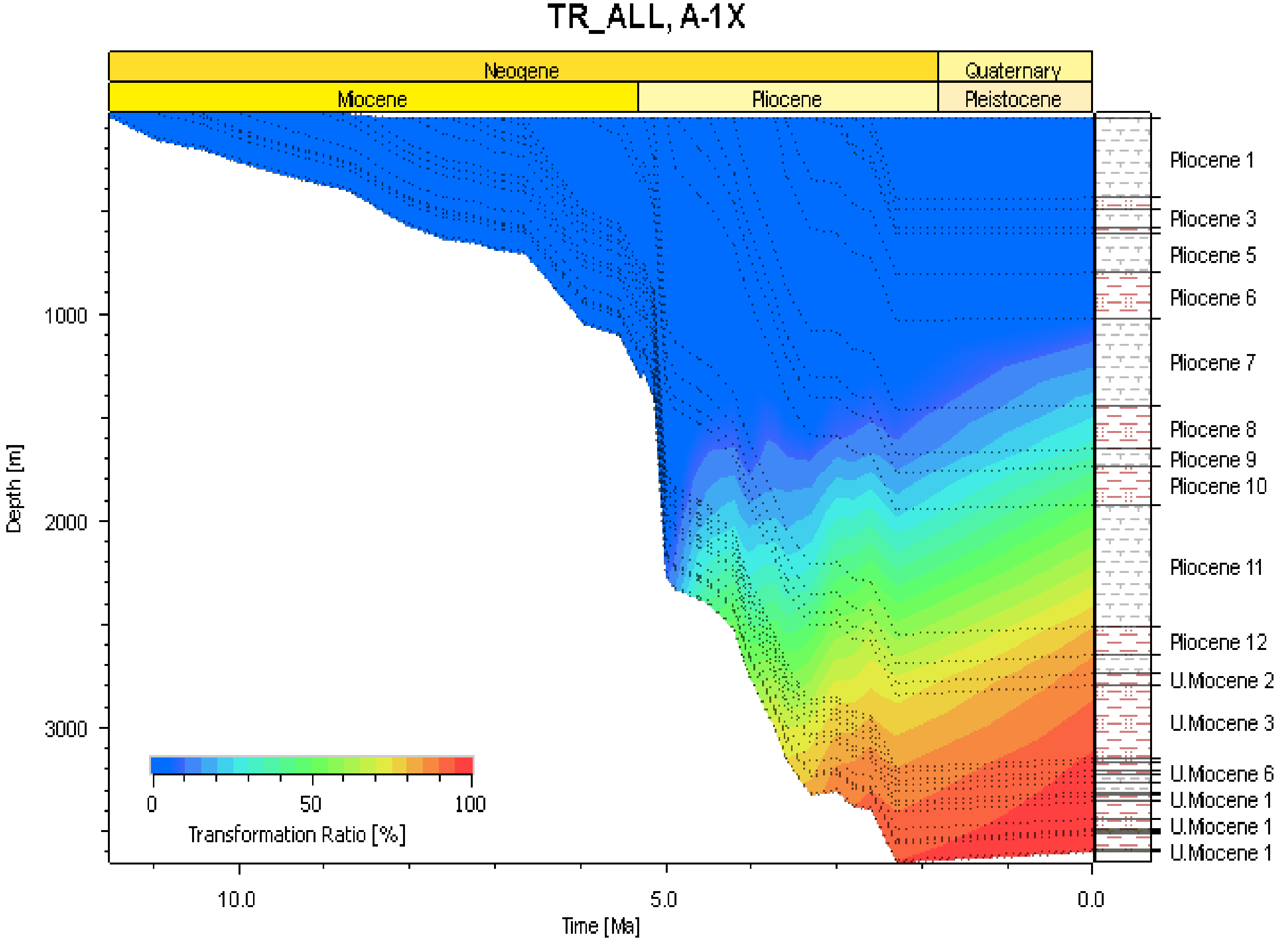


Thermal history

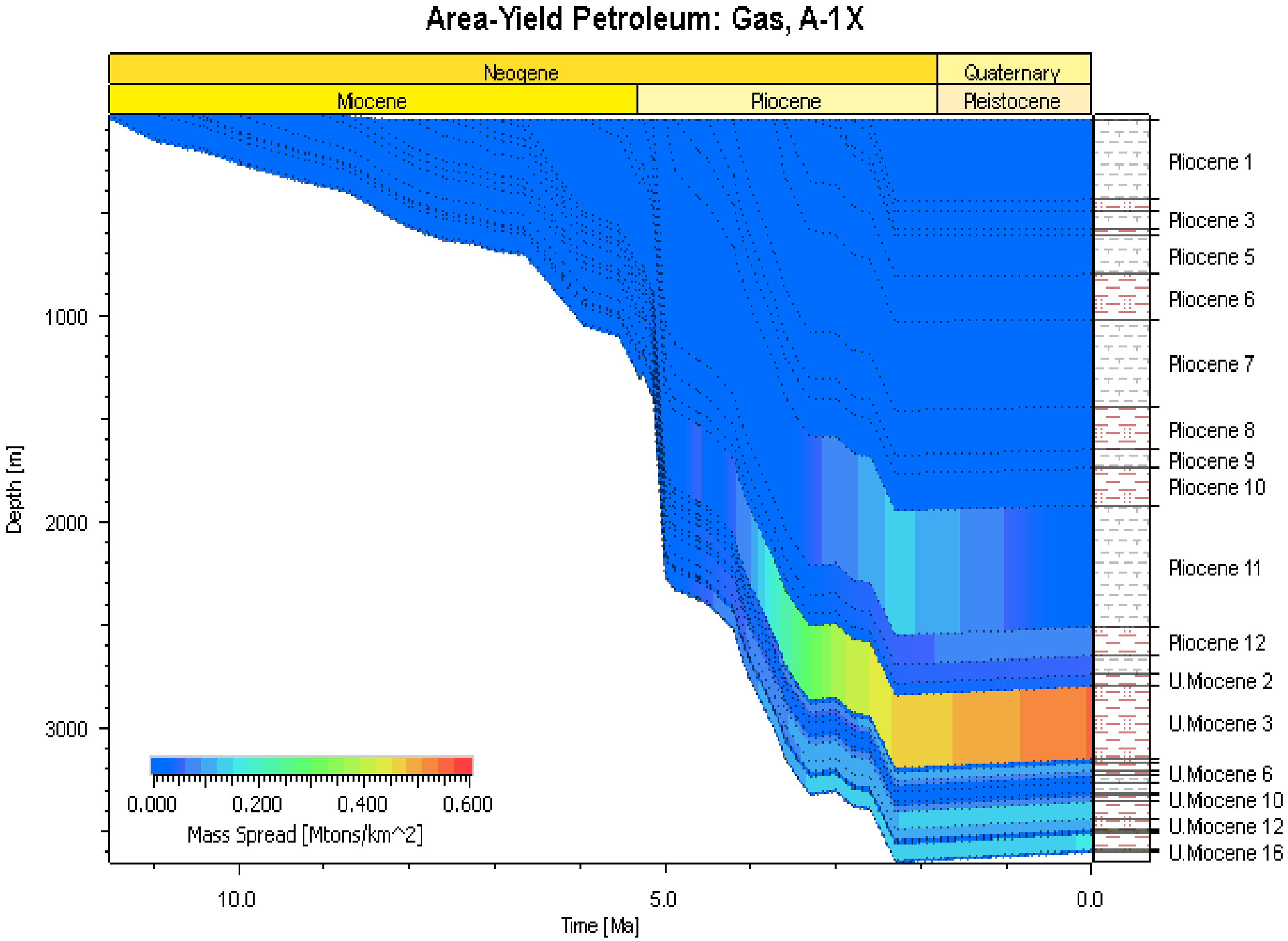


4. Results and Discussion

