

Geological Modeling with Seismic Inversion for Deepwater Turbidite Fields Offshore Northwestern Myanmar*

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Search and Discovery Article #40877 (2012)

Posted February 6, 2012

*Adapted from oral presentation at AAPG International Conference and Exhibition, Milan, Italy, October 23-26, 2011

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Abstract

Building a realistic geological model in the early exploration stage is highly desirable to design an effective appraisal program and development plan that can minimize subsurface uncertainties. One of the most common hurdles to geomodelers in this stage is the limited number of wells and resolution difference between conventional seismic and wells, which will impede establishing reliable relationship between the two and lower the confidence in resulting geological models. To overcome these limitations, we adopted a geostatistical inversion (GI) technique and constructed geological models for the late Pliocene deepwater turbidite deposits of three gas fields offshore northwestern Myanmar.

GI is the latest inversion technique which uses the Markov-Chain Monte Carlo algorithm together with seismic volume, well logs and geostatistics as the main inputs. GI outputs have at least 4 times higher vertical resolution than seismic as well as multiple realizations that all honor well data, being a useful tool for quality control and uncertainty analysis.

There were great benefits in building geological models using GI, especially for property modeling. First, reservoir properties guided by GI showed well defined correlation with well logs. Second, multiple realizations of GI output enabled us to control uncertainty in depositional facies distribution. Third, refined geological trends were obtained from GI through compensation of dimmed seismic amplitude affected by shallow geology.

A great improvement of geological models was achieved using GI in modeling sheet-like sandstone reservoirs thicker than 5 meters. However, it was still insufficient to build realistic models for thinner bedded levee-overbank deposits. Based on these models, we were able to reduce subsurface uncertainties, refine reserve estimation, and optimize production well locations.

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October 2011



- 1. Introduction**
- 2. Study Area**
- 3. Geostatistical Inversion**
- 4. Geological Modeling with GI**
- 5. Discussion**
- 6. Conclusion**

Introduction

Reservoir Characterization

Seismic data

- Sequence Analysis
- Horizon Picking
- Seismic attributes

Well data

- Well logs
- Cores
- DSTs

Petrophysical data

- Electrical facies
- Porosity, permeability
- Water saturation

Geological data

- Well correlation
- Analogues
- Depositional models



1D/ 2D/ 3D information → 3D geological models

Optimized Geological Model

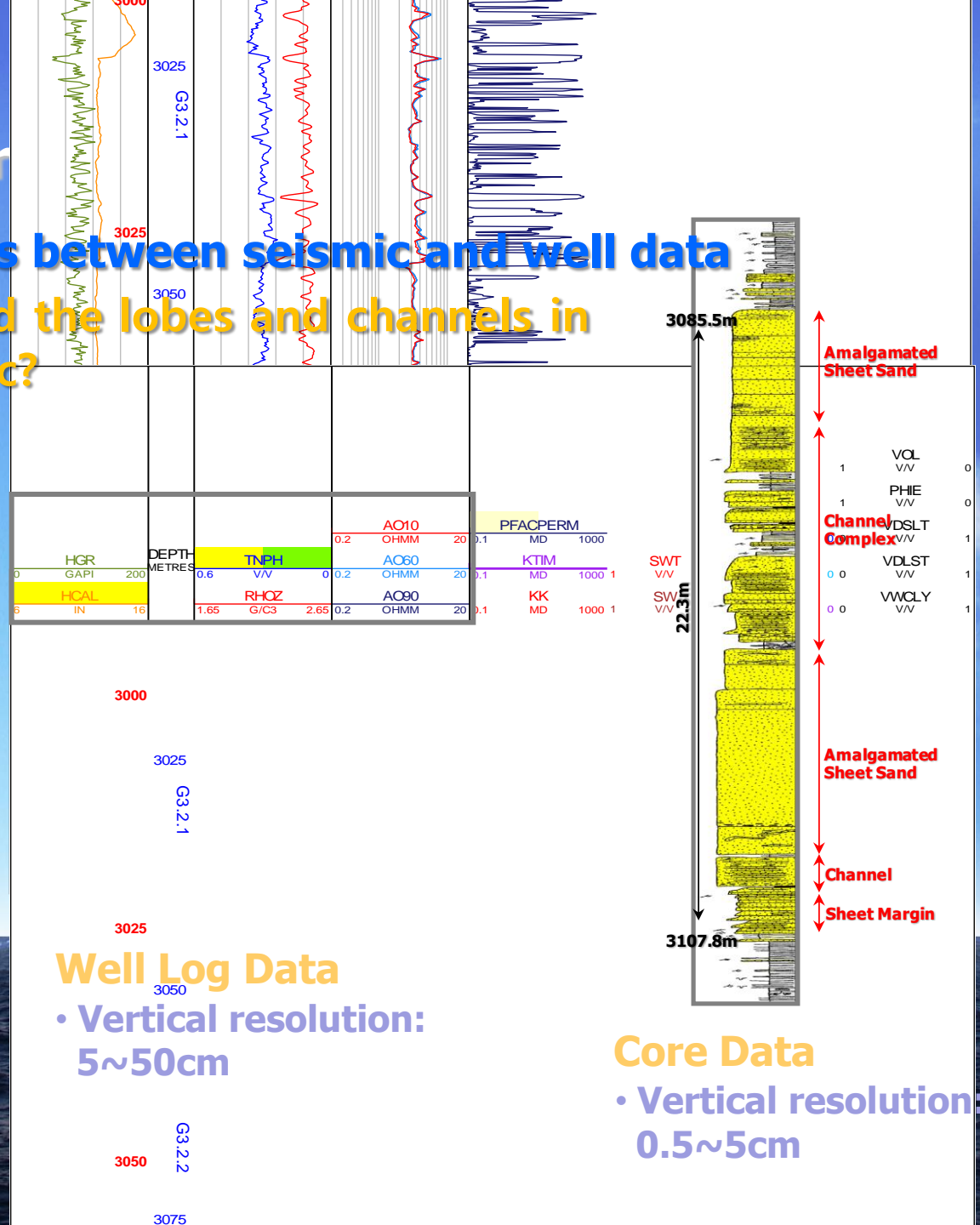
- Estimate hydrocarbon volume in place
- Input into reservoir engineering study
- Determine field development plan

