Application of 2D Basin Modeling for Evaluation of Petroleum Potential of Outer Part of Hazara-Kashmir Syntaxis (HKS), Sub-Himalayas*

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Abstract

One of the most logical ways to understand risk in frontier hydrocarbon exploration is to assess presence of effective source rock and hydrocarbon volume generated and expelled in an area. In addition to understanding these phenomena, basin modeling can address key questions related to maturation timing, transformation, migration and accumulation of hydrocarbons by considering geologically plausible range of thermal and geochemical parameters. Understanding thus gained may help to identify critical risk elements in a petroleum system context, which in turn, can provide proper risk mitigation measures.

Outer part of Hazara-Kashmir-Syntaxis (HKS) has been selected for hydrocarbon prospectivity evaluation, as it is still unexplored and located just to the east of prolific Potwar Basin (Pakistan). Literature review suggests presence of similar structural framework and Paleogene stratigraphy in HKS as that of Potwar Basin where Paleocene-Eocene petroleum system is producing oil and gas from a number of fields e.g., Pindori and Balkassar.

In this study, 2D basin modeling was performed by considering different geochemical and thermal parameters appropriate to the geological setting of HKS area along a structural cross-section prepared by using existing geological maps and relevant subsurface information gained from Potwar Basin well data. The results of the study are intriguing from an exploration standpoint and suggest hydrocarbon generation, expulsion and migration from Paleocene Patala source rock during Neogene time. A Pliocene migration event is recognized as being synchronous with major structuration in the area, which is conducive for hydrocarbon accumulation in Eocene

carbonate reservoirs. Results of the study support presence and validity of working of Paleocene-Eocene petroleum system in outer part of HKS.

Selected Reference

Wells, N.A. and P.D. Gingerich, 1987, Paleoenvironmental interpretation of Paleogene strata near Kotli, Azad Kashmir, Northeastern Pakistan: Kashmir Journal of Geology, v. 5, p. 23-42.

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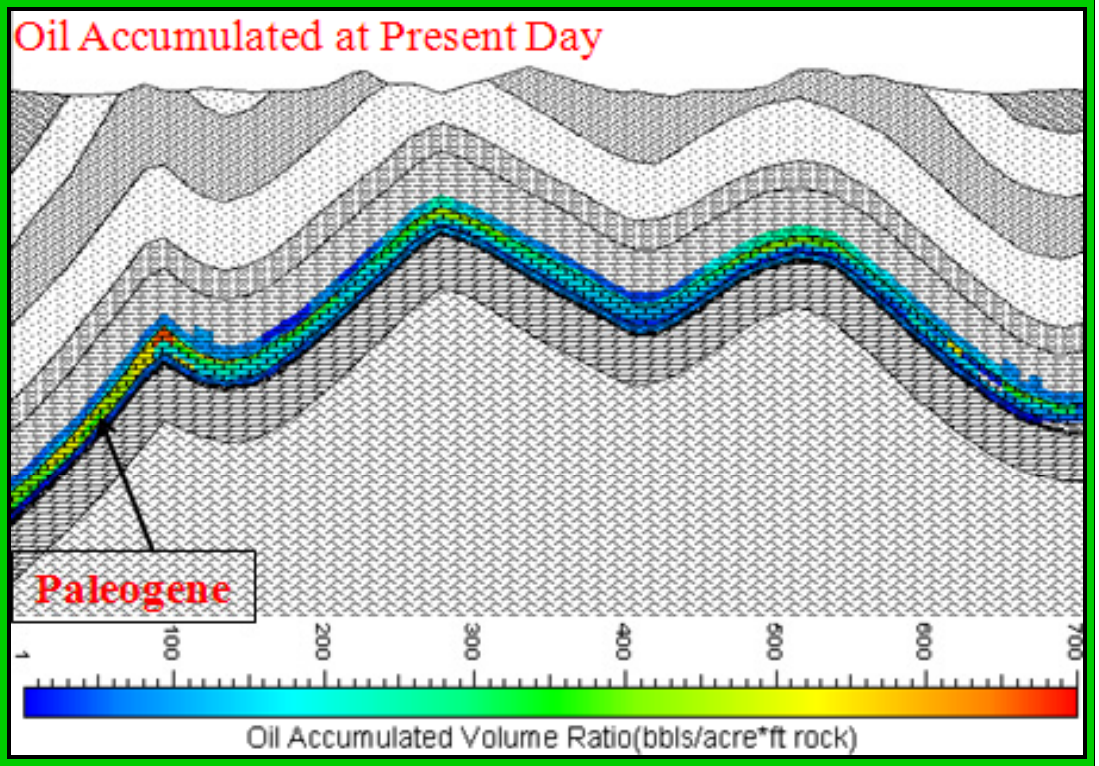


Presentation Outline

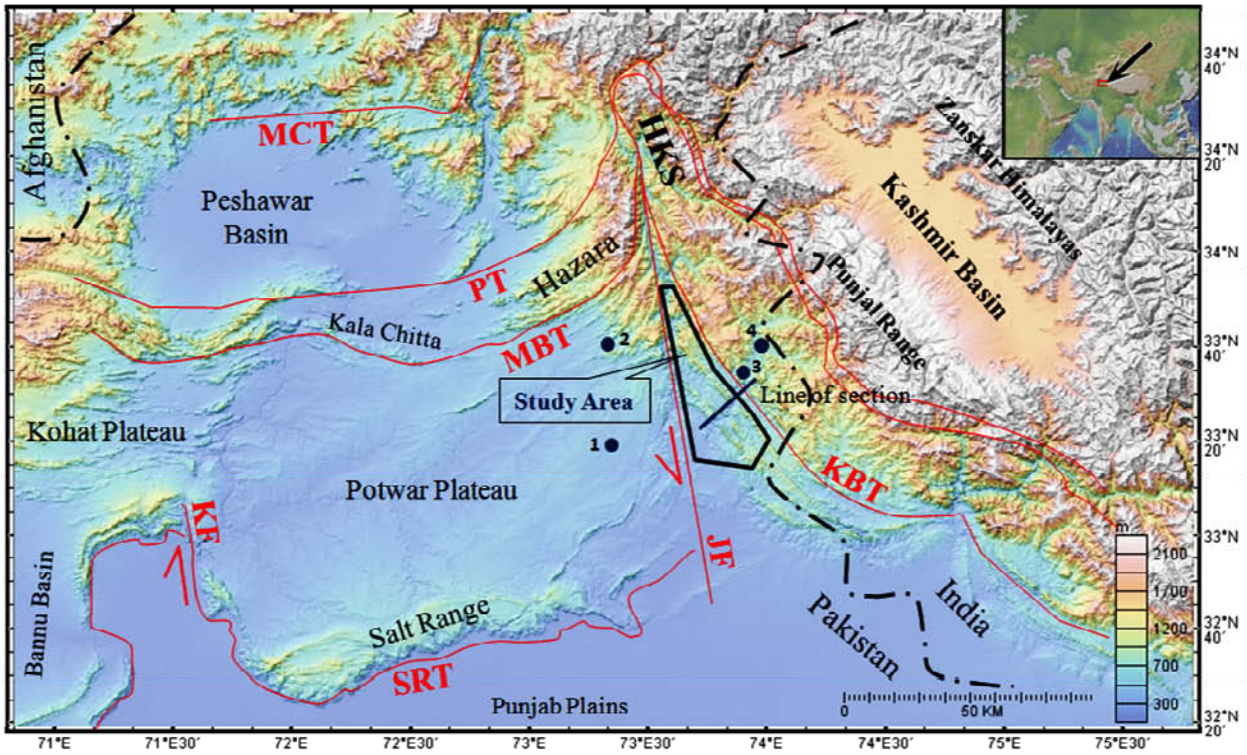
- Introduction
- Literature Review
- Stratigraphy and Play Elements
- Basin Modeling
  - Subsidence and Uplift History
  - Input Parameters
    - *Stratigraphy and Lithology Mixes*
    - *Paleobathymetry*
    - *Source Rock Parameters*
    - *Thermal Options* (*Surface Temperature and Heat Flow)*
  - Calibration
- Modeling Results
- Conclusion
- Acknowledgment