Transformation ratio

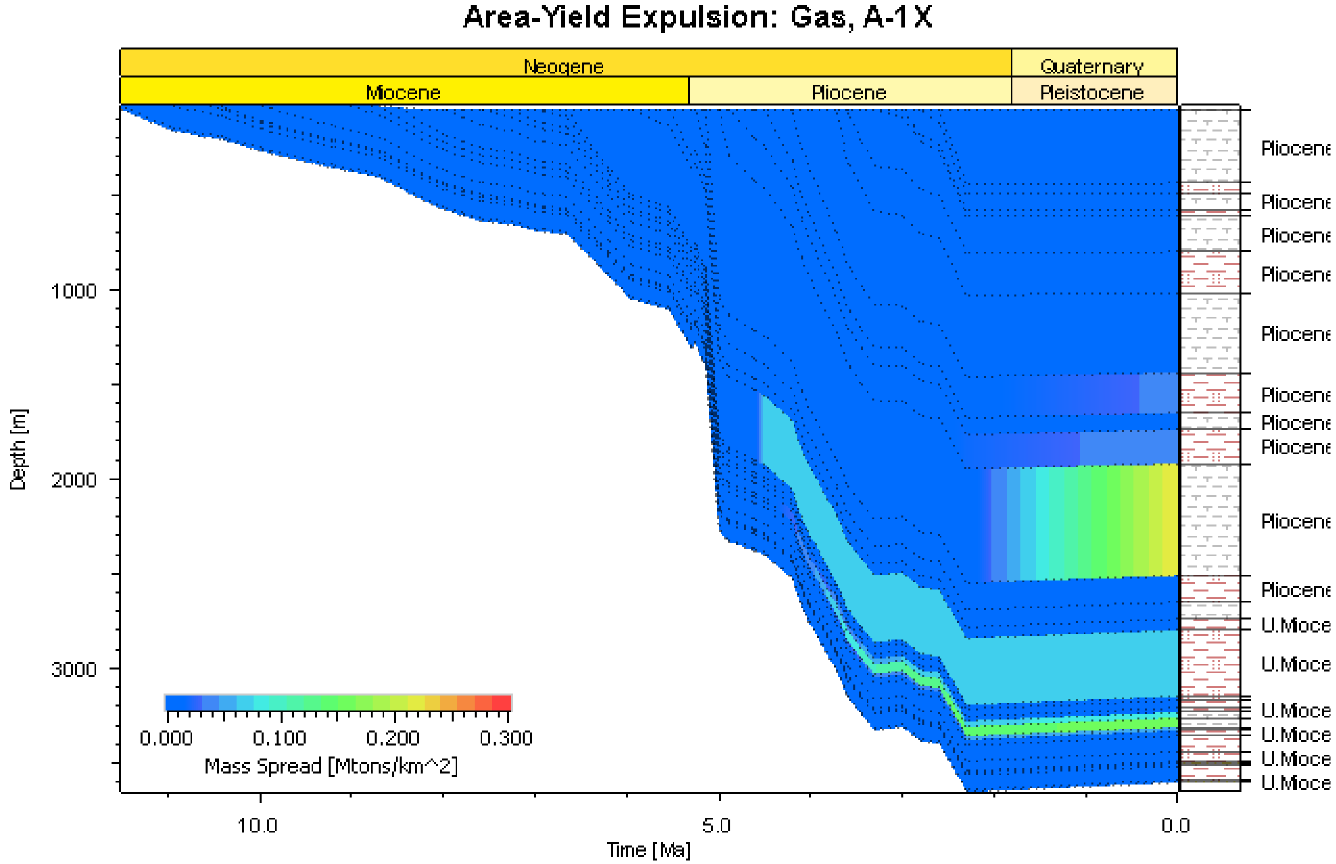


Area-yield gas

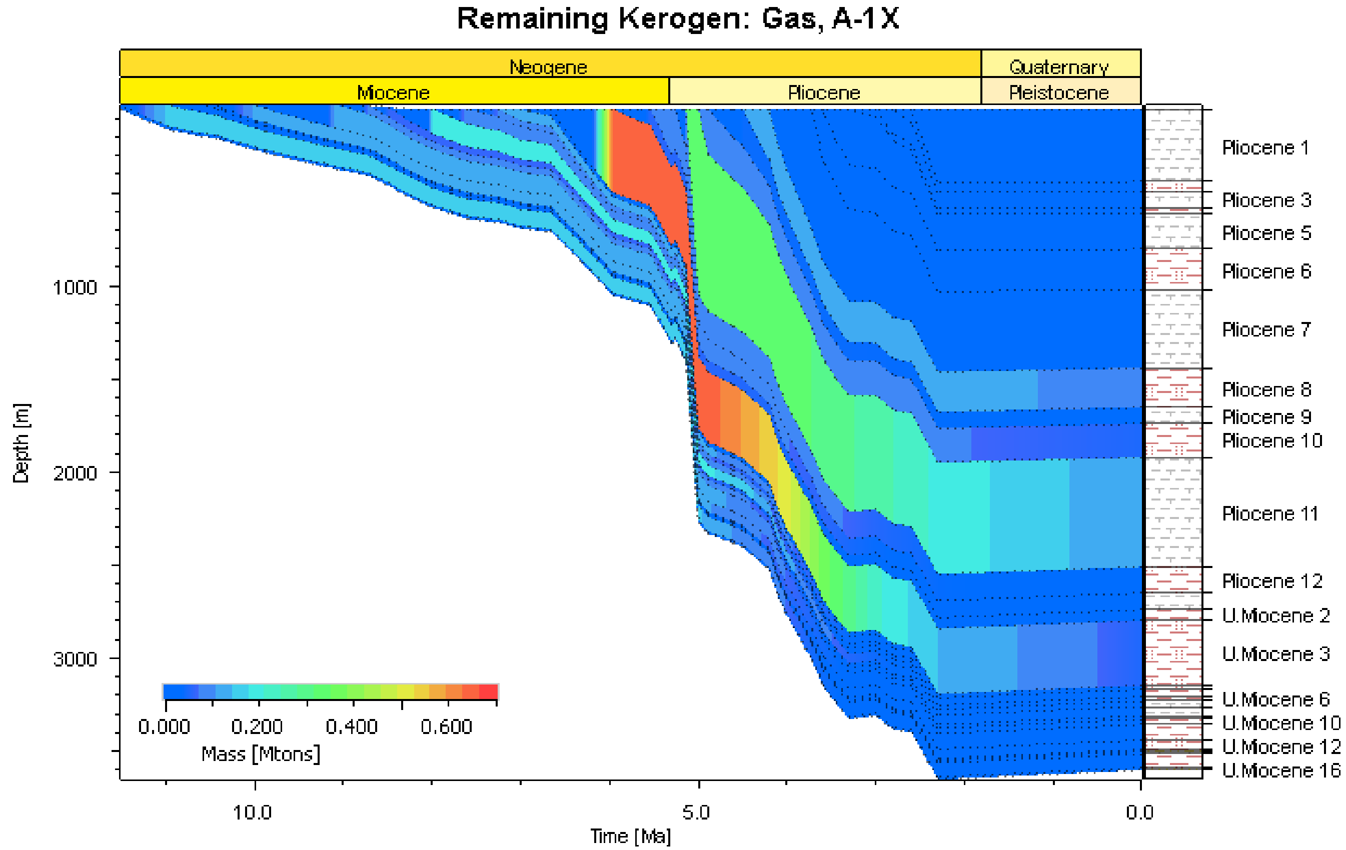


4. Results and Discussion

