Numerical Simulation of Deep Biogenic Gas Play Northeastern Bay of Bengal, Offshore Northwest Myanmar*

Young Hoon Chung[1], Su-Yeong Yang[1], Jae Woo Kim[1]

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[1]Myanmar E&P, Daewoo International Corporation, Yangon, Myanmar (yhchung@daewooenp.com)

Abstract

Commercial quantities of methane gas were discovered in the Late Pliocene reservoir, offshore northwest Myanmar between 2003 and 2005. The gas is stratigraphically trapped in deepwater turbidite sandstones, and occurs between 2,900 and 3,300 meters sub-sea. Gas accumulations are of biogenic origin, which was proven by its dryness (>99% methane) and enriched light isotope character ($\delta^{13}C$ ranging from 60 to 70 ‰). Little is known about the source rock potential in the area due to limited offset well data. A basin-modeling study using PetroMod 1D/2D packages was employed to test Pliocene and Miocene source rock potential, and to analyze gas generation, migration, and trapping history of the study area. Three seismic sections and eight wells were selected to construct 2D models. The method of Clayton (1992), which gives a nomogram for the conversion of source rock volume to volumetric yields of biogenic gas, was applied for biogenic gas generation modeling. The model output was calibrated with vitrinite reflectance, and bottom hole temperature data.

The model indicates that the stratigraphic section in the study area is thermally immature. There were three biogenic gas generation peaks during the Late Miocene, Early Pliocene, and Late Pliocene. Most of biogenic gas was generated from Middle Miocene and Early Pliocene shale. The model suggests the expelled biogenic gas migrated vertically, with a large amount of the generated gas being lost due to a lack of effective seals encountered. Accumulation of biogenic gas in commercial quantities requires relatively unusual geologic conditions, including formation of traps and seals in the early stage. Simulation results indicate that the existence of paleo-hydrates during Miocene to Pliocene period played an important role in gas accumulation, with the hydrates acting as seals in the initial gas generation stage. The presence of paleo-hydrates is supported by the occurrence of low-saline formation water. The paleo-hydrate was later released by changes in P-T conditions

due to sediment burial. The later stage of sealing is thought to be provided by thick shale overburden as well as homogeneous shale interbeds and authigenic carbonate cement beds within reservoir sandstones.

The numerical simulation shows that the Pliocene sediments in this region are far above thermogenic hydrocarbon generation windows. This study will provide insights on the biogenic gas potential of the Pliocene Bengal fan sediments in the northeastern Bay of Bengal.

Reference

Clayton, C., 1992, Source volumetrics of biogenic gas generation, *in* R. Vially, (ed.), Bacterial Gas: Edition Technip, Paris, p. 191-204.

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Young Hoon Chung, Su-Yeong Yang, Jae Woo Kim
Daewoo International Corporation

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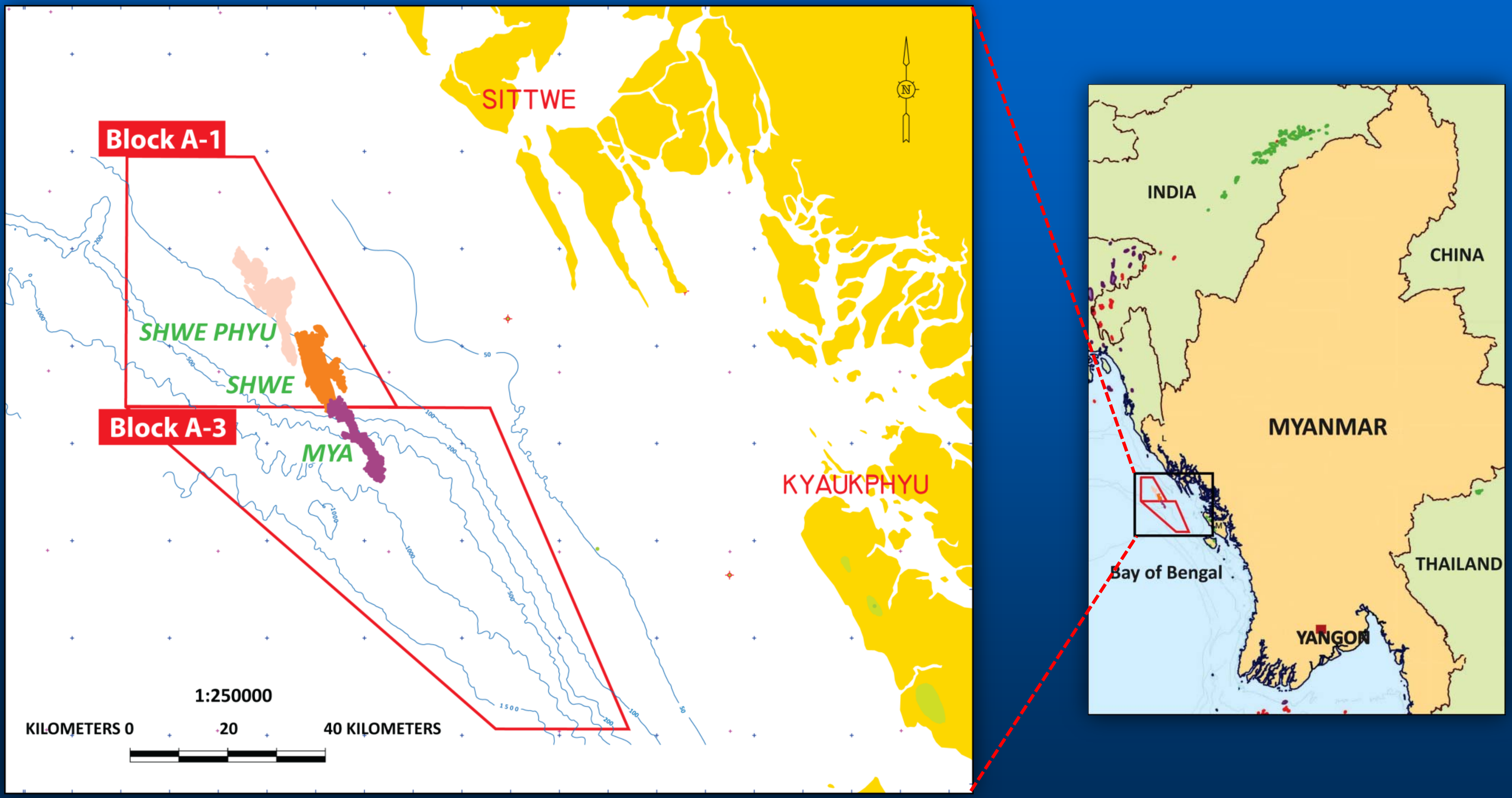
Outline

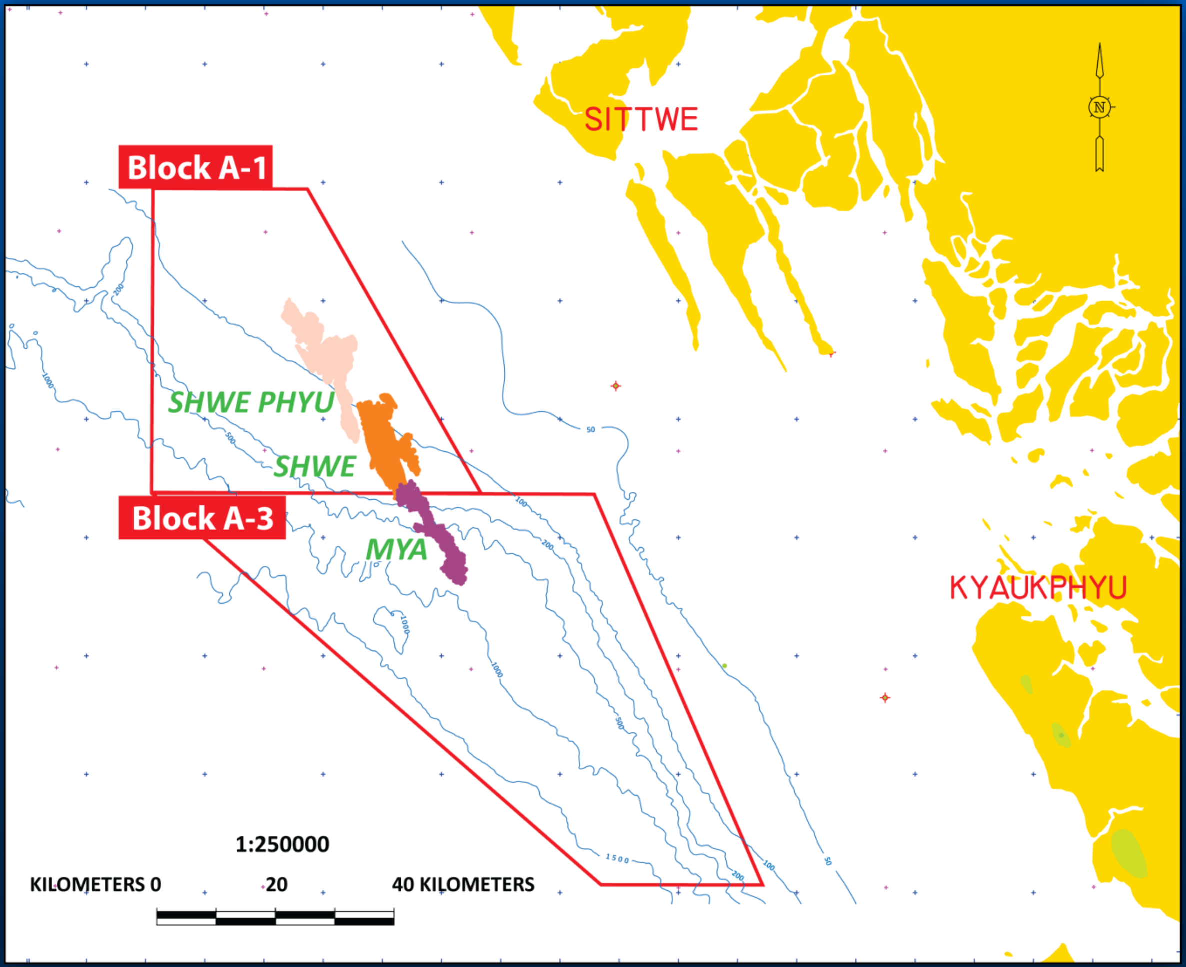
- Essentials of the Approach
- Geologic Setting
- Database
- Model Building
- Calibration and Results
- Trapping of Gas
- Conclusion