Introduction

- Outer part of Hazara-Kashmir-Syntaxis (HKS) selected for hydrocarbon prospectivity evaluation as it is unexplored and located just to the east of prolific Potwar Basin
- Both areas have similar structural framework and Paleogene stratigraphy
- 2D basin modeling performed along a 30 km long structural cross-section
- Range of Heat Flow considered for modeling
- Results are intriguing from an exploration standpoint and suggest hydrocarbon generation, expulsion and migration from Paleocene Patala source rock during Neogene time
- A Pliocene migration event is synchronous with major structuration in the area, which is conducive for hydrocarbon accumulation in Eocene carbonate reservoirs

Location Map

- Study area located in Kashmir region of Outer Himalayan Fold Belt (Kashmir Foothills)
- Extends from Kotli in southeast to Muzaffarabad in northwest
- Kashmir Boundary Thrust (KBT) to the East and Jhelum Fault to the West
- Outcrops of molasses (Siwaliks) of Himalayan provenance present
- Deformation involving recent sediments indicates active collision and juvenile structuration



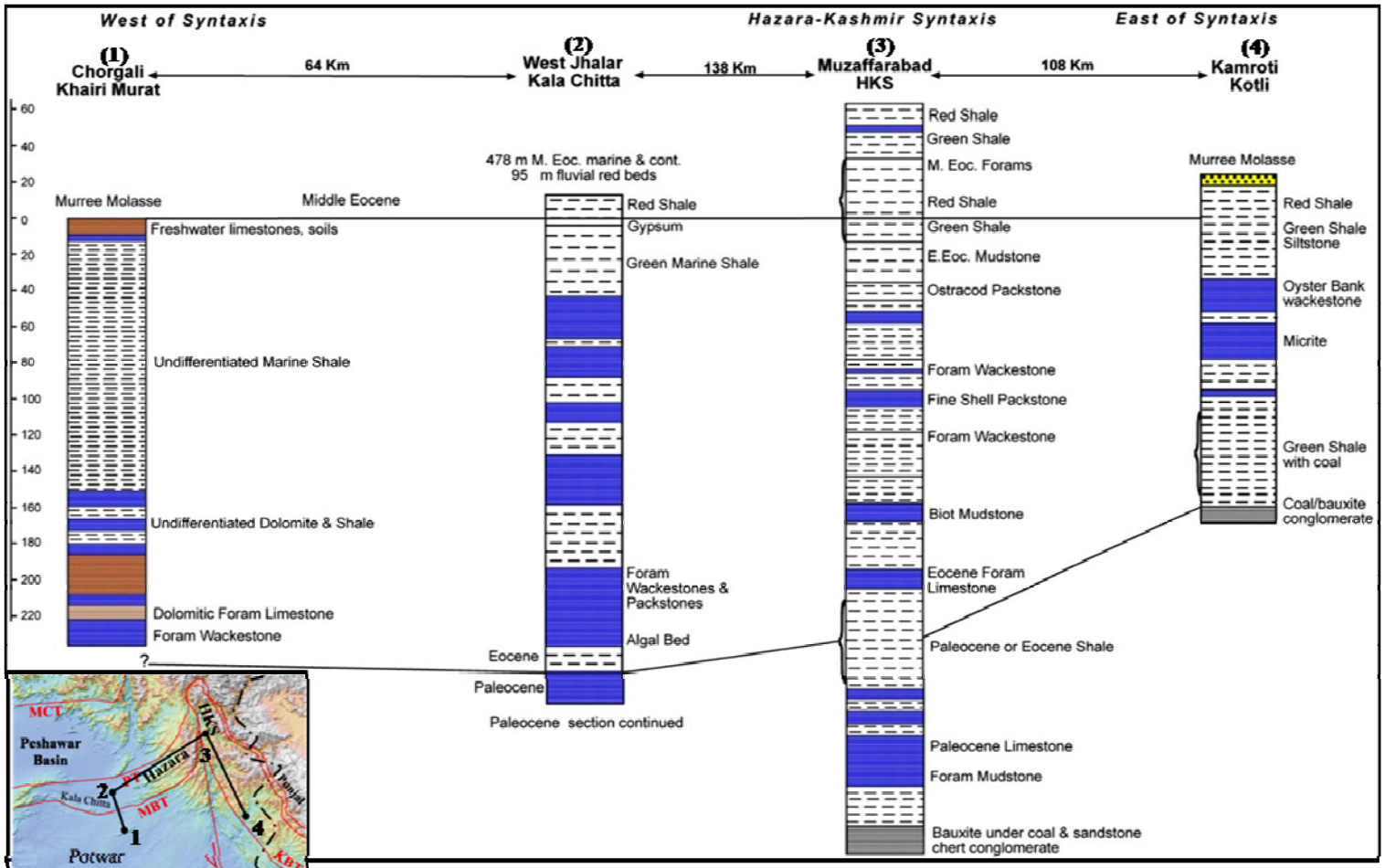
HKS= Hazara Kashmir Syntaxis; **MCT**= Main Central Thrust; **PT**= Punjal Thrust; **MBT**= Main Boundary Thrust; **KBT**= Kashmir Boundary Thrust; **SRT**= Salt Range Thrust; **JF**= Jhelum Fault; **KF**= Kalabagh Fault; **1**= Adhi; **2**= Jigyot Oil Seep; **3**= Kotli; **4**= Tatta Pani

Literature Review

- Previous work mostly in isolation; aimed at understanding different geological aspects
- Little work done to understand petroleum prospectivity
- Previous geological work of regional nature, along somewhat detailed stratigraphic, paleontological and structural studies
- Baig (1984) and Wells (1987) work discusses important structural aspects and stratigraphic framework which constitute important elements of petroleum system
- Study benefited from the work of these authors

Correlation of Early Eocene Rocks

Cross-section hung at top Middle Eocene (after Wells et al., 1987)