Gas expulsion

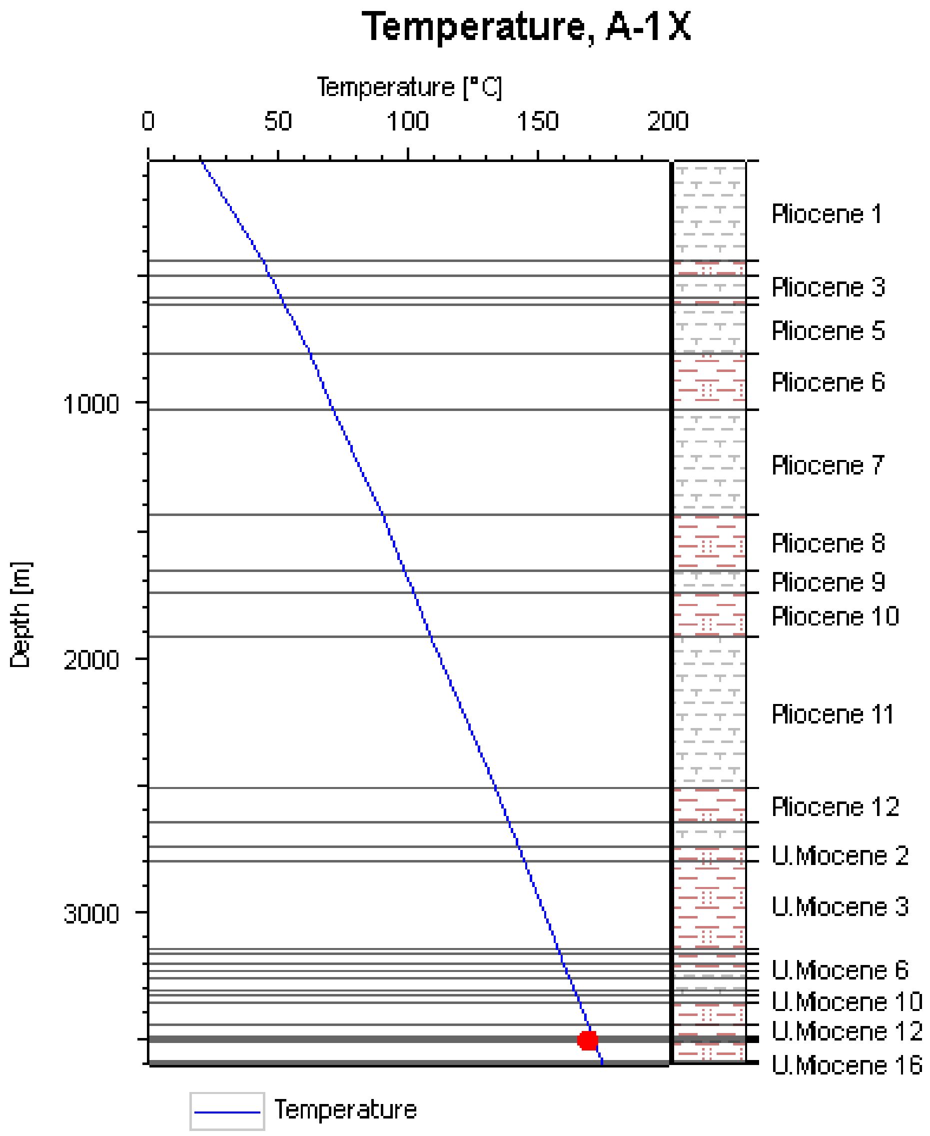


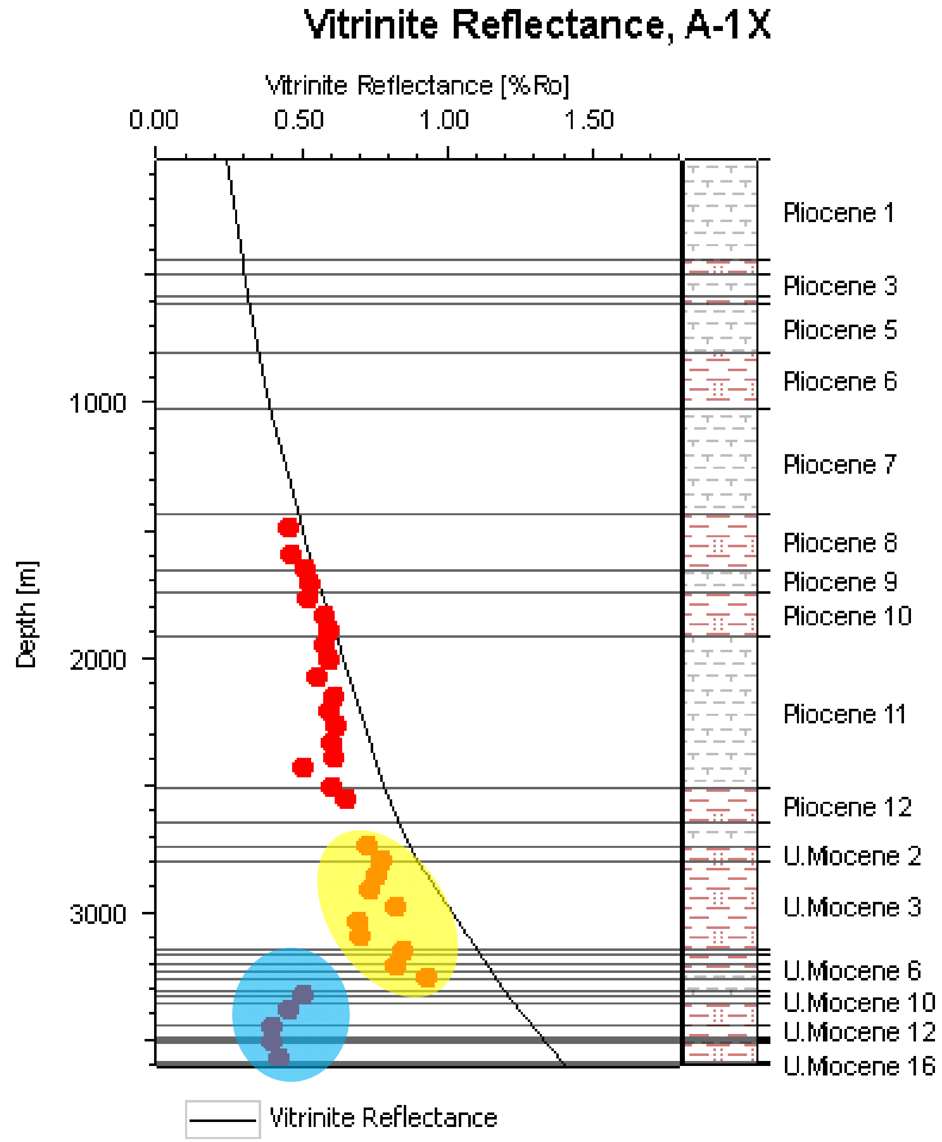
Remaining gas



4. Results and Discussion

Calibration with temperature and Vitrinite Reflectivity





4. Results and Discussion

Volumetric estimations

Free GIIP = $V_{gross} * \phi * S_w * B_g * 10^9$ (Tcf)

$V_{ads} = V_L * P_{res} / (P_{res}+P_L) * 10^6$ (Tcf)

Total GIIP = Free GIIP + V_{ads} (Tcf)