Essentials of the Approach



Block and Gas Field Location

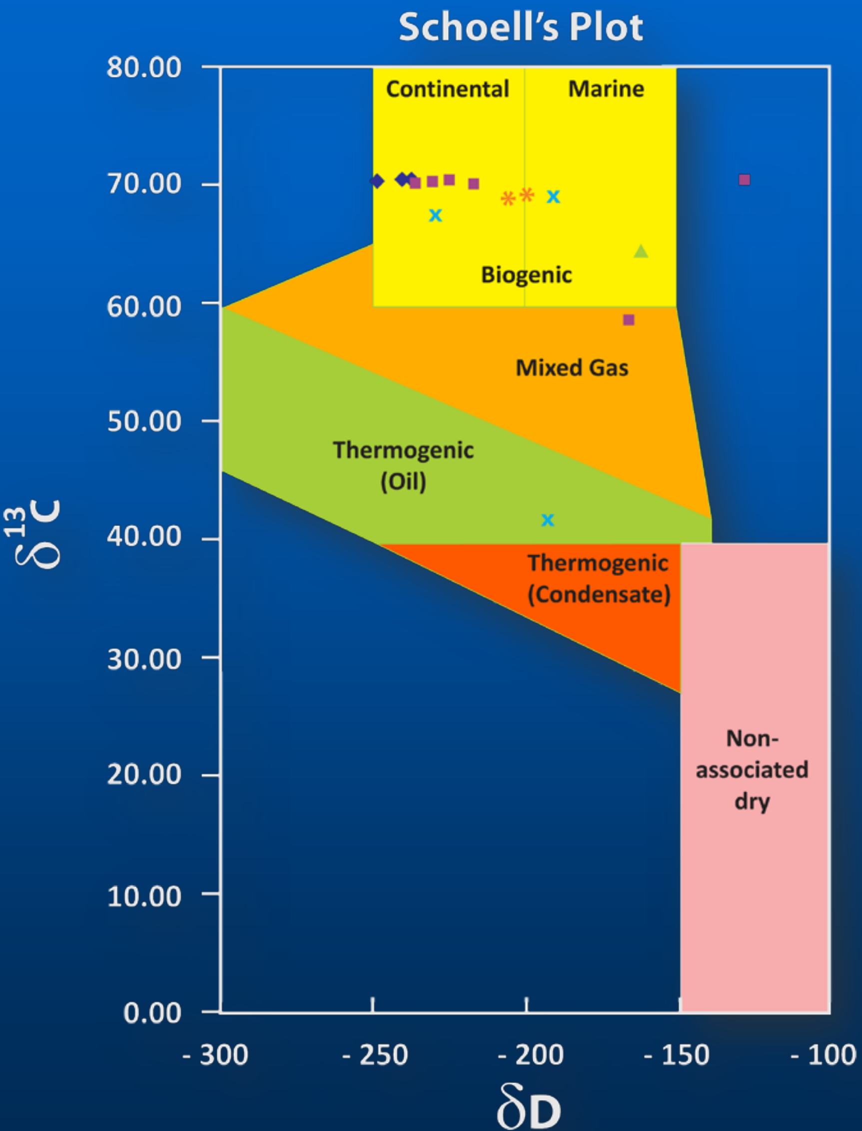
Essentials of the Approach



- Biogenic origin gas
- Reservoir is deepwater turbidite sandstones in Late Pliocene
- Burial depth is 2,900 to 3,300m sub-sea
- 23 exploration – appraisal and 4 production wells were drilled

Block and Gas Field Location

Model Building



Biogenic Gas Origin: Isotope Indicator and >99% Methane

Essentials of the Approach

Location	Habitat	Age	Depth (m)	Organic
Brunei[1]	Delta	Tertiary	1600-2600	Type III
Canada[2]	Shelf	Cretaceous	30-1000	Type III
China[3]	Fluvial	Pleistocene	65-1380	Type III
Germany[4]	Delta	Tertiary	900-2000	Type III
Italy[5]	Deep Water	Tertiary	140-4600	Type III
Nigeria[6]	Delta	Tertiary	650	Type III
U.S.A[7]	Delta	Pleistocene	458-3600	Type III
U.S.S.R.[8]	Coastal Plain	Cretaceous	684-1275	Type III

1. Baram Delta, 2. S.E. Alberta, 3. Qaidam Basin, 4. Molasse Basin, 5. Po Basin, 6. Niger Delta, 7. Offshore Gulf of Mexico, 8. West Siberia

Occurrence of Ancient Biogenic Gas

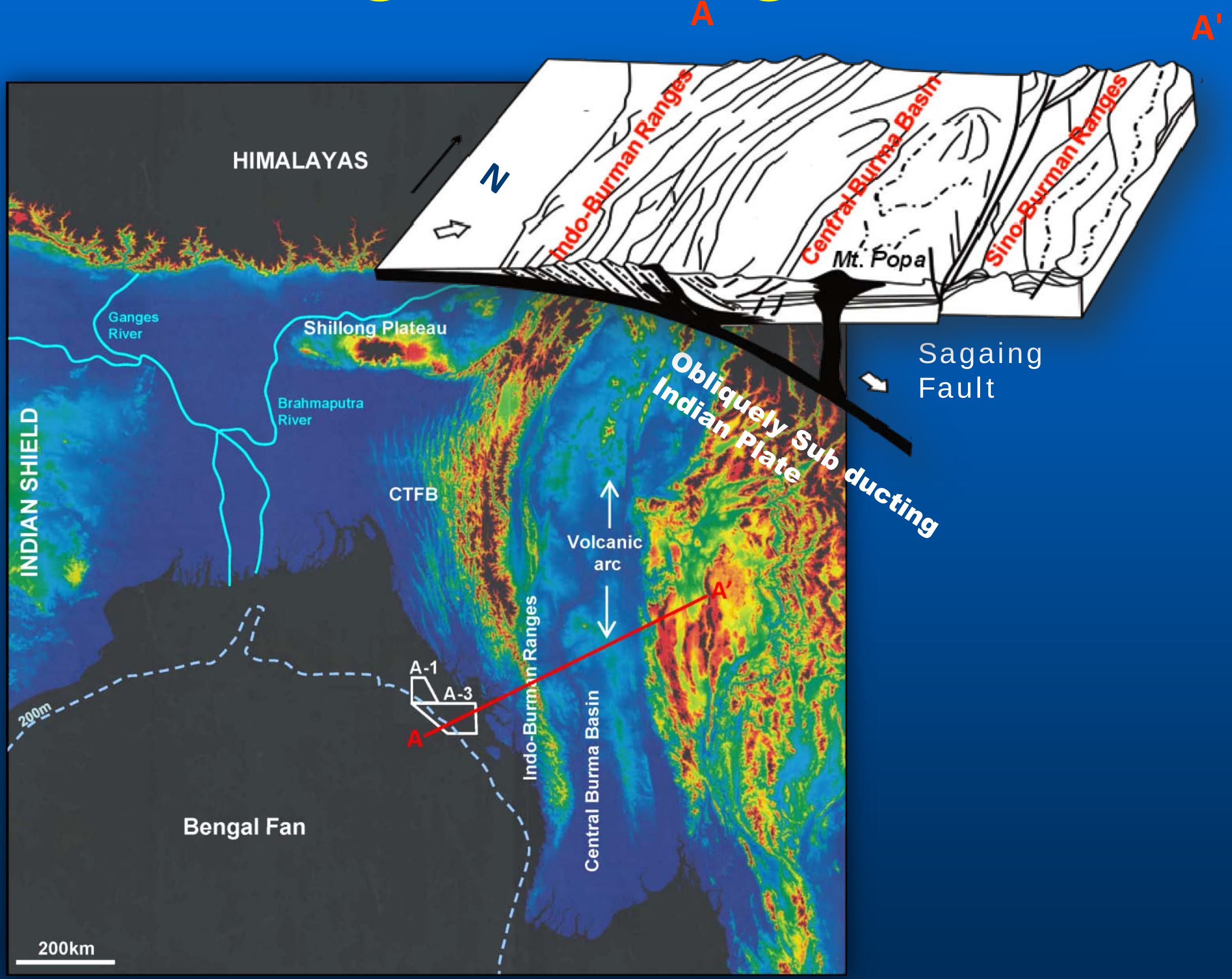
Essentials of the Approach

- **Little is known about generation, migration, and trapping history in deeply buried biogenic gas**

- **The main goals of this study were to**
  - Reconstruct the burial and thermal history
  - Investigate biogenic gas generation with appropriate kinetic
  - Model migration and trapping history