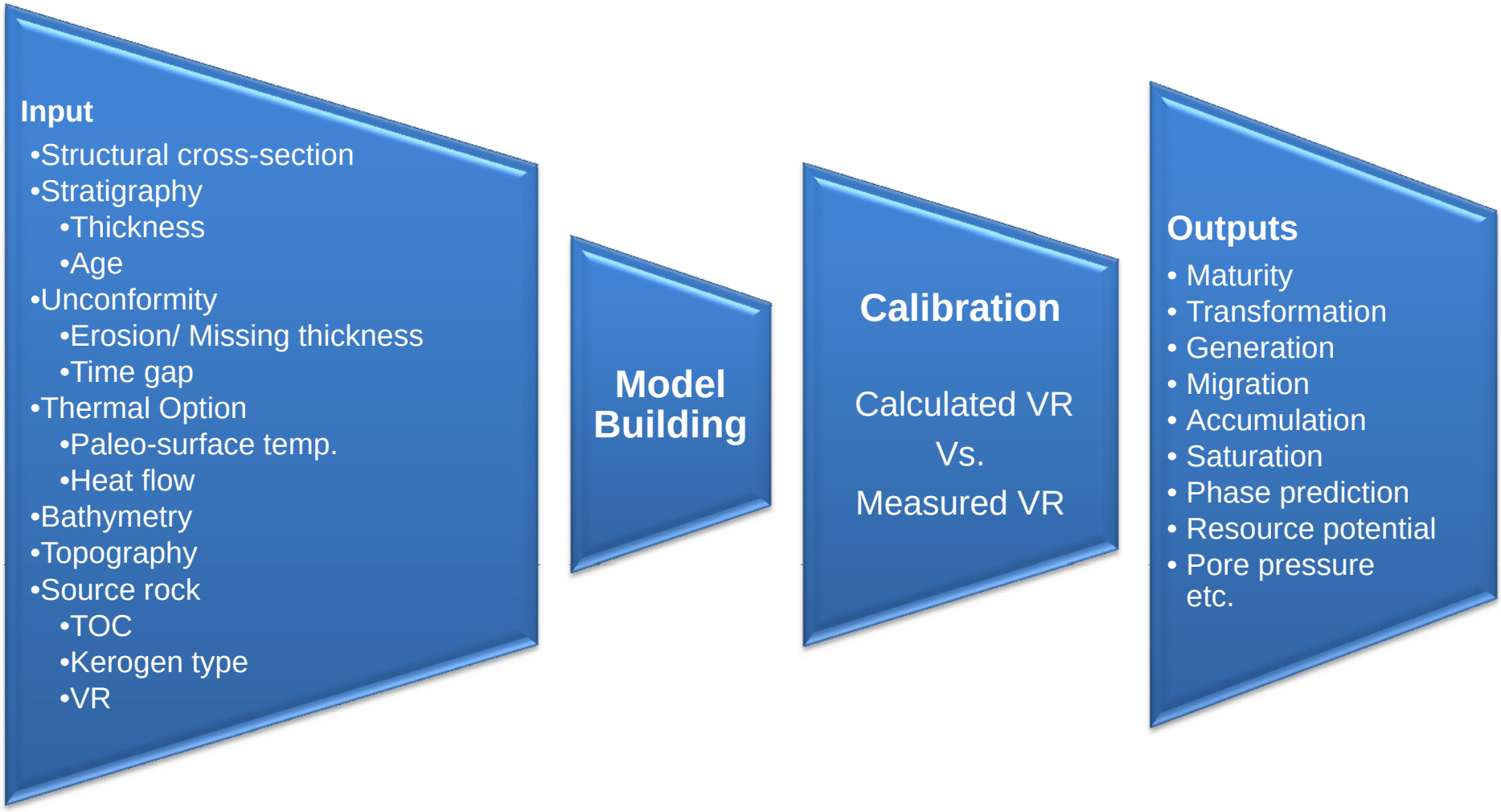


Correlation suggests the study area has similar Paleogene stratigraphy as that of adjacent areas.

Basin Modeling

- Basin modeling simulations performed using the forward modeling approach
- Input data from outcrops of study area and analogous wells in Potwar
- Heat flow calibrated with range of VR values from Potwar Basin
- BasinMod 2D® (Platte River Associates, Inc.) used for the study
- Reverse faults and overturned folds, known to be present in the study area, cannot be modeled by current software version. Hence, a buckle fold cross-section considered for basin modeling
- However, hydrocarbon generation occurred prior to faulting and does not have bearing on Paleogene source rock maturation.

Modeling Flow Chart



Input Parameters

- No wells have been drilled or seismic acquired in the study area to date
- Control subsurface data would be required to produce a detailed model in future
- This study utilizes:
  - All available surface data of the area
  - Some subsurface data of Potwar, as the western part of the study area is considered analogous to eastern Potwar Basin

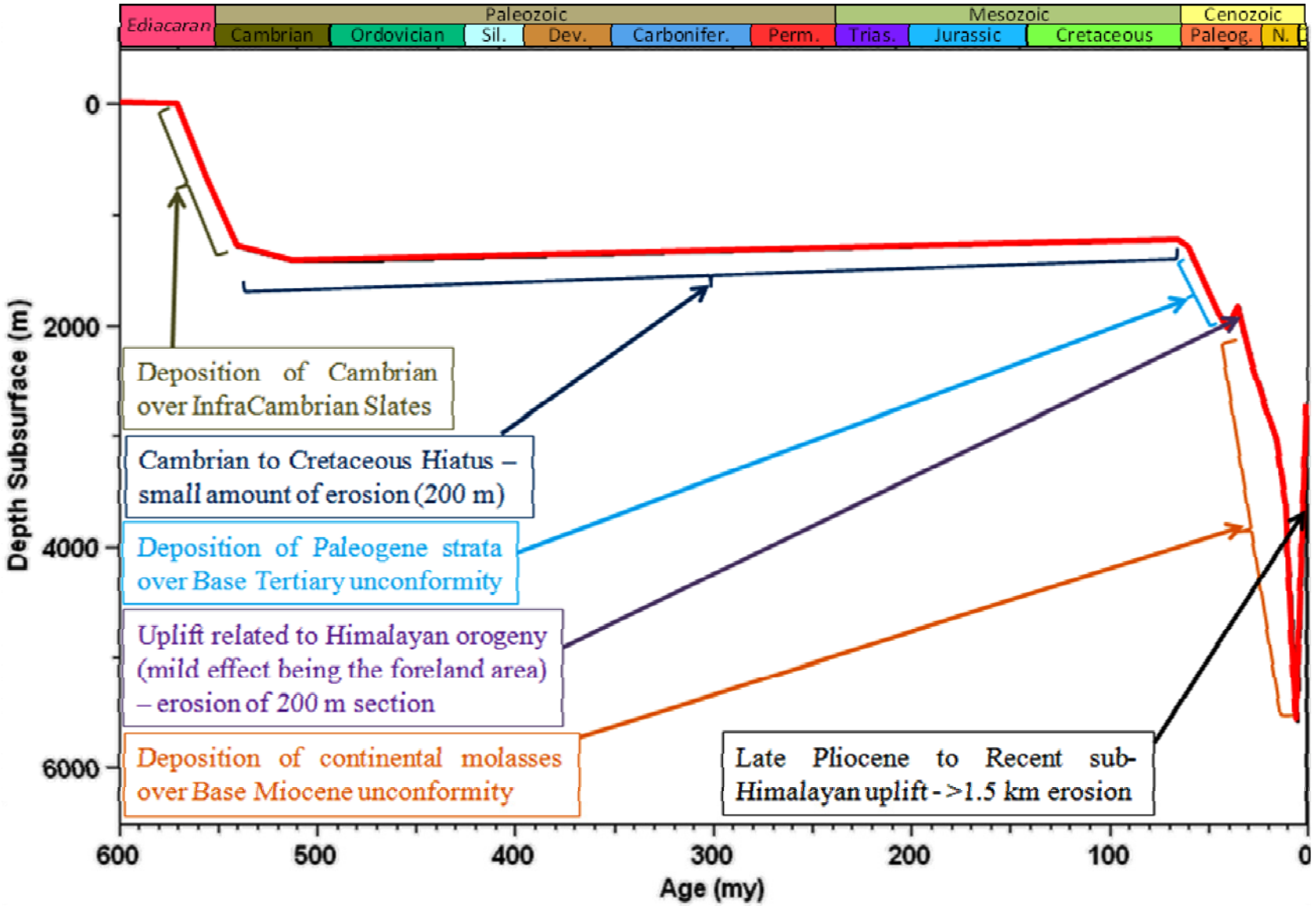
Stratigraphy and Play Elements

Stratigraphy, input parameters for basin modeling and petroleum play elements

Age			Formation	Lithology	Lithology Mixes (%)	Present Thickness (m)	Eroded Thickness (m)	Kerogen Type	TOC %	Petroleum System		
										Source	Reser.	Seal
Quat.	Recent	1.5-0	Mirpur Conglomerates		Cong70;Sandstone30	500+						
	Pleistocene	5-1.5	Soan Formation		Cong70;Sandstone30	700						
Tertiary	Pliocene	9-5	Dhok Pathan Formation		Sandstone50;Shale50	900						
		12-9	Nagri Formation		Sandstone60;Shale40	1000						
		15-12	Chinji Formation		Shale70;Sandstone30	800						
	Miocene	18-15	Kamlial Formation		Sandstone80;Shale20	300						
		23-18	Murree Formation		Sandstone60;Shale40	650						
	Oligocene	35-23	Unconformity		Shale100		200					
	Eocene	42-35										
		47-42	Kuldana Formation		Shale75;Limestone25	200						
		50-47	Chorgali Formation		Limestone80;Shale20	35						
		56-50	Margala Hill Limestone		Limestone85;Shale15	60		Type II	1			
	Paleocene	60-56	Patala Formation		Shale95;Limestone5	30		Type II	1.4			
		62-60	Lockhart Limestone		Limestone95;Shale5	0-70*						
		65-62	Hangu Formation		Sh50;Coal30;Laterite20	20						
Mesozoic	Cretaceous	145-65	Unconformity		Shale50; Limestone50		200					
	Jurassic	210-145										
	Triassic	245-210										
Paleozoic	Permian	290-245										
	Carboniferous	360-290										
	Devonian	410-360										
	Silurian	440-410										
	Ordovician	510-440										
	Cambrian	570-510	Muzaffarabad Formation		Dolomite80;Sand10;Sh1	300						
Ediacaran		650-570	Hazara / Dogra Slates		Slate70;Evap20;Shale10	500+						

*Lockhart Limestone is only present in north of section line; not included in the cross-section/modeling. Geological Time Scale by Herald, 1989.