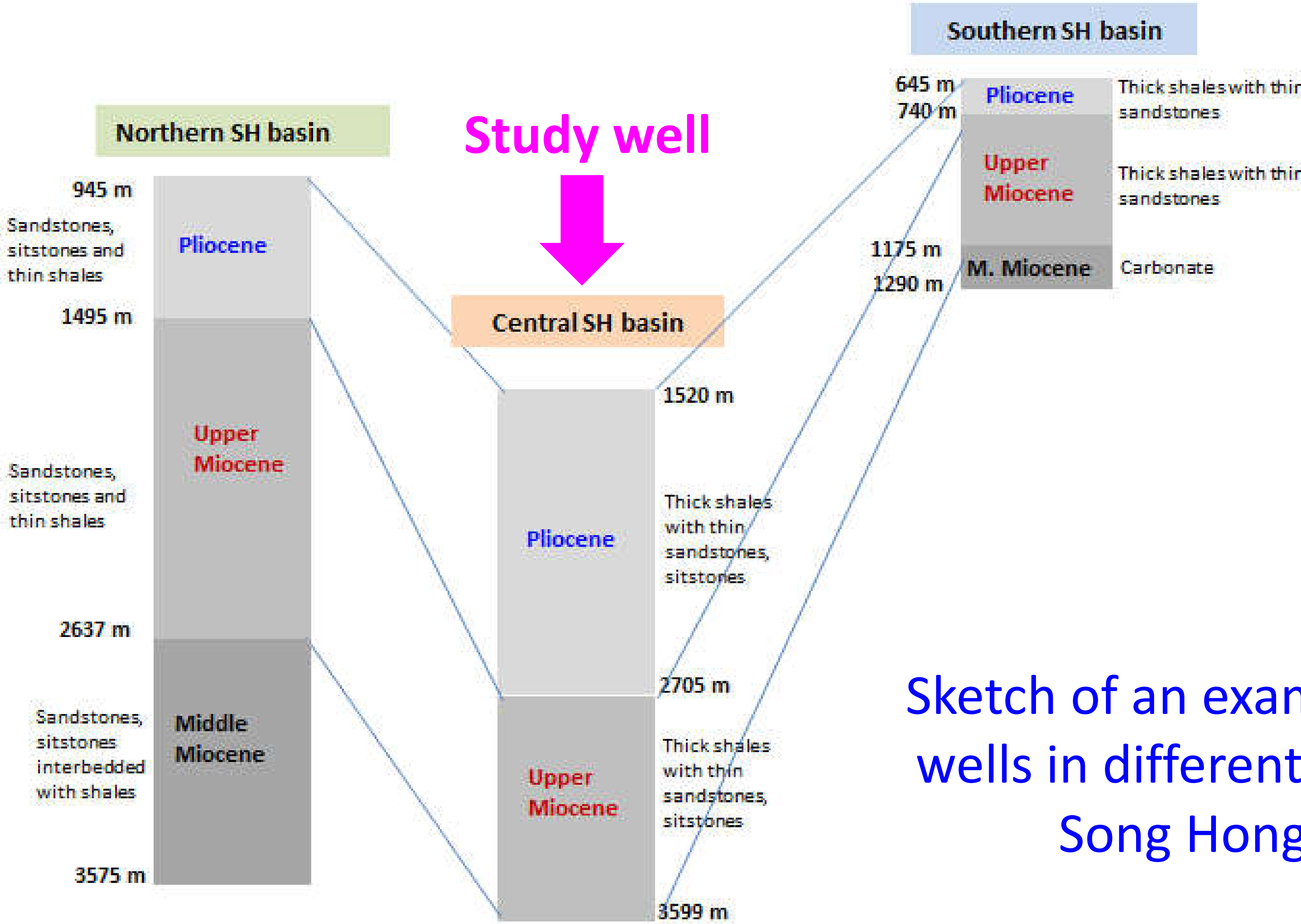
Parameters	Calculations		Remarks
	Pliocene	Upper Miocene	
A, km^2	40	40	Area
h_{sand}, m	10	22	thickness of sand
h_{shale}, m	480	590	thickness of shale
V_{sand}, km^3	400	880	volume of sand
V_{shale}, km^3	19,200	23,600	volume of shale
ϕ, %	0.05	0.05	porosity
S_w, %	0.60	0.60	water saturation
B_g	0.0283	0.0283	B factor of gas

4. Results and Discussion

Volumetric estimations

Parameters	Calculations		Remarks
	Pliocene	Upper Miocene	
Free GIIP, Tcf	**0.58**	**0.71**	free gas initial in place
TOC, wt.%	0.17	0.54	Total organic carbon
R_{o}, %	0.56	0.66	vitrinite reflectance
T_{res}, oC	90	168.3	reservoir temperature
P_{res}, psi	4,136	6,600	reservoir pressure
V_{L}, km^3	2,511	3,732	Langmuir volume
P_{L}, psi	734	771	Langmuir pressure
V_{ads}, Tcf	**0.08**	**0.12**	volume of adsorbed gas
Total GIIP, Tcf	**0.66**	**0.83**	total gas initial in place