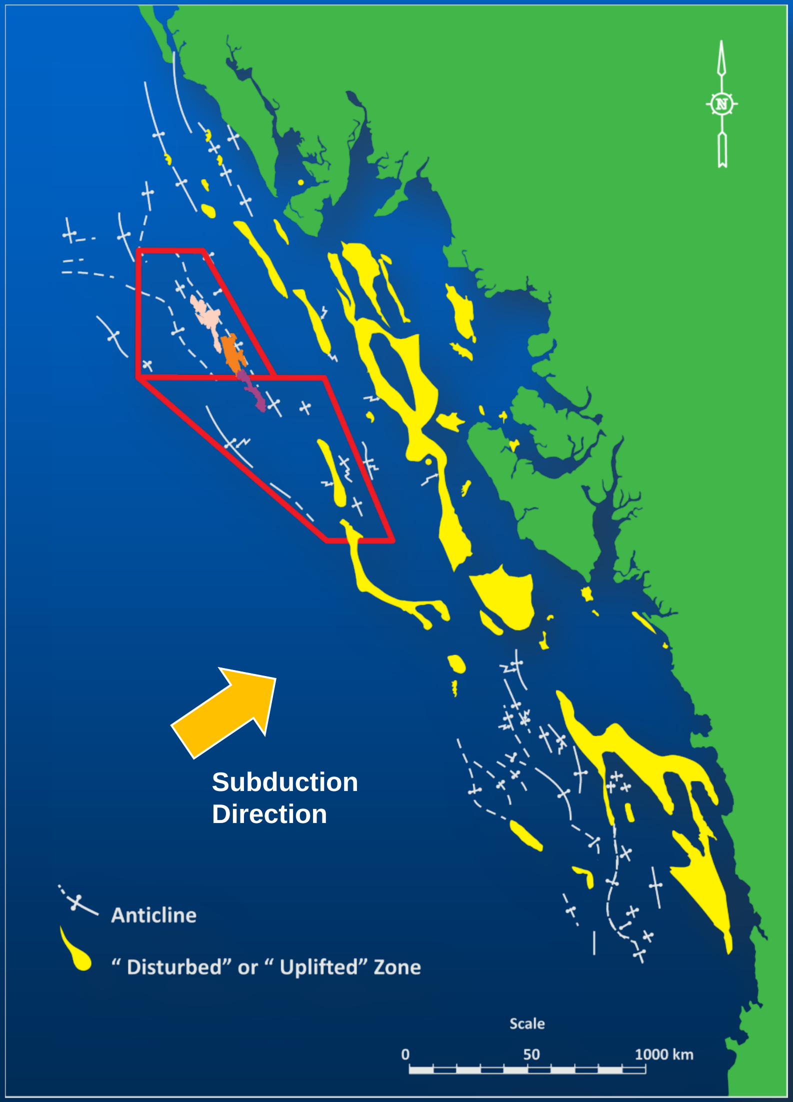
- **PetroMod 1D/2D packages was employed to construct basin model**