Subsidence and Uplift History – Geohistory Curve

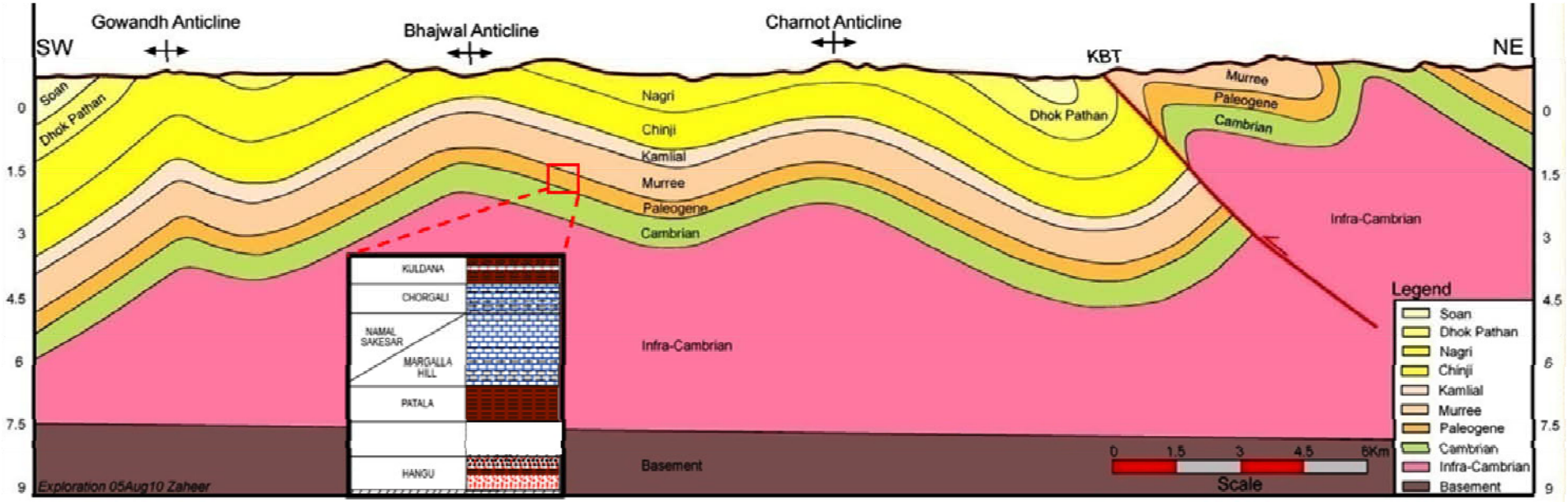


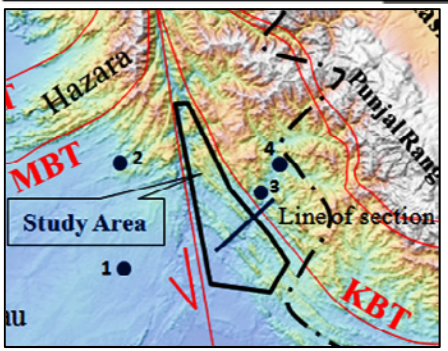
2D Basin Modeling of Hazara-Kashmir Syntaxis

Ahsan, et al., 2010

Cross-section used for Basin Modeling

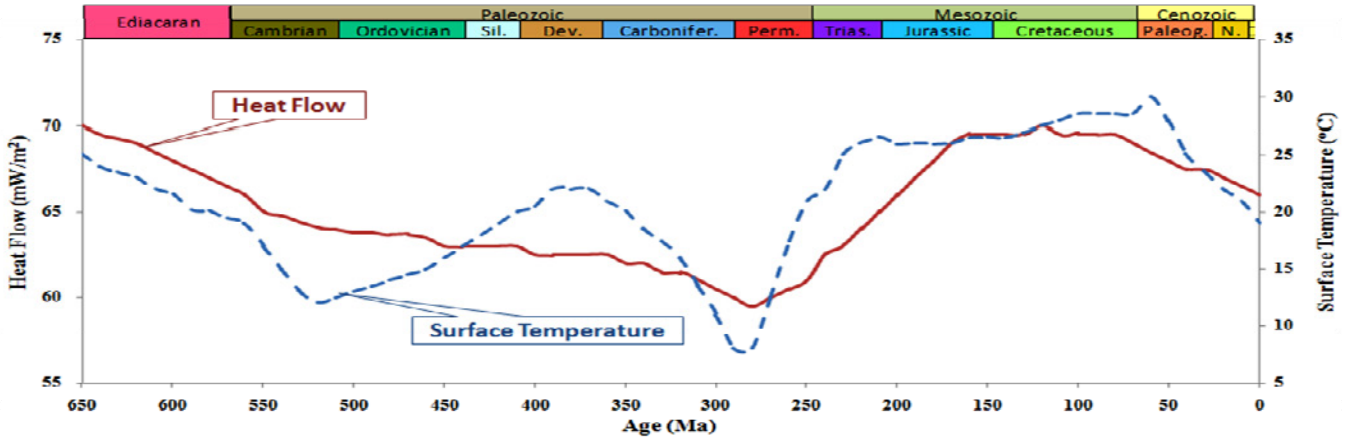
Possibility of blind thrusts presence; not considered due to software constraints



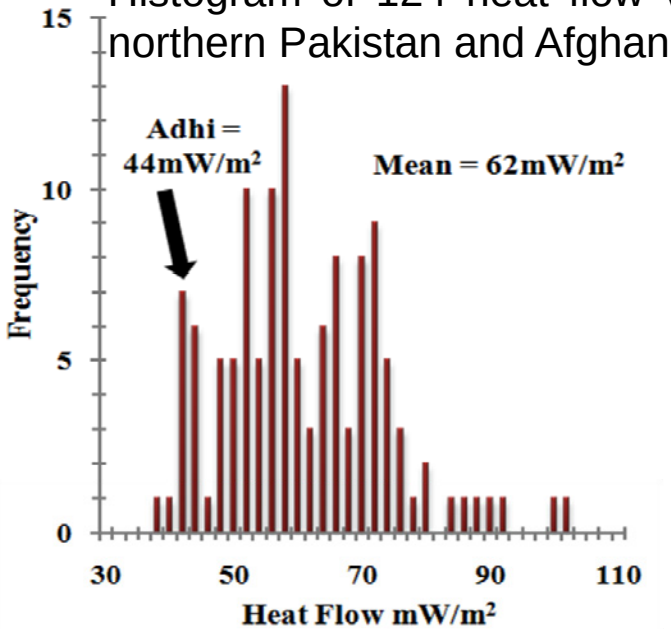


Thermal Options

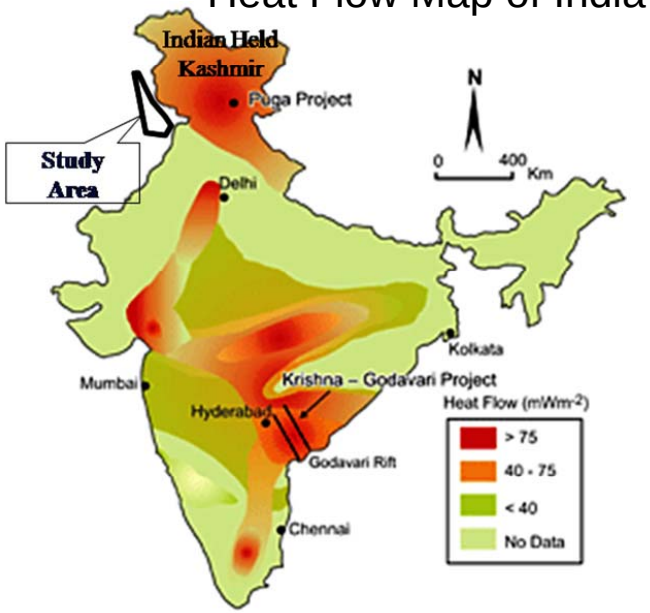
Estimated heat flow and mean surface temperature through geological time