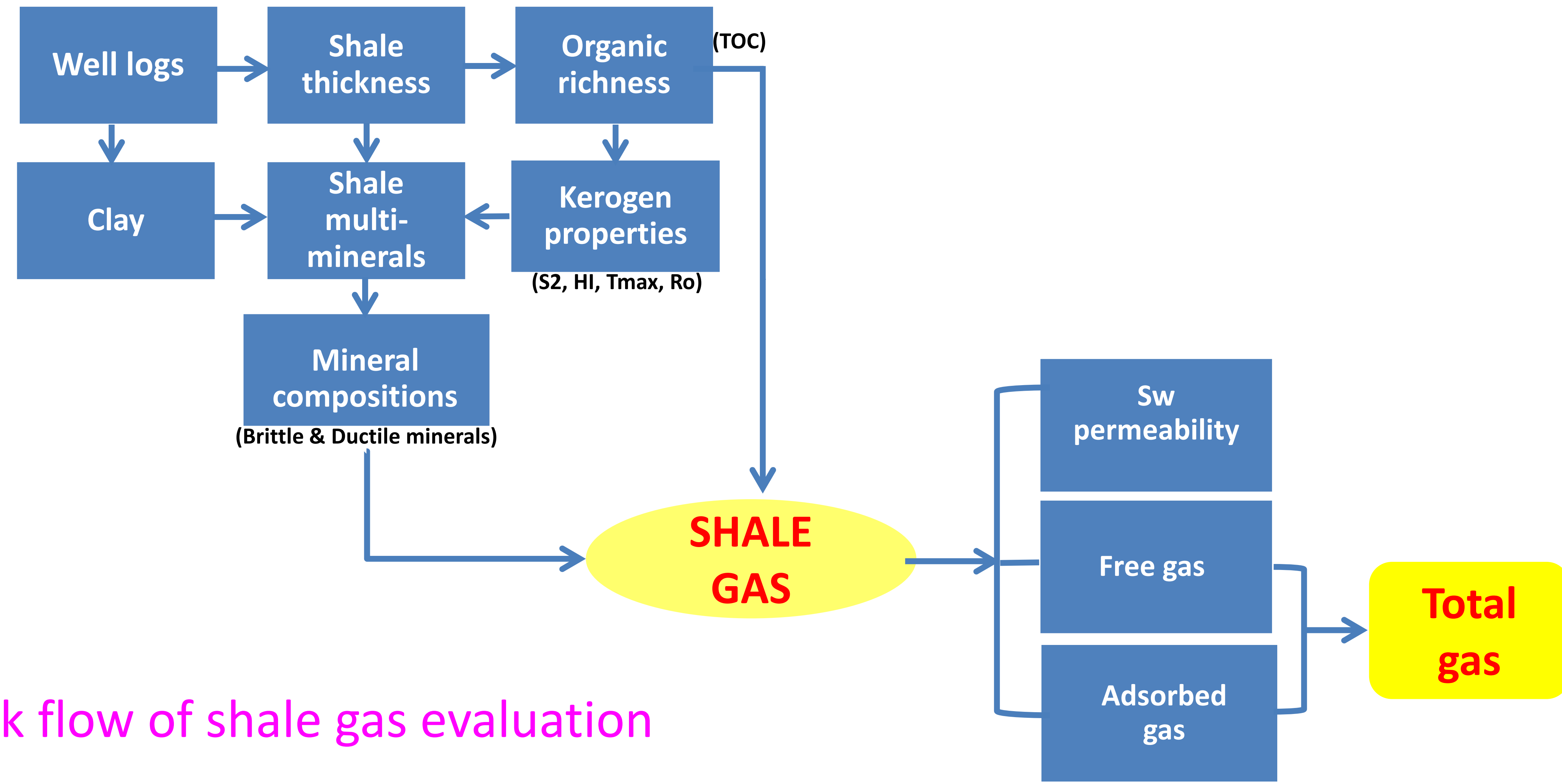
5. Shale gas properties



Sketch of an example of three wells in different parts of the Song Hong basin

5. Shale gas properties

2. Shale gas evaluation

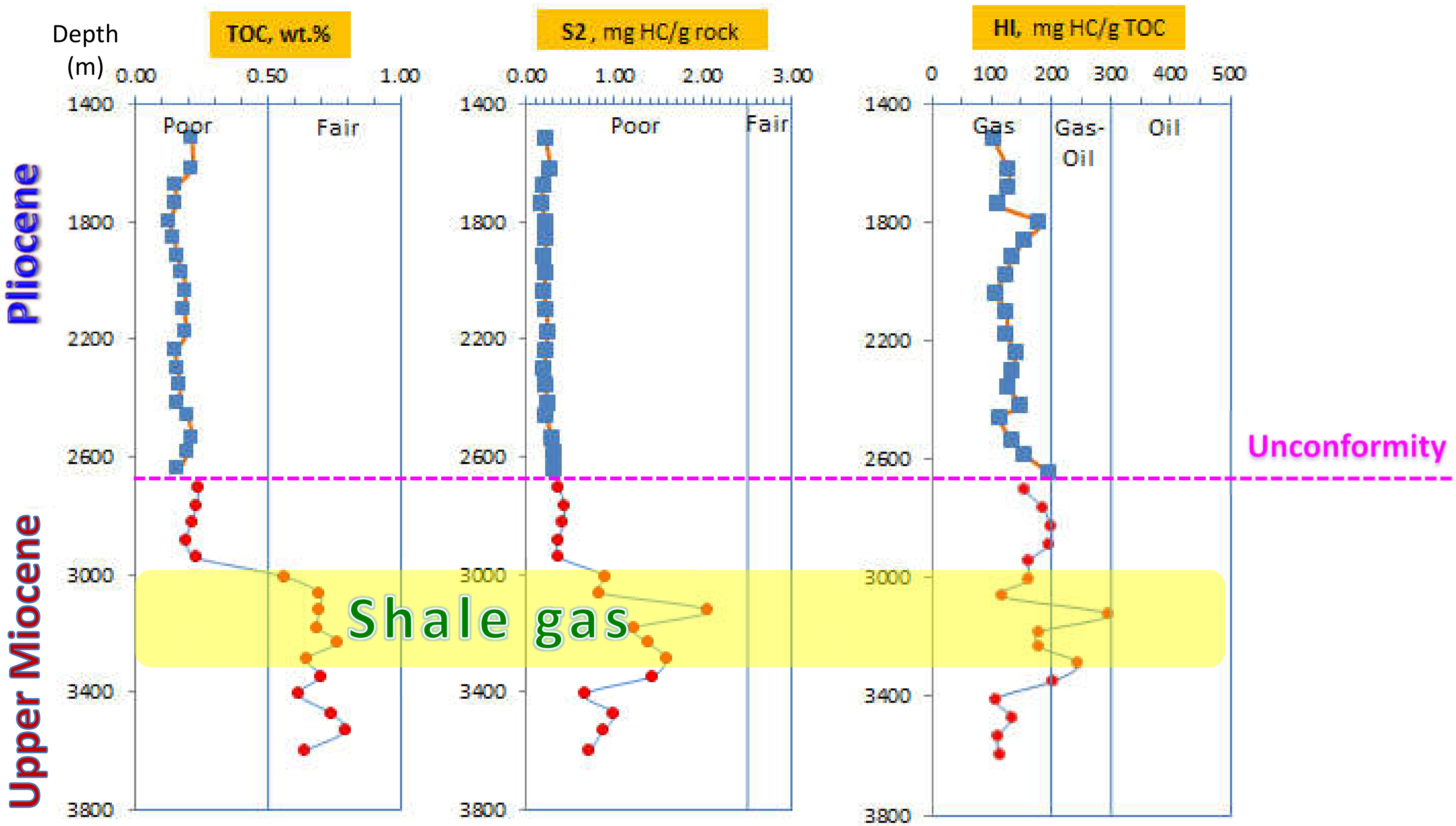


Work flow of shale gas evaluation

5. Shale gas properties

2. Shale gas properties

- ✓ Thickness = 345 m
- ✓ TOC = 0.56-0.76 %
- ✓ Type III/II kerogens
- ✓ Ro = 0.69-0.93 %
- ✓ Brittle minerals > 40 %
- ✓ Clay minerals: Illite-type



6. Conclusions

1. Source rock properties

- Pliocene and Upper Miocene shales are poor to fair organic richness;
- mainly derived from type III kerogen;
- Poor to fair hydrocarbon generation potential;
- Pliocene and Upper Miocene shales are currently active and probably generating an amount of gas;
- Deeper shales would be more effective source rocks that can produce a significant amount of gas from sand and shale reservoirs

6. Conclusions

2. Petroleum system

- HC generation mainly related to basin burial history rather than basin evolution during the deposition from Upper Miocene to Pliocene;
- The burial history model shows the oil window starts at 2,700 m in Pliocene and spreading to a part of the Upper Miocene;
- The organic matters are mostly favorable for gas-prone that have reached gas generation onset in the interval 1,986-3,456 m of the Upper Miocene;
- Gases are probably originated from biogenic gas and thermogenic gas with high CO_2 contents. The mass is estimated about 17.88 Mtons;

6. Conclusions

2. Petroleum system

- HC expulsion starts at the Upper Miocene to Pliocene (~9-5.1 Ma) with approx. 4.3 Mtons/km^2;
- The expulsion recently started in Pleistocene (∼1.8 Ma) after both the generation of gas in the Upper Miocene and Pliocene;
- The remaining of kerogen is estimated approx. 62.81 Mtons and GIIP of about 1.49 (Tcf)

6. Conclusions

3. Shale gas properties

- Shale gas found in the interval 2700-3290 m and the main shale reservoir at 3000-3290 m;
- The thickness of shale is about 345 m;
- Containing moderate quantity of Total Organic Carbon contents;
- Originated from type III kerogen with a little type II kerogen;
- Organic matters are in mature stage and possibly generating a significant amount of gas;
- Brittle minerals are dominant in the shales, indicating a favorable condition for the fracturing

GEOPET

THANK YOU