Geologic Setting



Geographical Feature and Cross Section

Geologic Setting

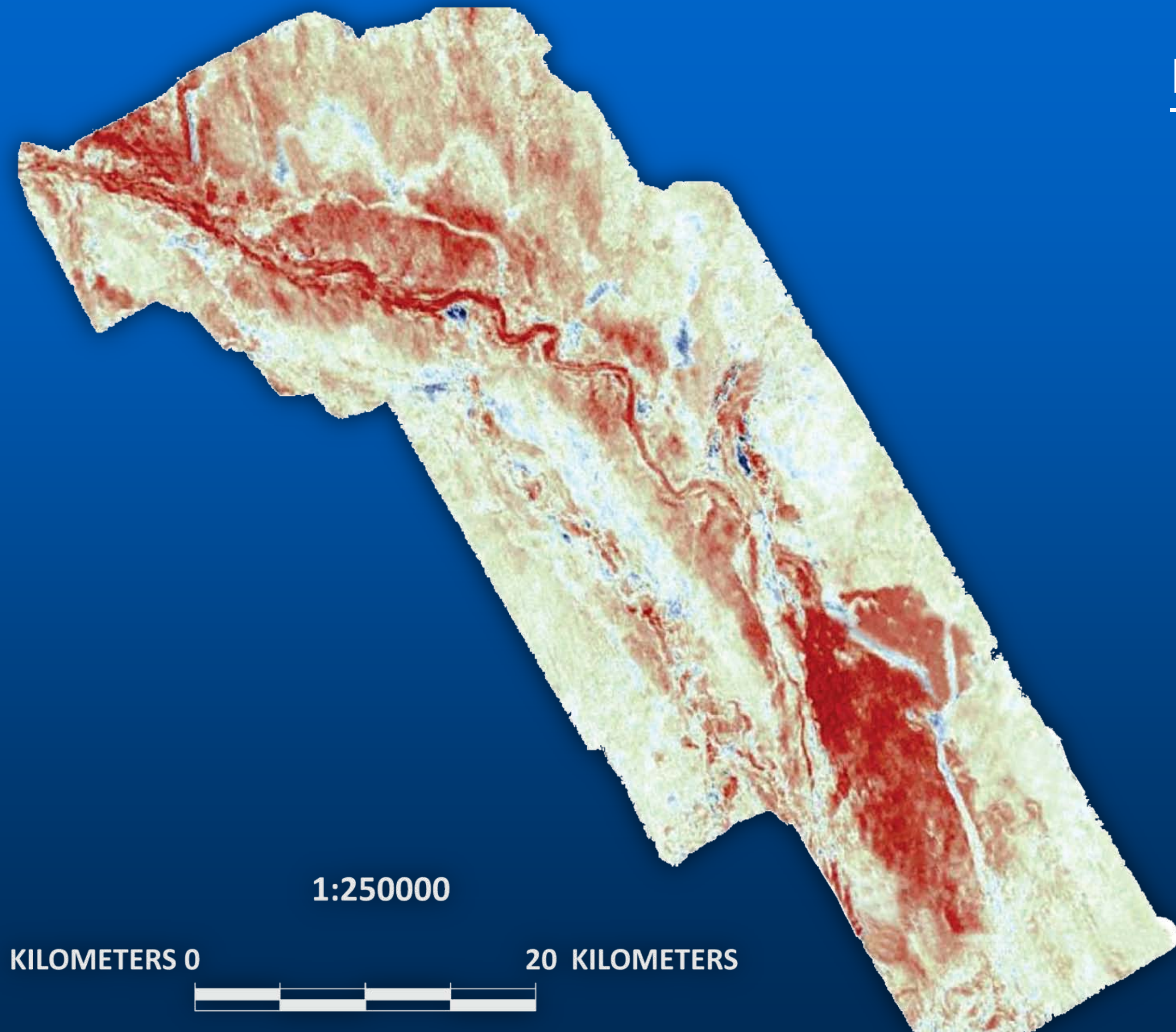


Structural Map

Geologic Setting

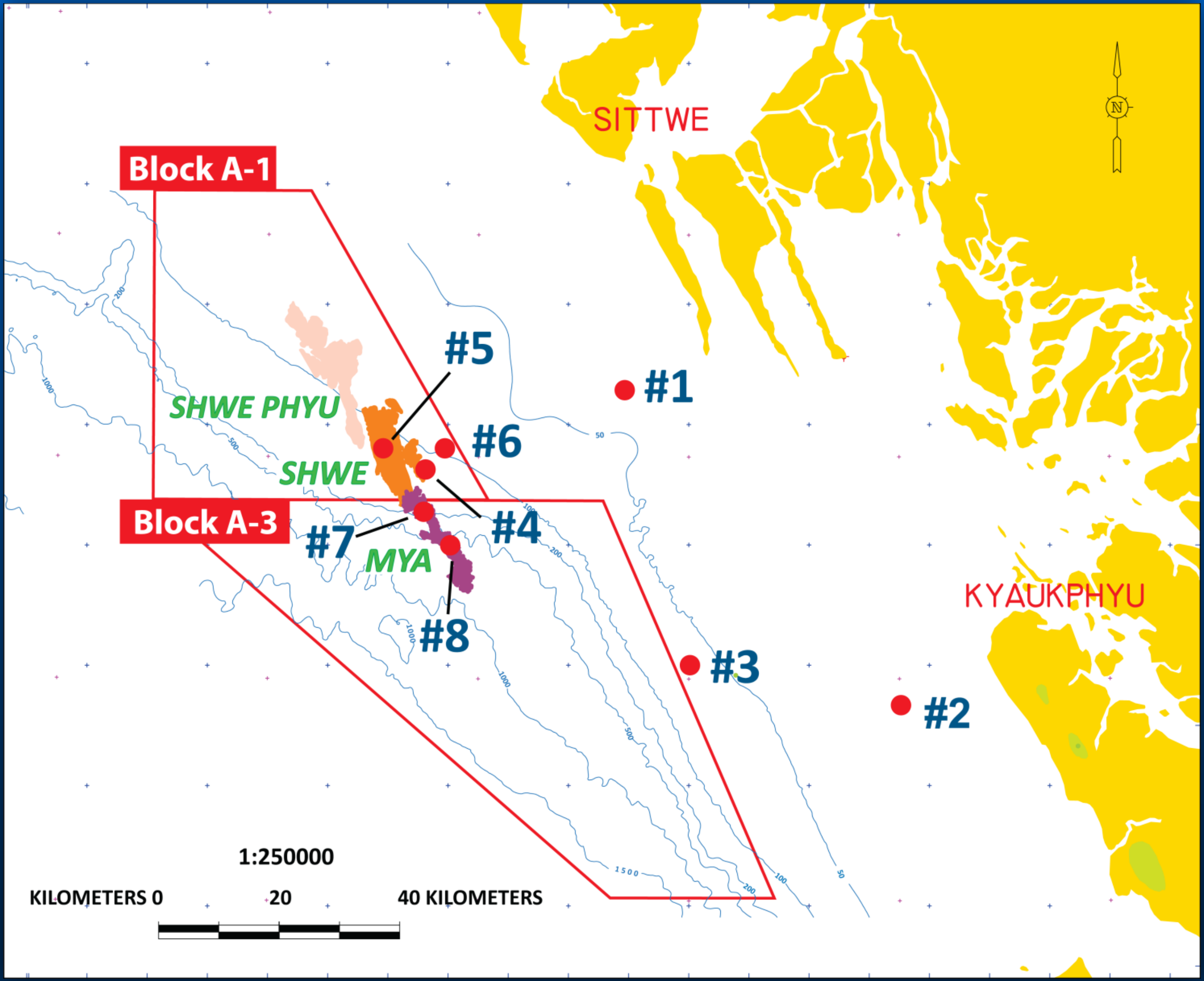
West ←

East →



Seismic Amplitude Map: Major Depositional System

Database



8 wells were selected to construct 2D Model

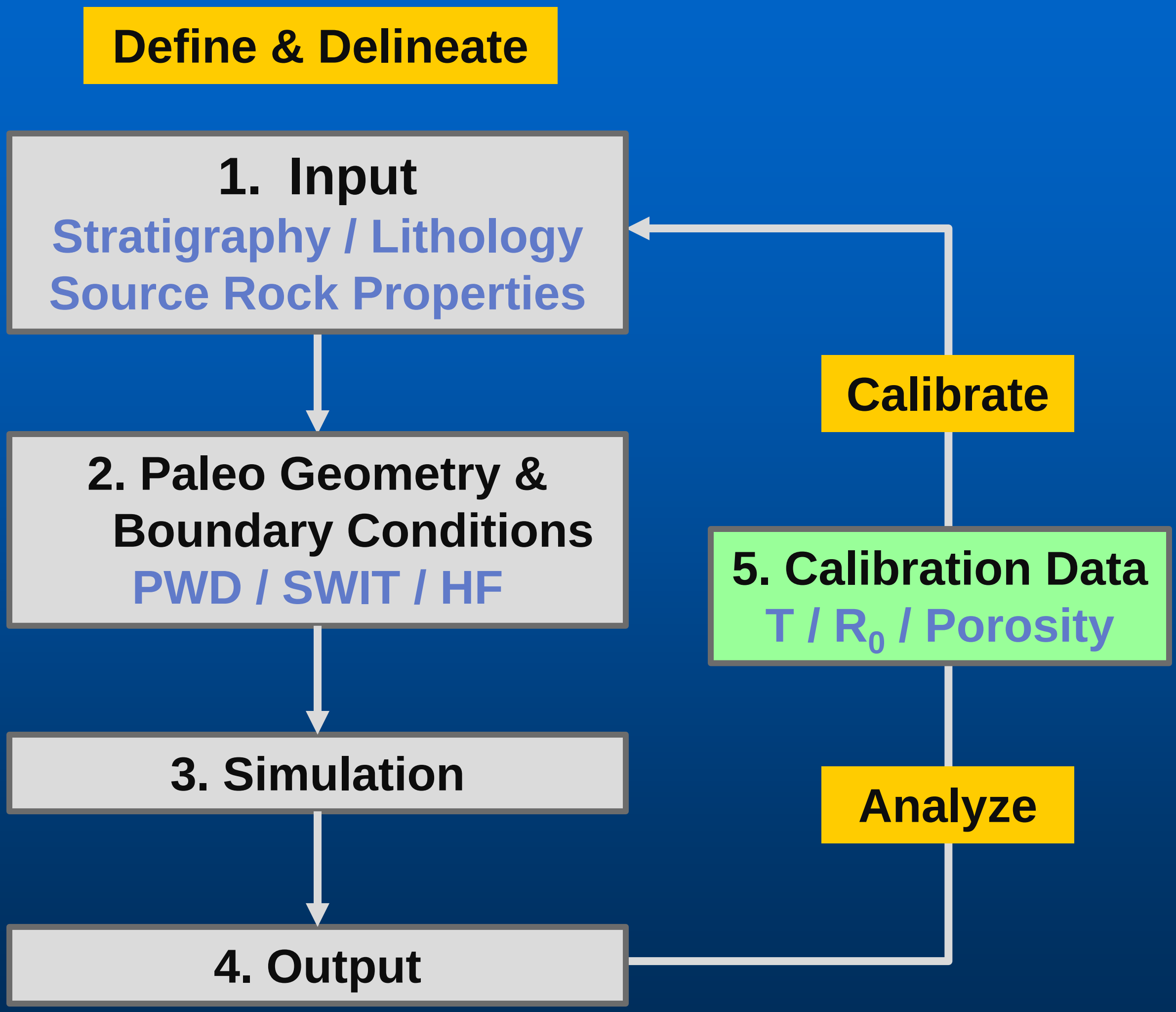
Database

Well	Bio-stratigraphy	Geochemistry of Cutting Samples[1]	Geochemistry of Gas Samples[2]	Core Analysis (RCA)
#1		√		
#2		√		
#3		√		
#4	√	√	√	√
#5	√		√	√
#6	√	√		
#7	√			√
#8	√		√	

1. TOC, Rock-Eval, Kerogen Typing and Vitronite Reflectance, 2. Chemical Composition and Stable Isotope

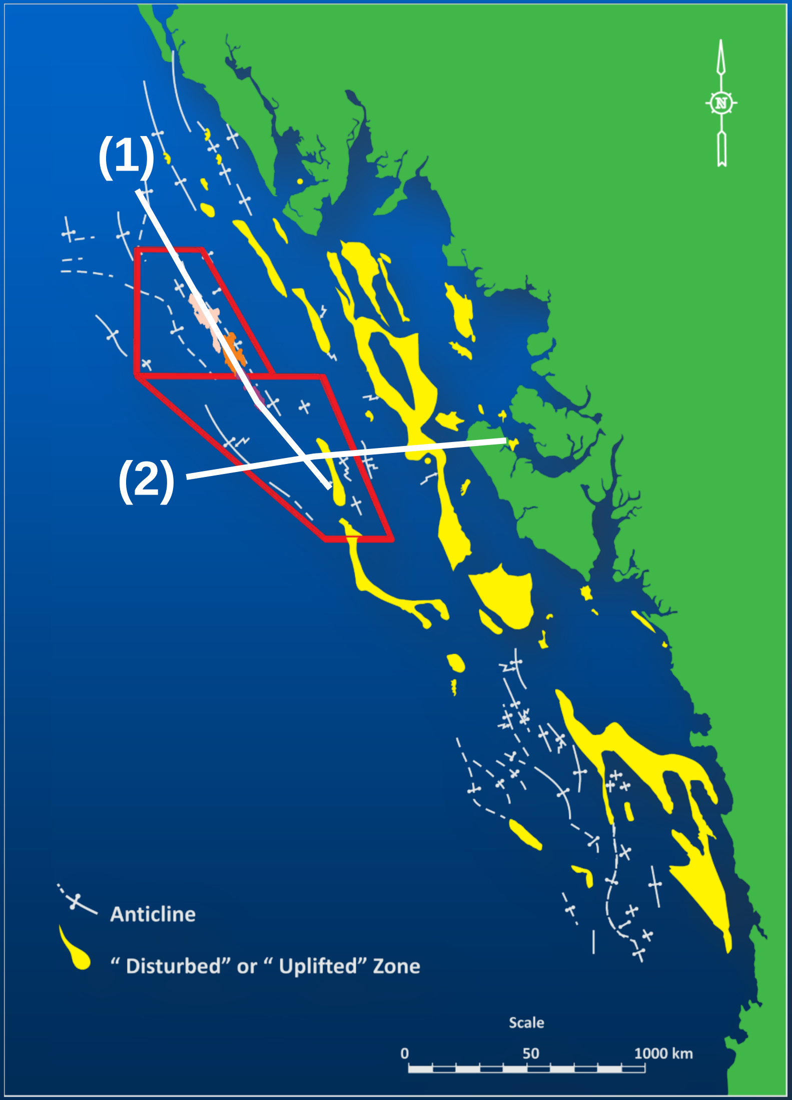
Available Cutting, Gas Samples and Core Data