Histogram of 124 heat flow values from northern Pakistan and Afghanistan



Heat Flow Map of India



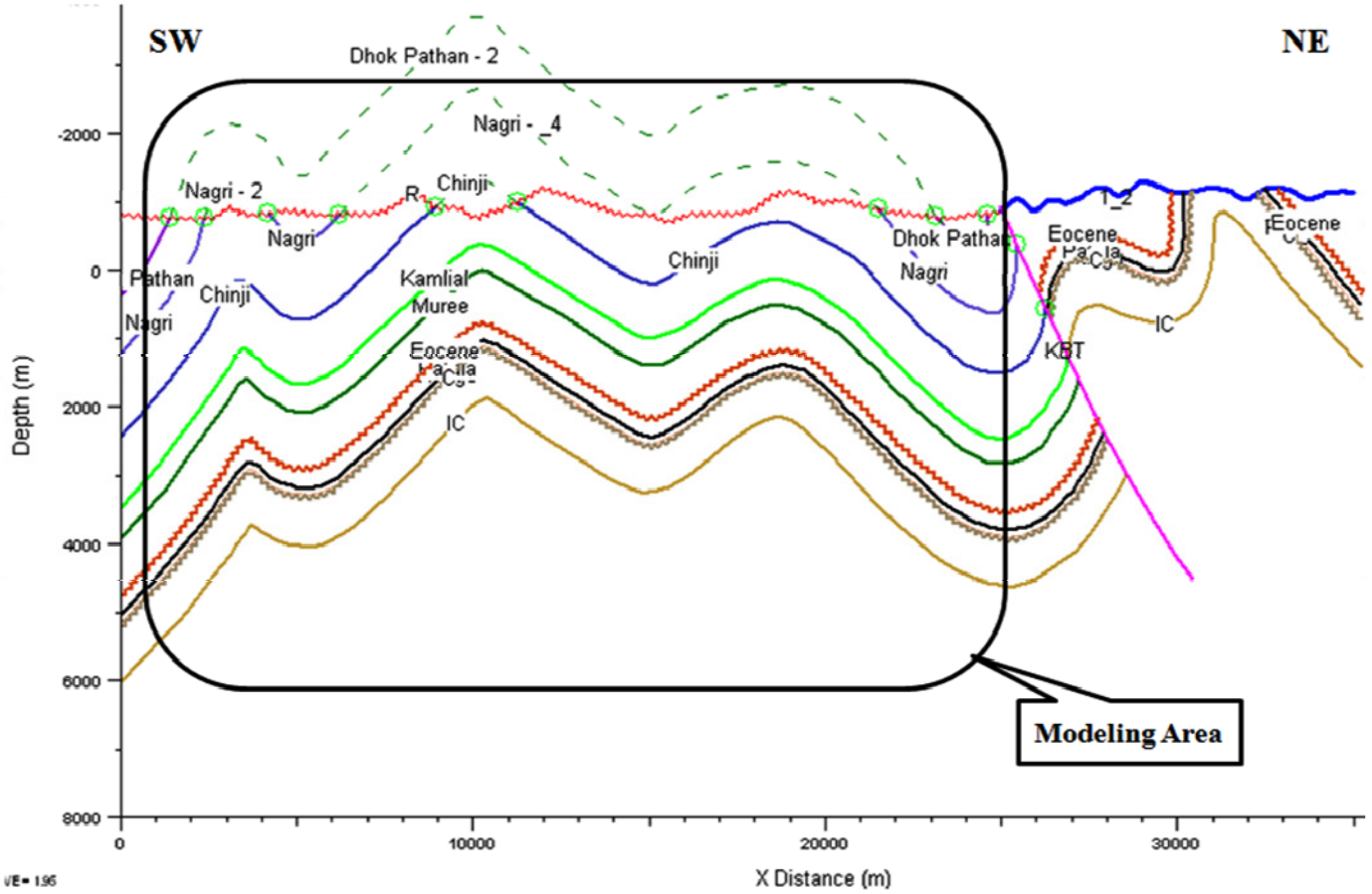
Heat Flow Scenarios

Five geologically plausible heat flow scenarios for basin modeling were used.

Scenario	Heat Flow	Spatial Variation
1	Variable paleo-heat flow based on tectonic history	Constant
2	Constant paleo-heat flow (62 mW/m^2= av. of north Pakistan)	Constant
3	Constant paleo-heat flow (44 mW/m^2= calibrated with Adhi maturity profile)	Constant
4	Constant paleo-heat flow (53 mW/m^2= Mean of Scenario-2 & -3)	Constant
5	Present day heat flow	Laterally variable (increasing from SW to NE)

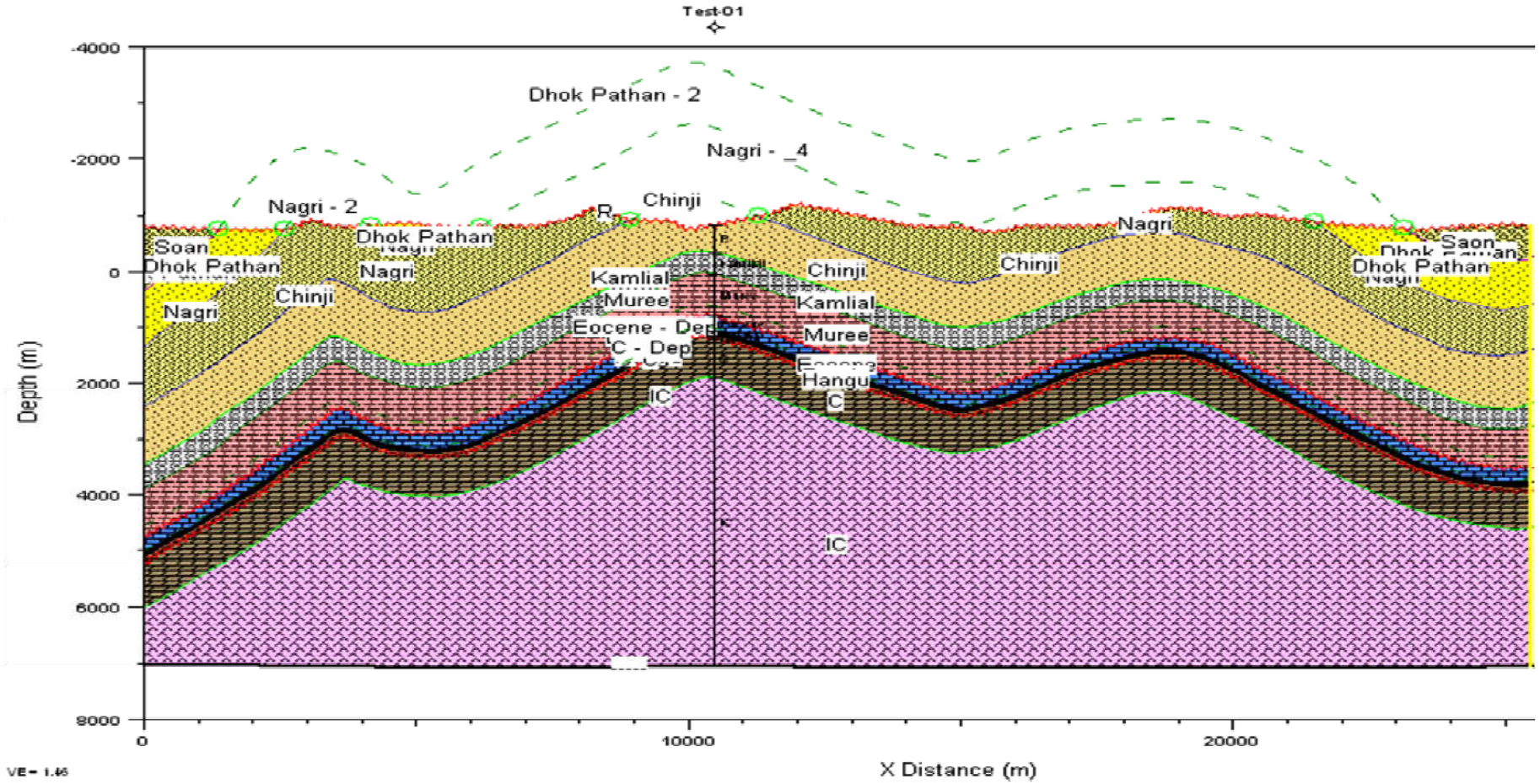
Cross section in 2D BasinMod

Properties (age, lithology, thickness, eroded thickness, kerogen type and TOC%) assigned to the events (horizons, unconformities and fault).



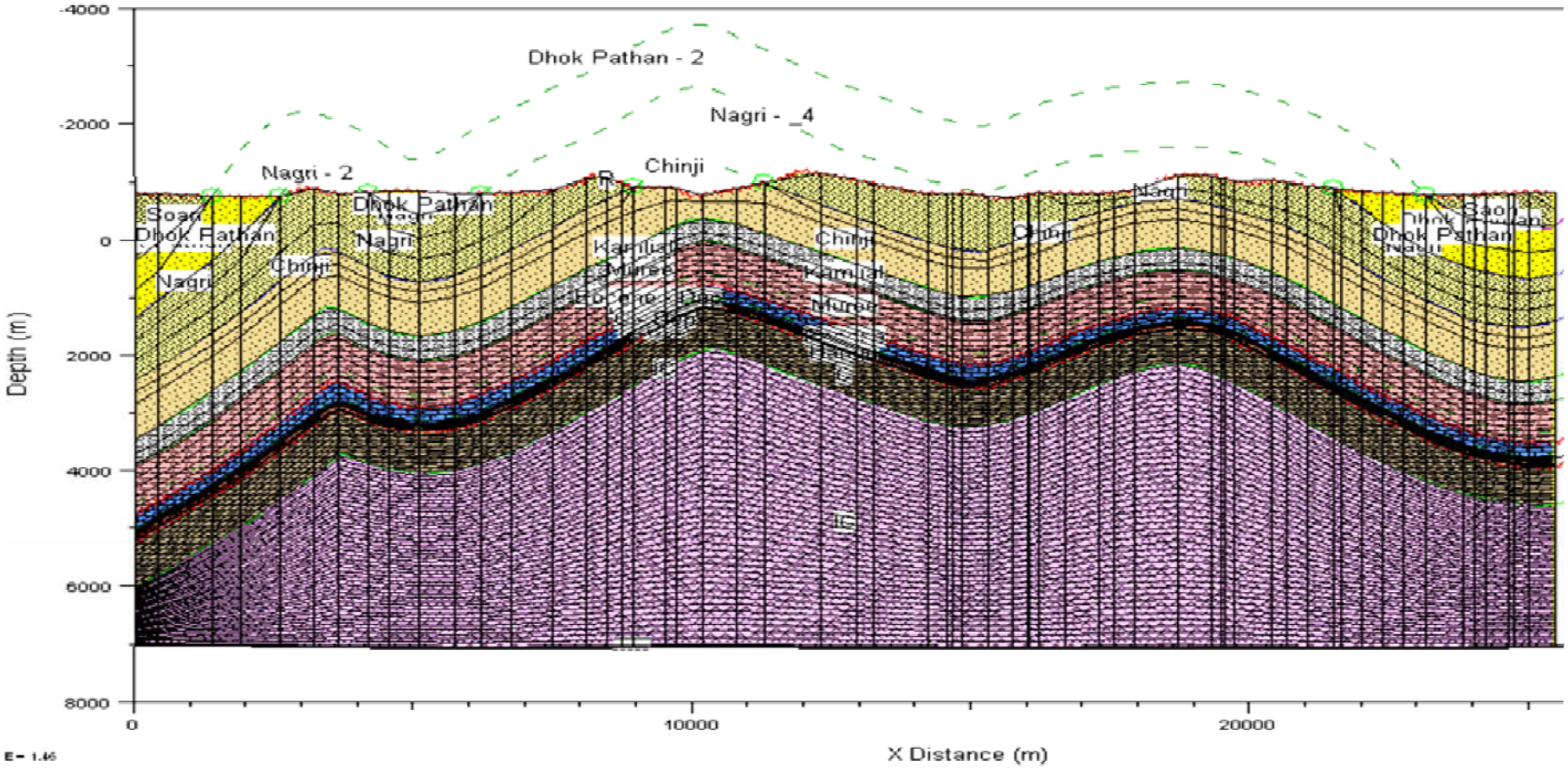
Modeled Section

Pseudo-well Test-01 created for maturity calibration

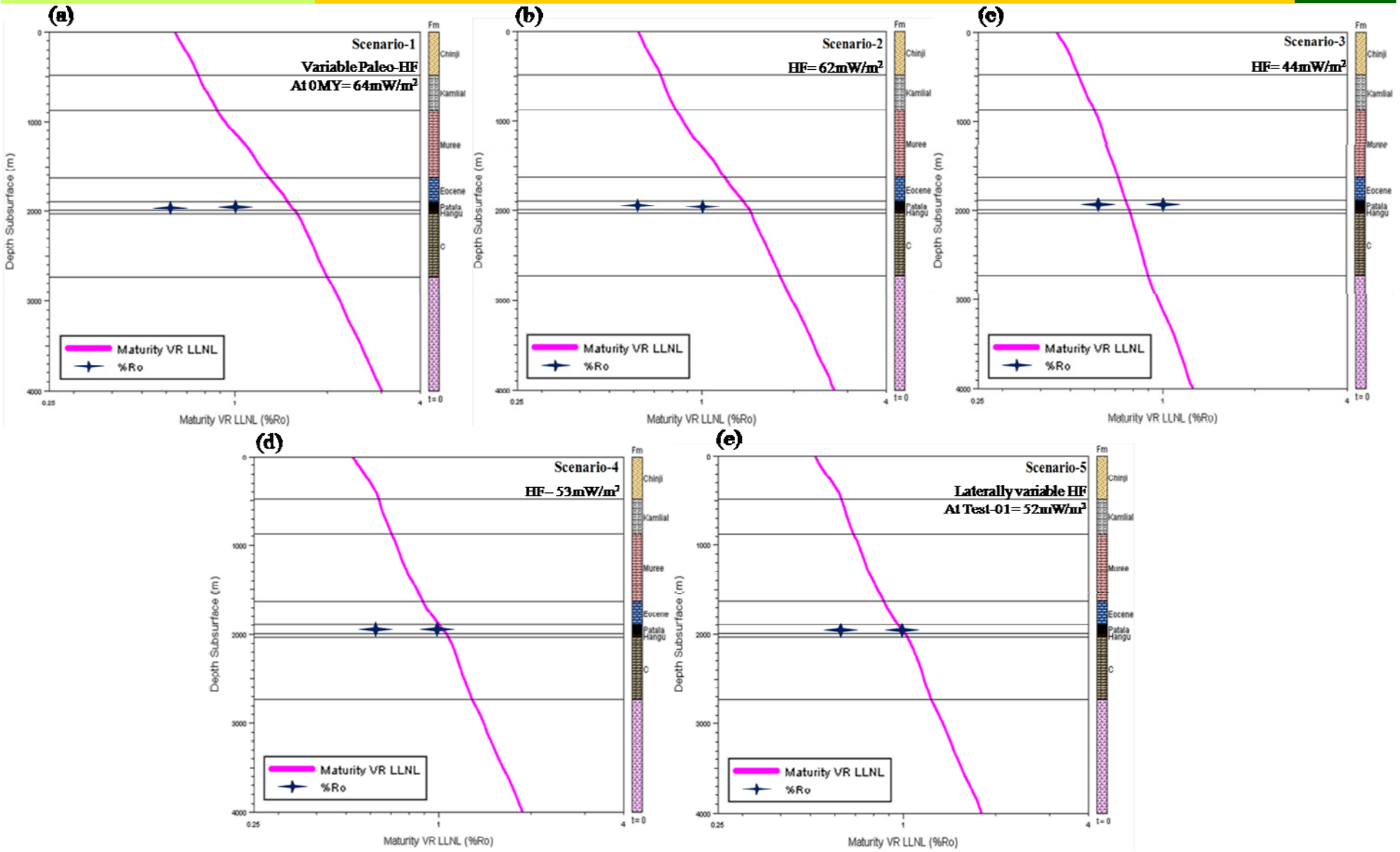


Calculated Model

- Based on gridding of time interval (3 MY with time-step precision of 0.01 MY)
- 43 Special X's (vertical line) were added for smoothing of time-lines