Model Building



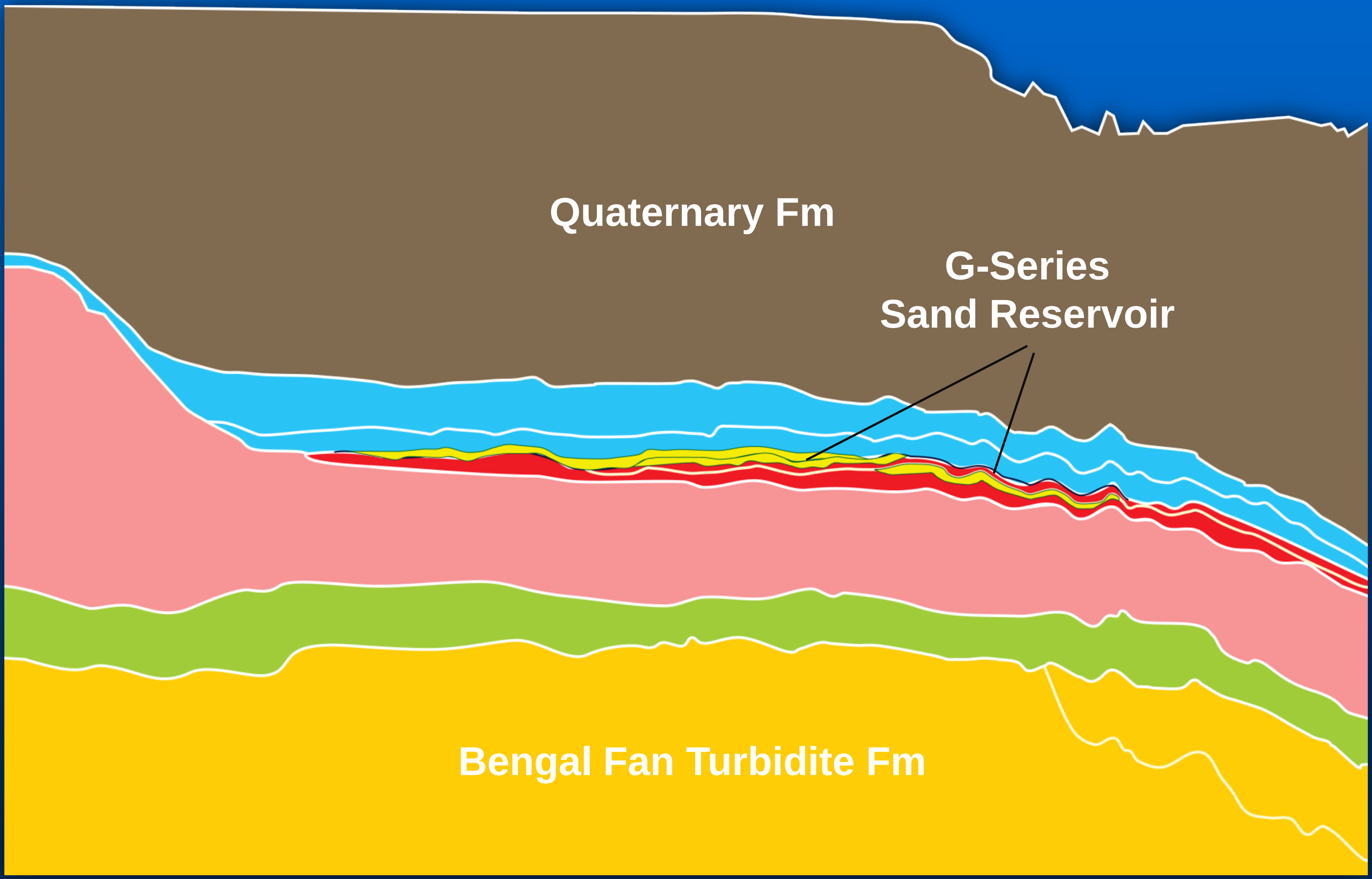
Workflow

Model Building



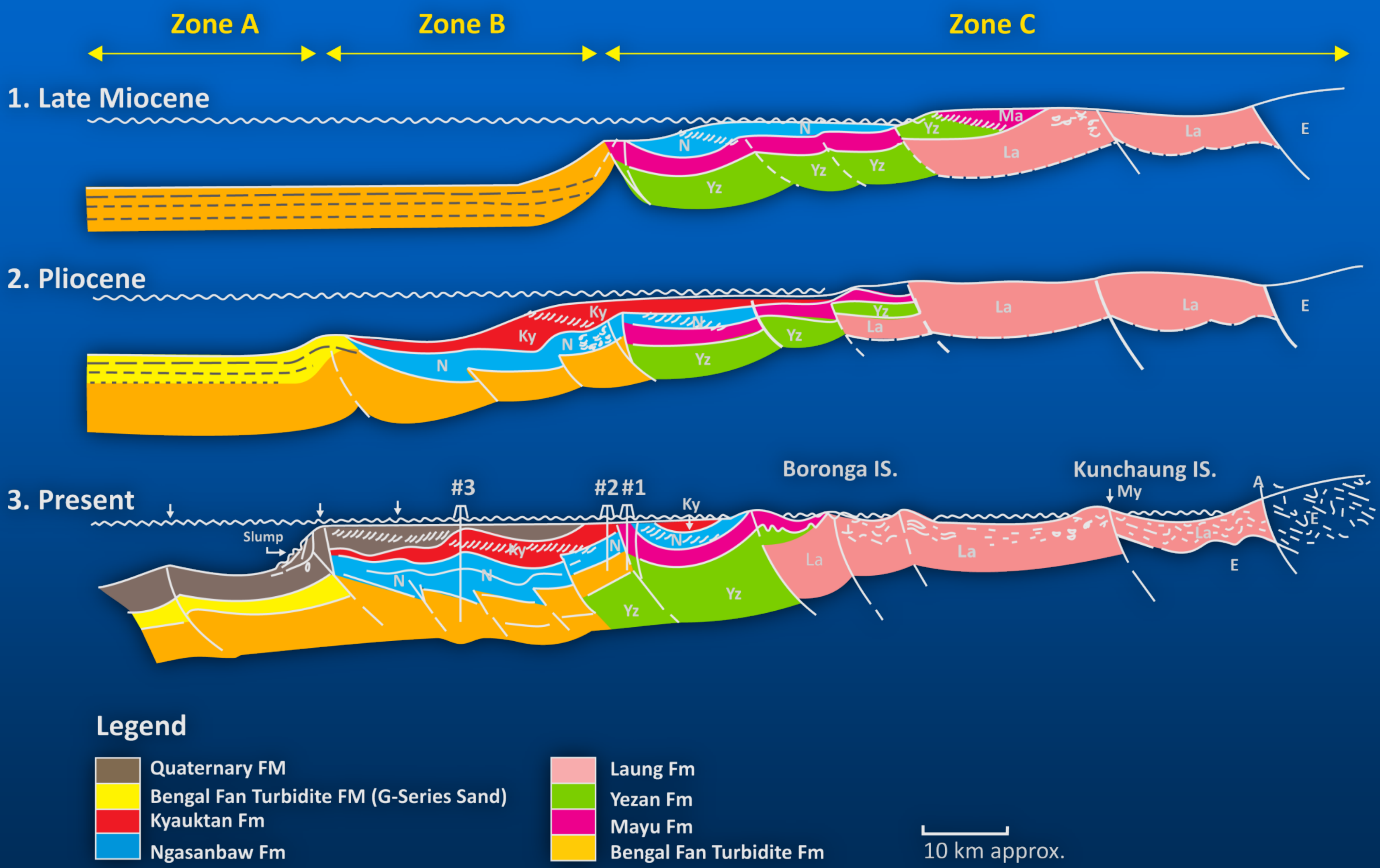
Structural Map

Model Building



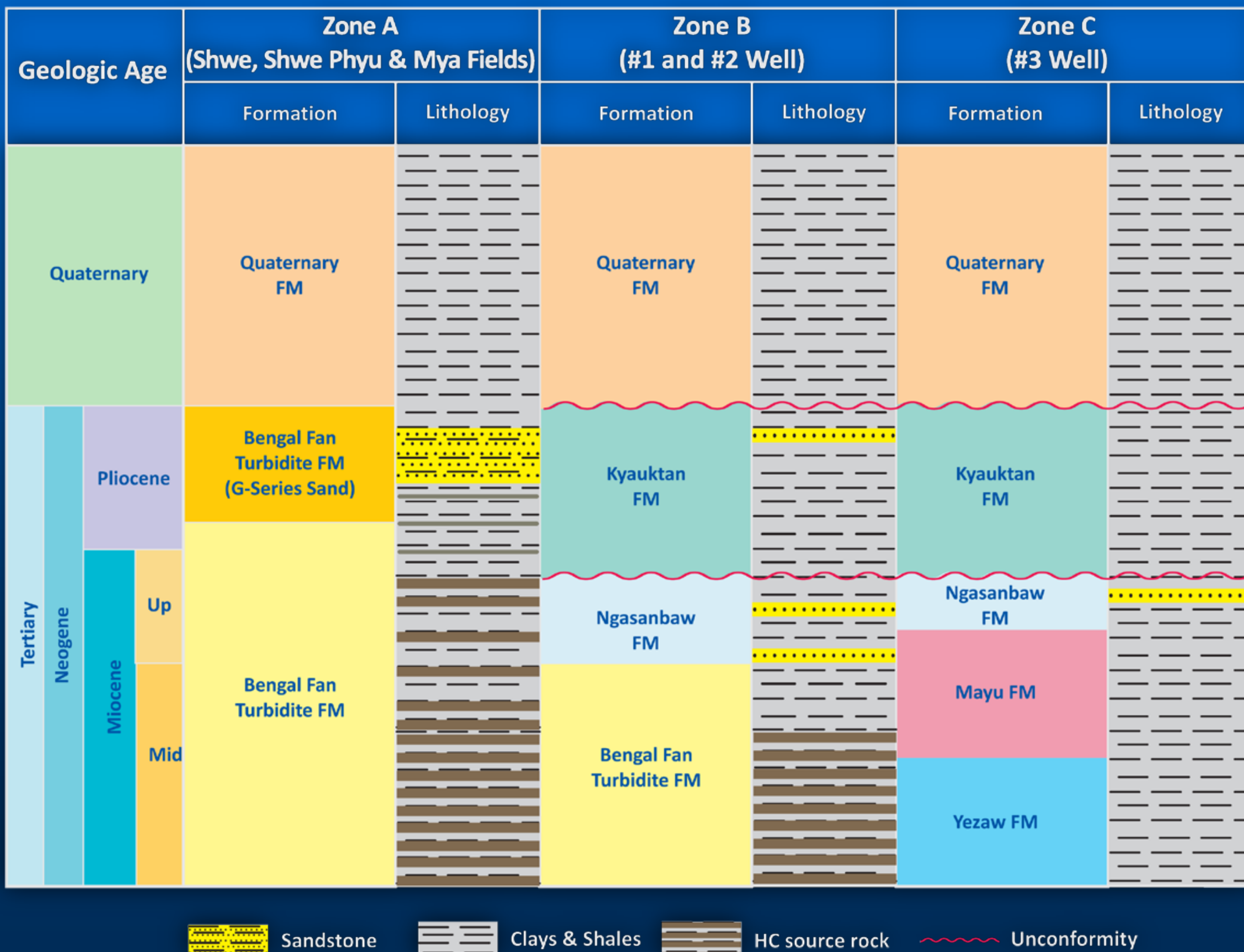
Cross Section (1): Seismic Data with Lithostratigraphy