Calibration



Modeling Results

Pakistan Section

Scenario 1 & 2

Variable Paleo-heat flow / Av. of North Pakistan (62mW/m^2)

Scenario 3

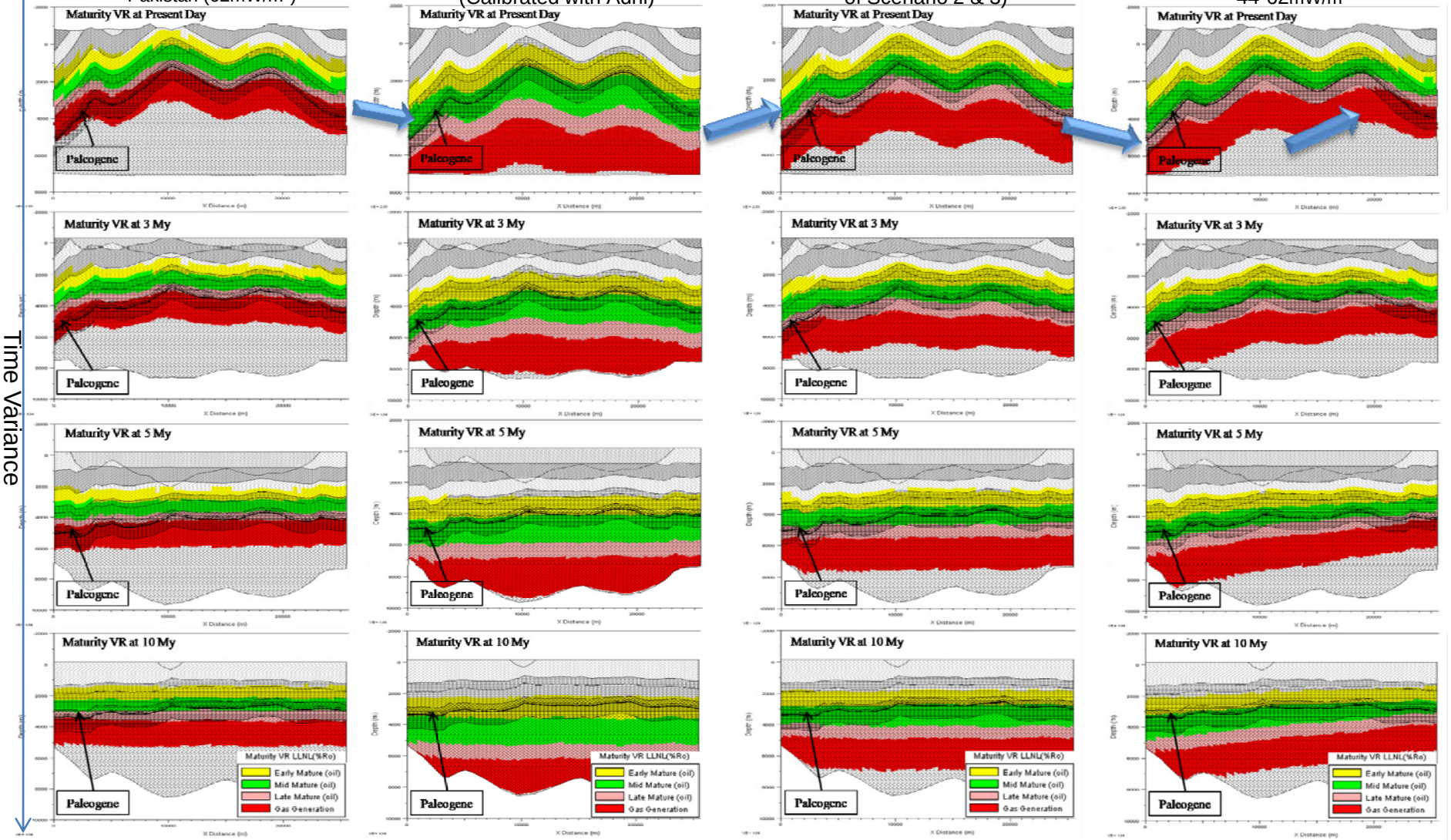
Paleo heat flow=44mW/m^2 (Calibrated with Adhi)

Scenario 4

Paleo heat flow=53mW/m^2 (Mean of Scenario 2 & 3)

Scenario 5

Laterally variable heat flow = 44-62mW/m^2



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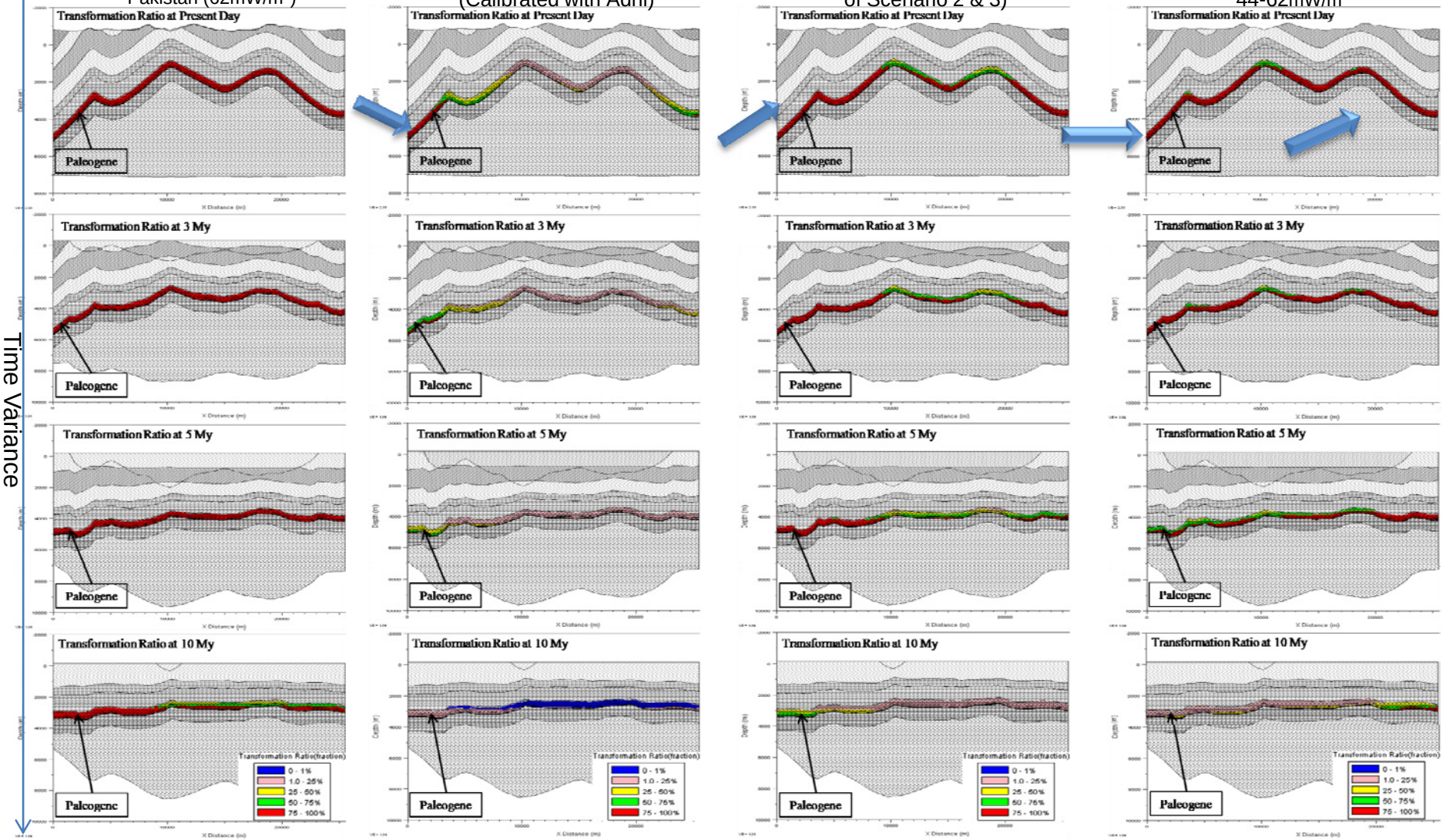
Transformation Ratio