Model Building



Cross Section (2): Structural Development of the Area

Model Building



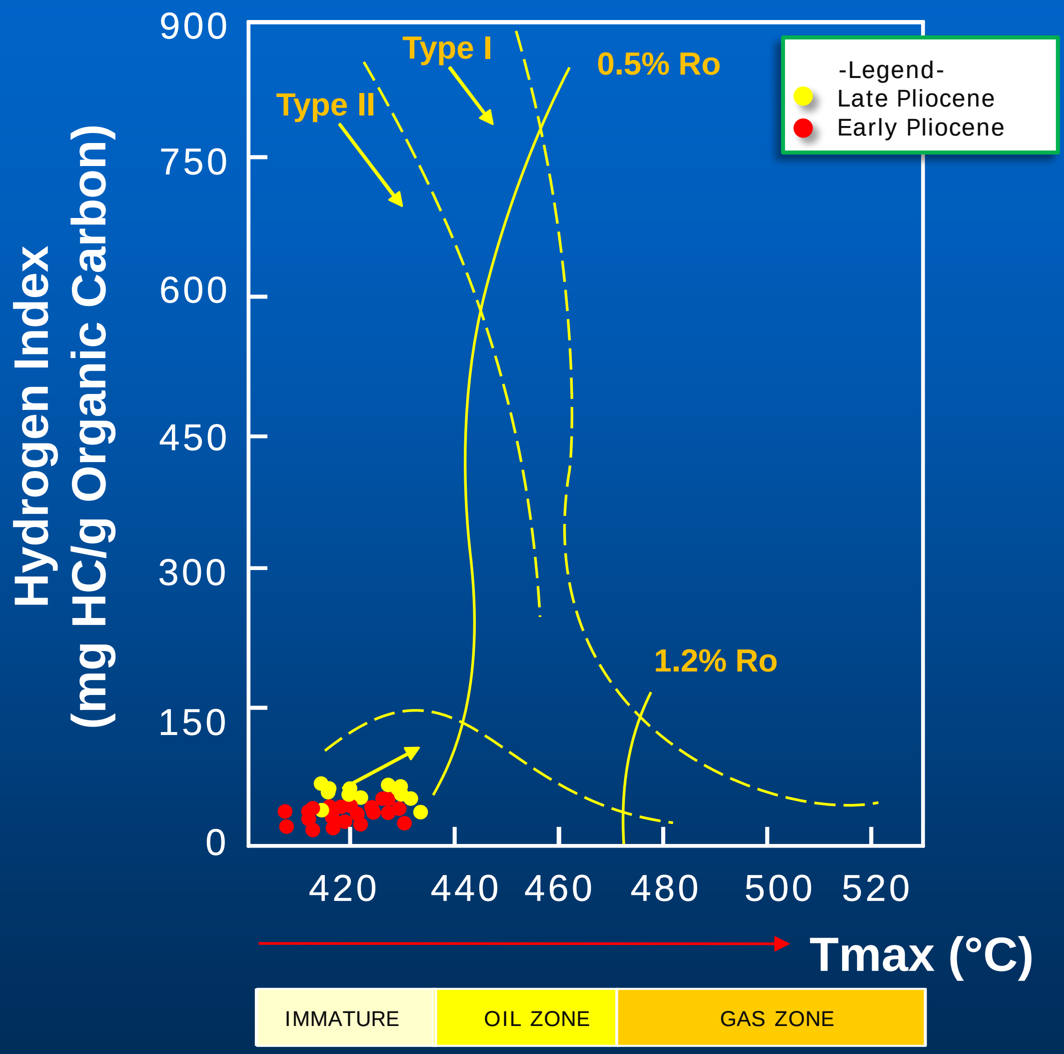
Stratigraphic Column: Formation and Lithology in Three Zones

Model Building

Age	TOC (%)	HI (mg HC / gTOC)	Organic Type
Miocene	0.45-6.7	27-196	Type III
Pliocene	0.33-0.85	126-188	Type III
Pleistocene	0.53-1.7	191-366	Type III

Source Rock Properties in Zone A

Model Building



Source Rock Properties (HI / Tmax Diagram)

Model Building

Pliocene

Miocene

Horizon	Age (Ma)	Lithology	TOC (%)	HI	PSE[1]
Layer 1	0	Shale100	0	0	Overburden
Layer 2	1.81	Shale100	0	0	Seal
Layer 3	2.49	Shale100	0	0	Seal
Layer 4	2.83	Sand80Shale20	0	0	Reservoir
Layer 5	2.92	Sand80Shale20	0	0	Reservoir
Layer 6	3.00	Sand10Shale90	0.75	150	Source
Layer 7	3.09	Sand70Shale30	0	0	Reservoir
Layer 8	3.17	Sand80Shale20	1	150	Source
Layer 9	3.51	Sand10Shale90	1	150	Source
Layer 10	5.33	Shale100	1.5	180	Source
Layer 11	8.20	Sand70Shale30	0	0	Reservoir
Layer 12	8.70	Shale100	1.5	180	Source

1. Petroleum System Element

Input Parameters

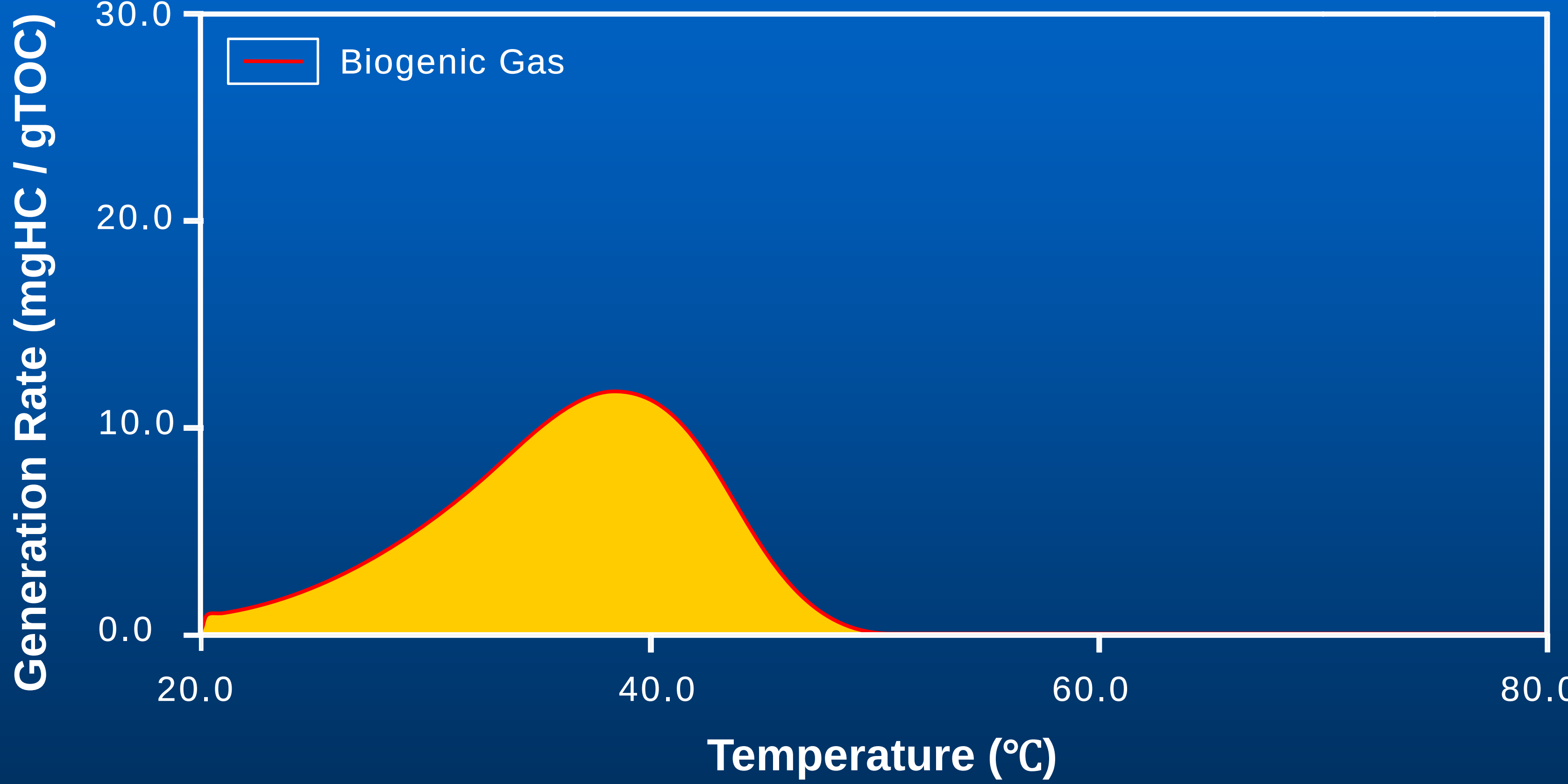
Model Building

Age	Paleo Water Depth (m)	SWIT [1] (℃)	Heat Flow (mWm^{-2})
Miocene	2000-2500	3-7	40-45
Pliocene	1600-2000	7-10	40-45
Pleistocene	100-1600	10-23	40-45