Scenario 1 & 2
Variable Paleo-heat flow / Av. of North Pakistan (62mW/m^2)

Scenario 3
Paleo heat flow=44mW/m^2 (Calibrated with Adhi)

Scenario 4
Paleo heat flow=53mW/m^2 (Mean of Scenario 2 & 3)

Scenario 5
Laterally variable heat flow = 44-62mW/m^2



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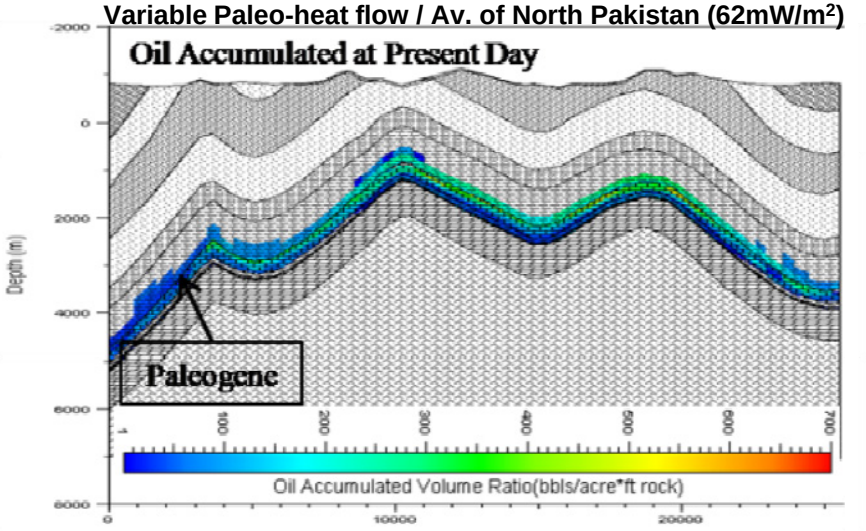
Oil Accumulation

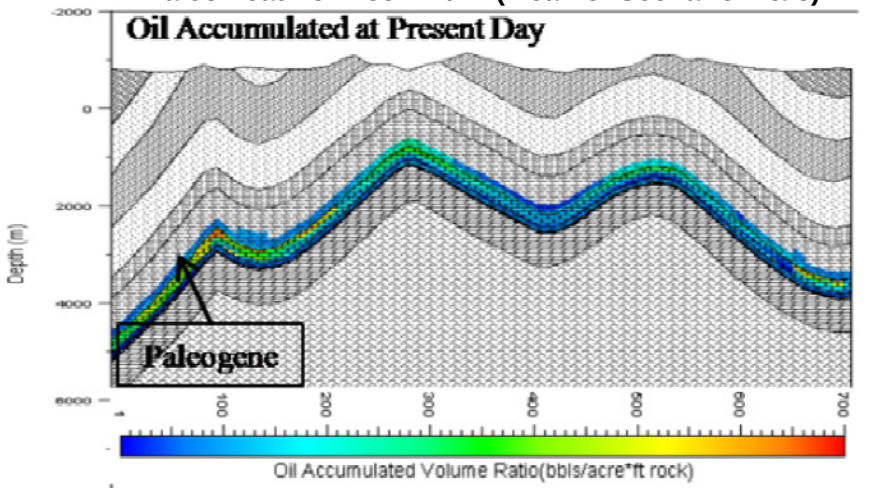
Scenario 1 & 2

Variable Paleo-heat flow / Av. of North Pakistan (62mW/m^2)



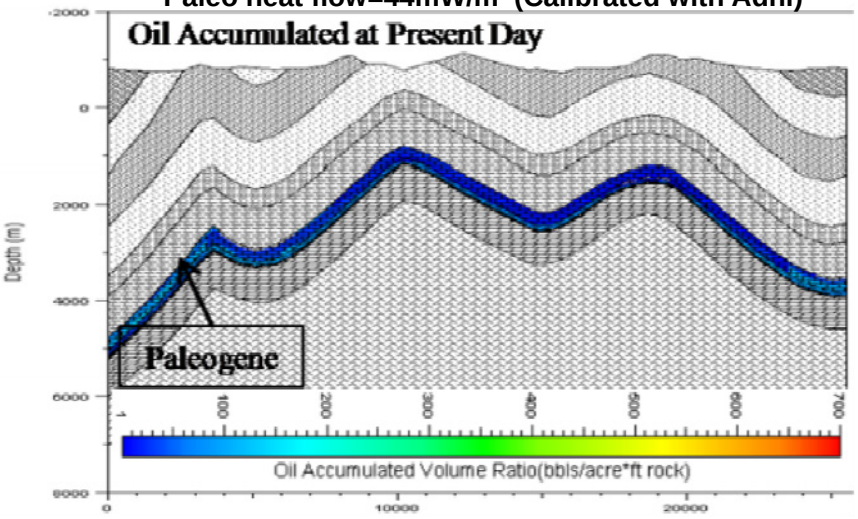
Scenario 4

Paleo heat flow=53mW/m^2 (Mean of Scenario 2 & 3)



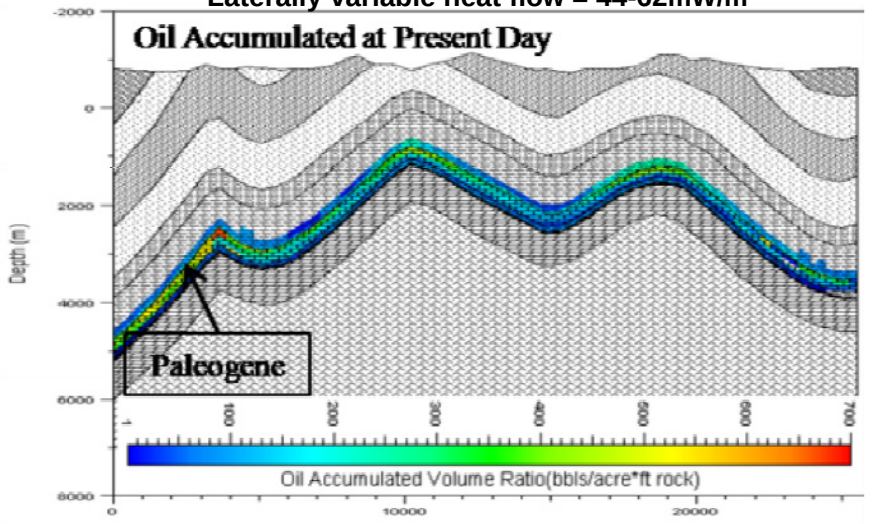
Scenario 3

Paleo heat flow=44mW/m^2 (Calibrated with Adhi)



Scenario 5

Laterally variable heat flow = 44-62mW/m^2



Conclusion

- The study attempts to understand hydrocarbon maturity of a frontier Kashmir area along a selected regional cross section having three prominent surface structures
- These structures are shown to have petroleum prospectivity
- Different heat flow scenarios were run to understand its sensitivity on hydrocarbon generation
- Heat flow in the study area can better be constrained by vitrinite reflectance data measured on outcrop samples
- Our approach to integrate the outcrop data (thickness and lithology) and surface geological mapping with analogue well data, has enabled us to construct a useful indicative model
- This model can be reinforced in future when subsurface data will become available

Acknowledgment

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Thank You…