1. SWIT: Sediment Water Interface Temperature

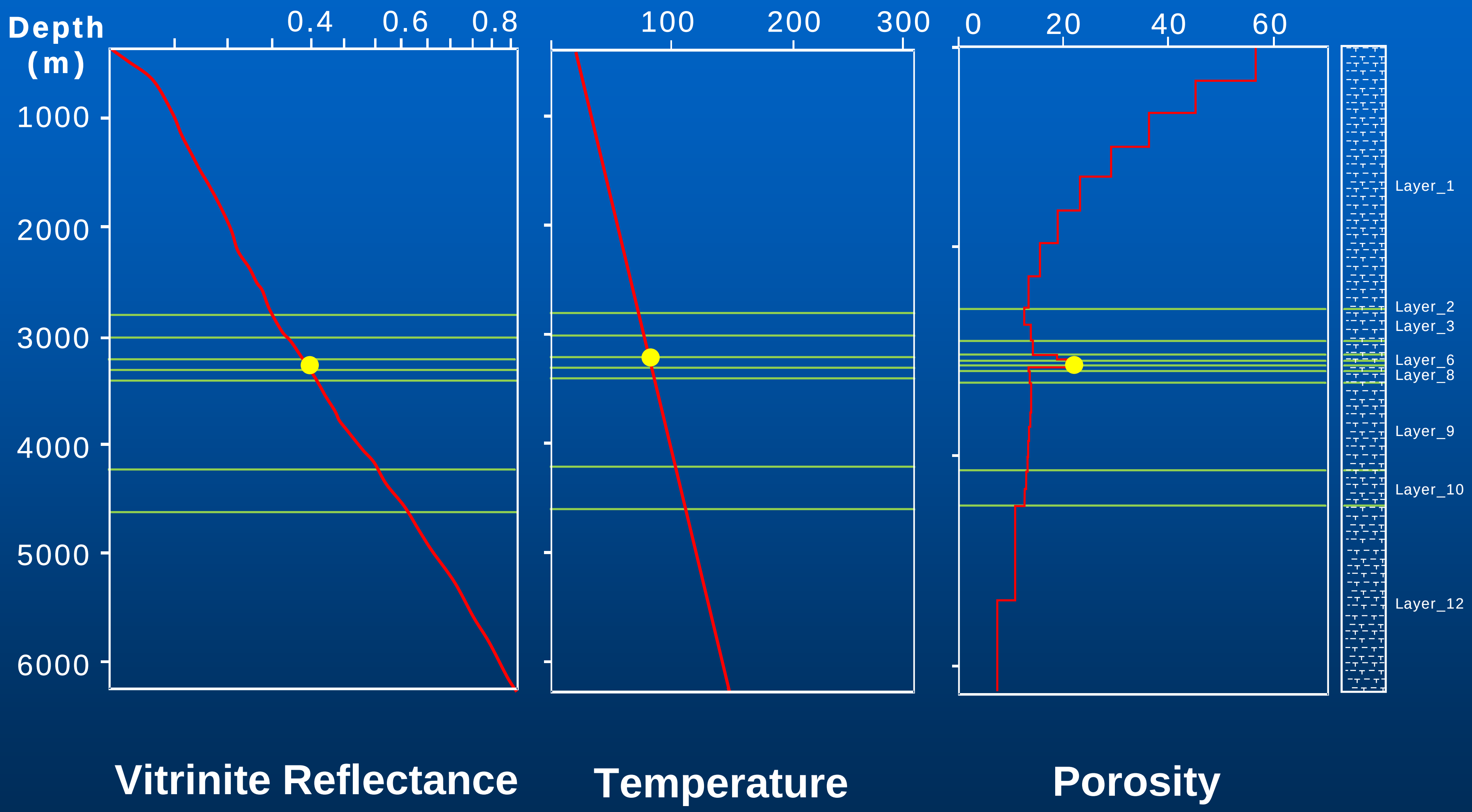
Paleo Geometry and Boundary Conditions

Model Building

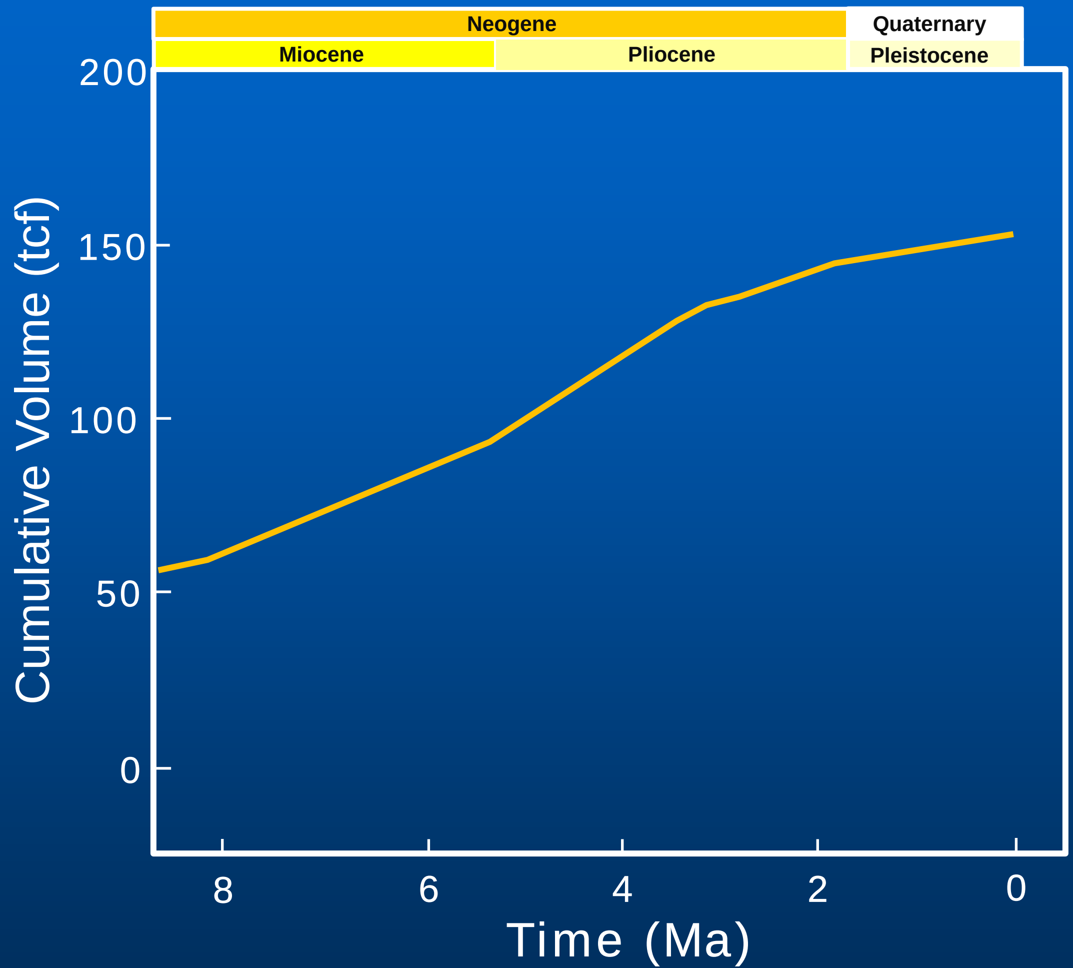


Biogenic Gas Kinetic: Generation Volume is Function of Temperature

Calibration



Results



Timing of Hydrocarbon Generation and Cumulative Volume

Results

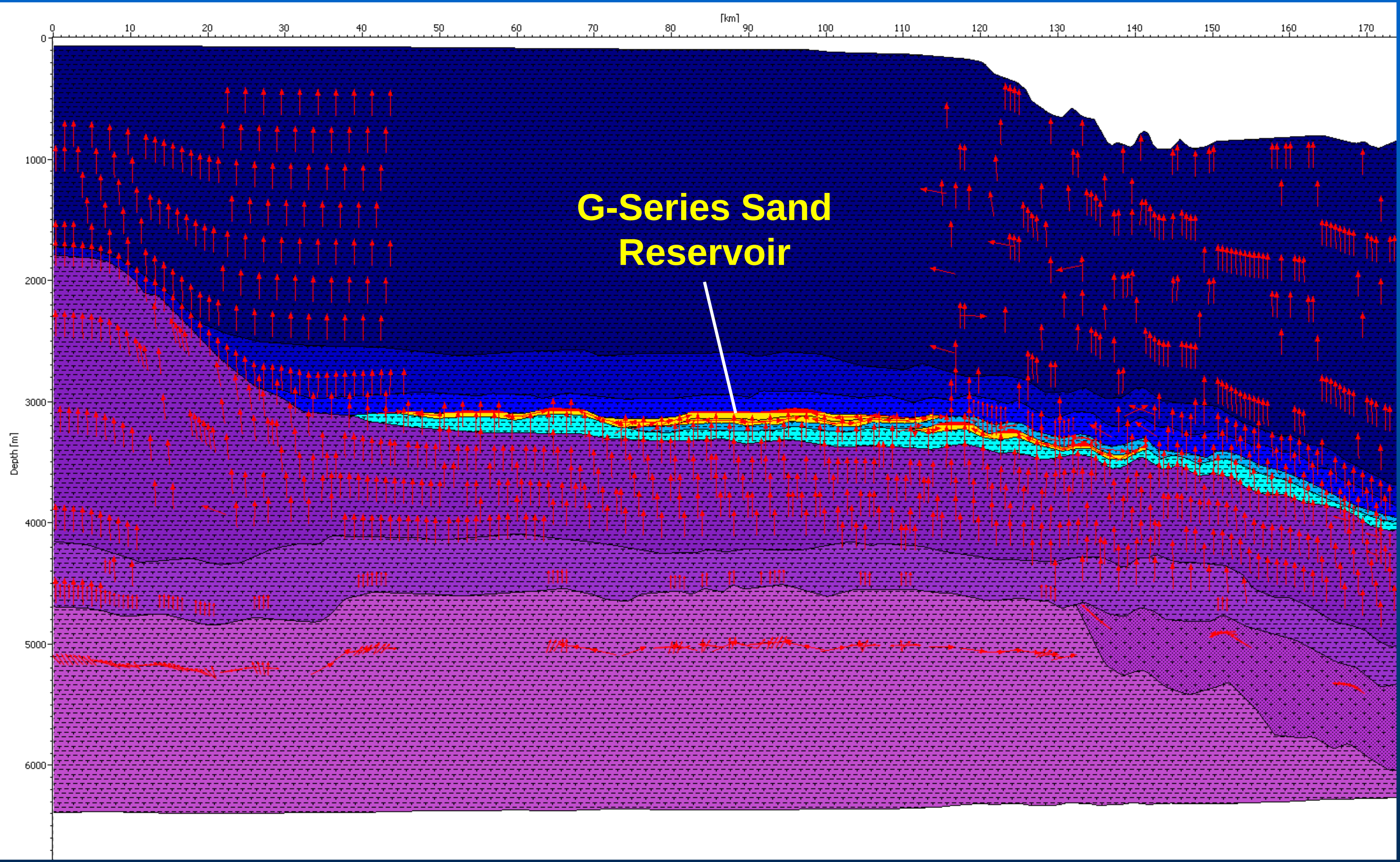
Pliocene

Miocene

Horizon	Generation Balance	Expulsion Balance	Accumulated in Reservoir	HC Losses
Layer 2	0	0	0	7.37
Layer 3	0	0	0	2.37
Layer 4	0	0	2.64	0.30
Layer 5	0	0		0.20
Layer 6	0.74	0.66	0	0.75
Layer 7	0	0	1.07	0.15
Layer 8	2.47	2.40	0	4.65
Layer 9	32.58	31.51	0	32.73
Layer 10	23.56	22.48	0	26.75
Layer 11	0	0	0	0.80
Layer 12	89.82	86.83	0	58.80
Total	149.17	44.44	3.71	140.17

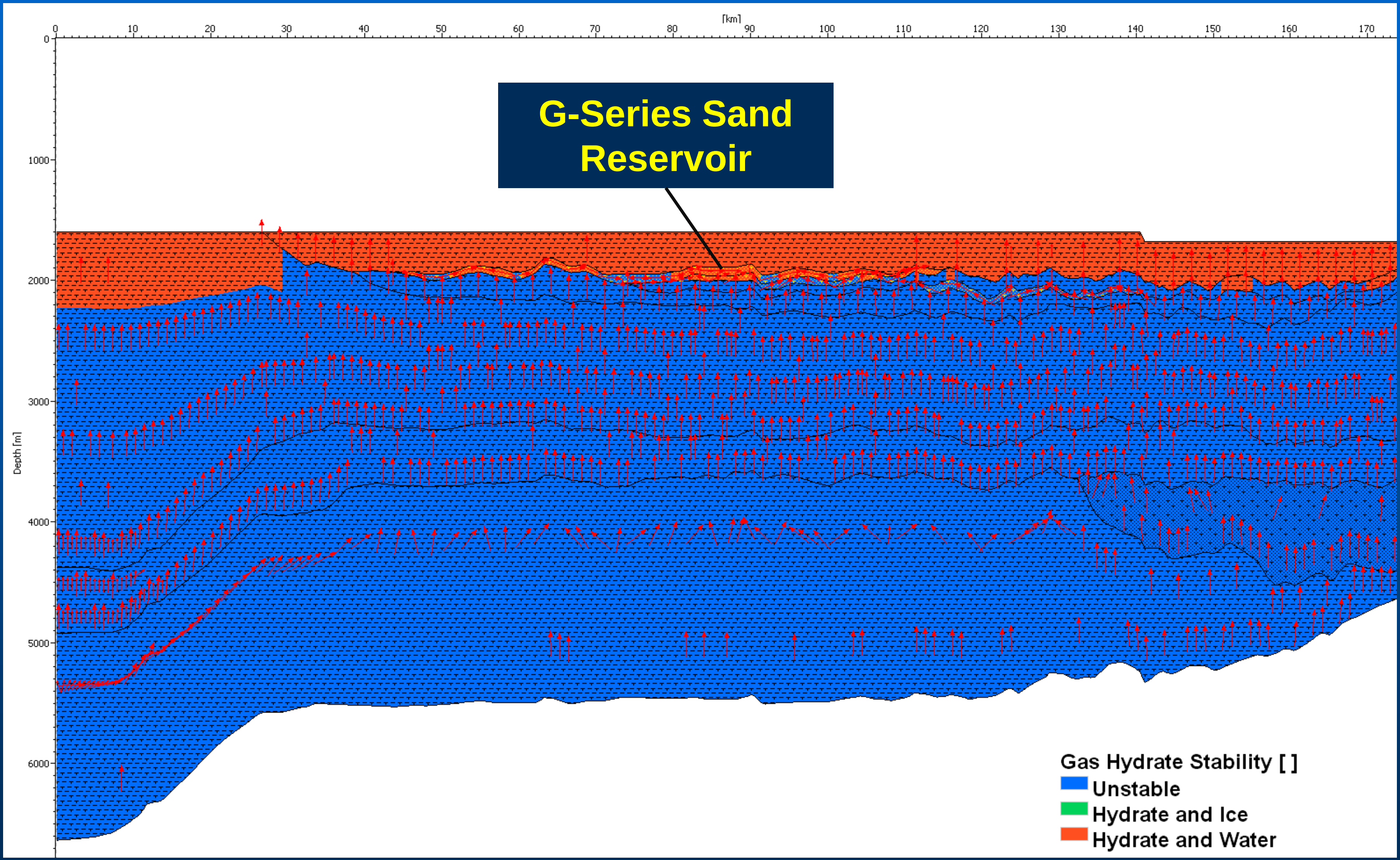
Estimating the Volume of Hydrocarbon Charge (Width = 1km)

Results



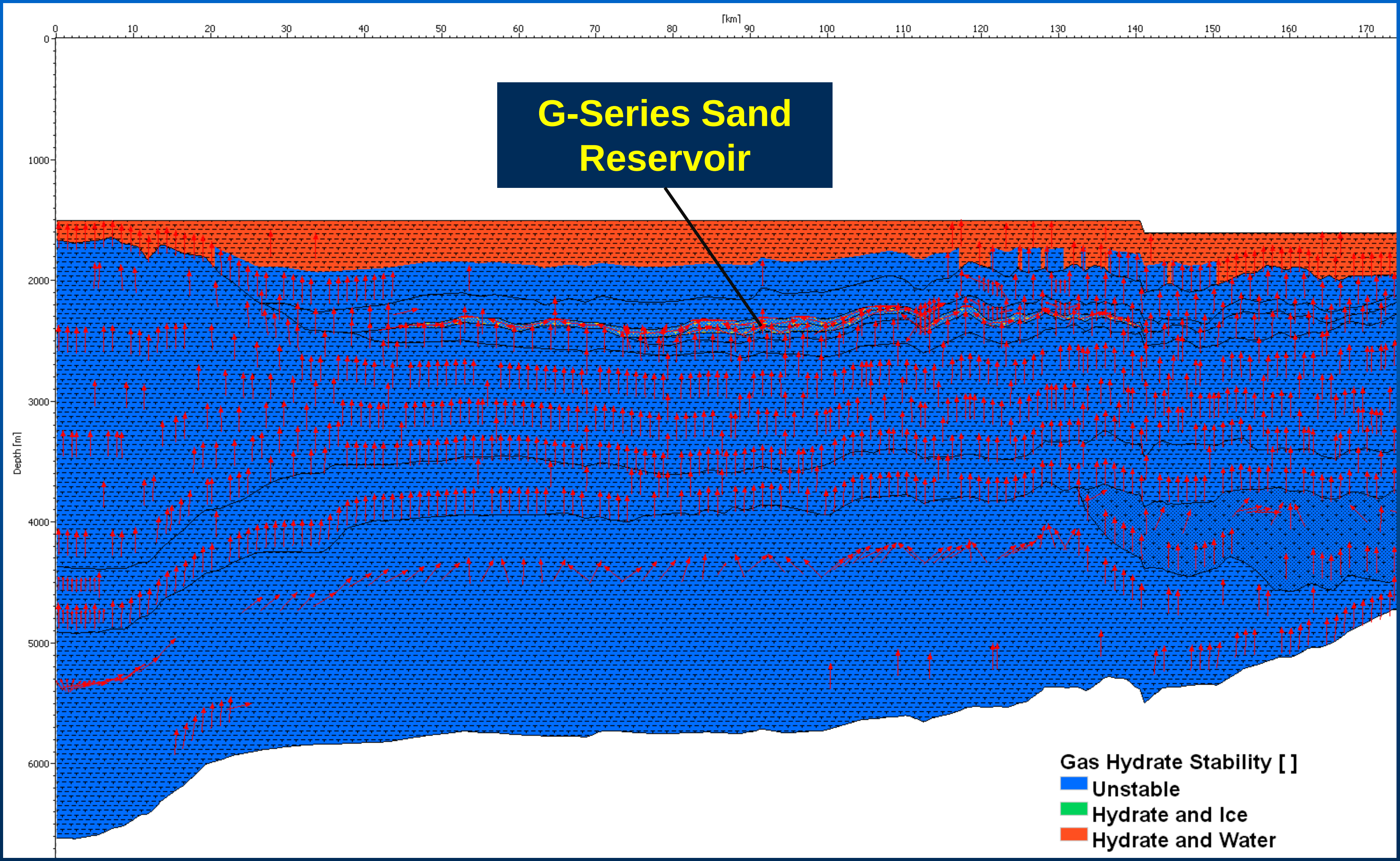
Model of Petroleum Migration in Cross Section at Present

Results



Gas Hydrate Stability Zone w/ Gas Migration at 2.48Ma

Results



Gas Hydrate Stability Zone w/ Gas Migration at 1.81Ma

Trapping of Gas

- **Initial Stage**

1. Gas Hydrate

- **Later Stage**

2. Thin-Bedded Turbidite Sediments

3. Calcite Cement Bed

(2-3 calcite bed are recognized regionally)

Calcite Bed (30cm)

Conclusion

- Main reservoirs are developed perpendicular to the uplifted zone in the area
- Accumulated biogenic gas in reservoir generated during Late Pliocene to Pleistocene from Miocene to Pliocene Source Rock
- Paleo-hydrates played an important role in initial stage gas accumulation and trapping system
- The paleo-hydrate was later released by change in P-T condition due to sediment burial
- Later stage trapping systems are thin-bedded turbidite shale and authigenic calcite cement bed