Introduction

Reservoir Character

Resolution differences between seismic and well data

→ Where can we find the lobes and channels in core from the seismic?



Seismic Data

- Vertical resolution: 30~40m

Well Log Data

- Vertical resolution: 5~50cm

Core Data

- Vertical resolution: 0.5~5cm

AAPG ICE
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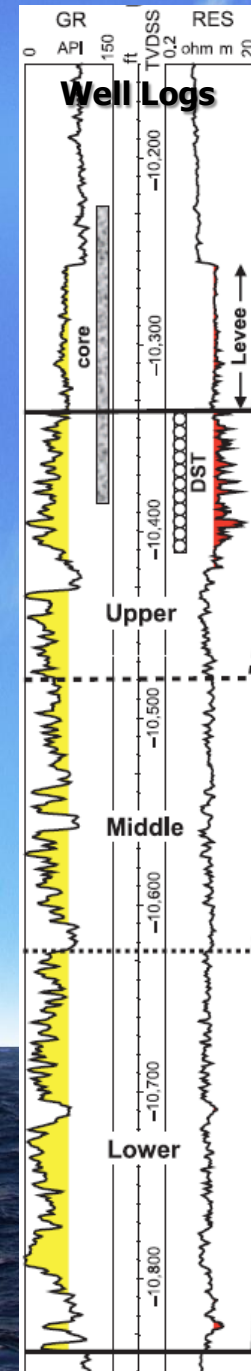
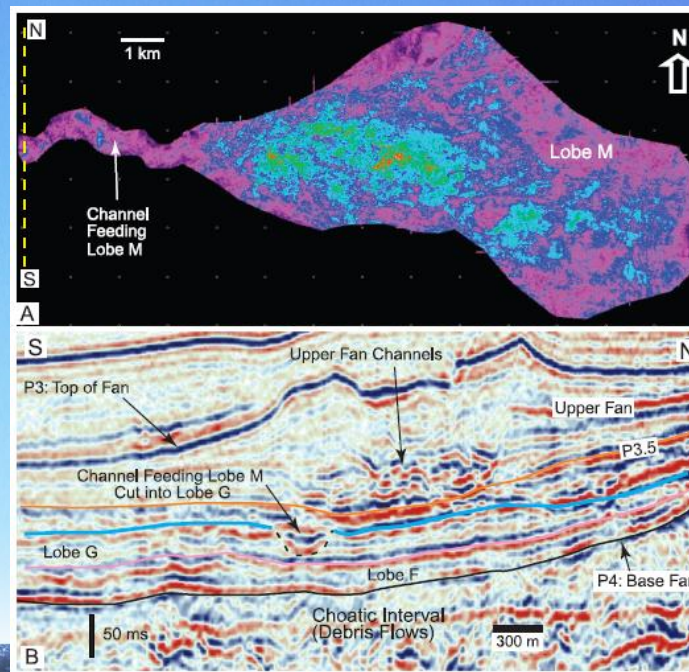
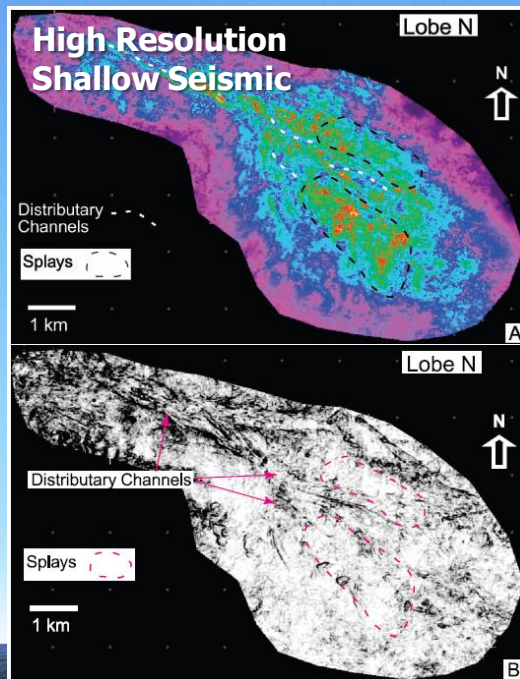
AAPG

Introduction

Reservoir Characterization

How to overcome the resolution differences?

→ Outcrop/ subsurface analogues



Saller et. al., 2008

→ High resolution inversion results from stochastic methods

Study Area

Block Locations A-1/A-3/AD-7, Myanmar



MYANMAR
A-1 (operator)

MYANMAR
AD-7 (operator)

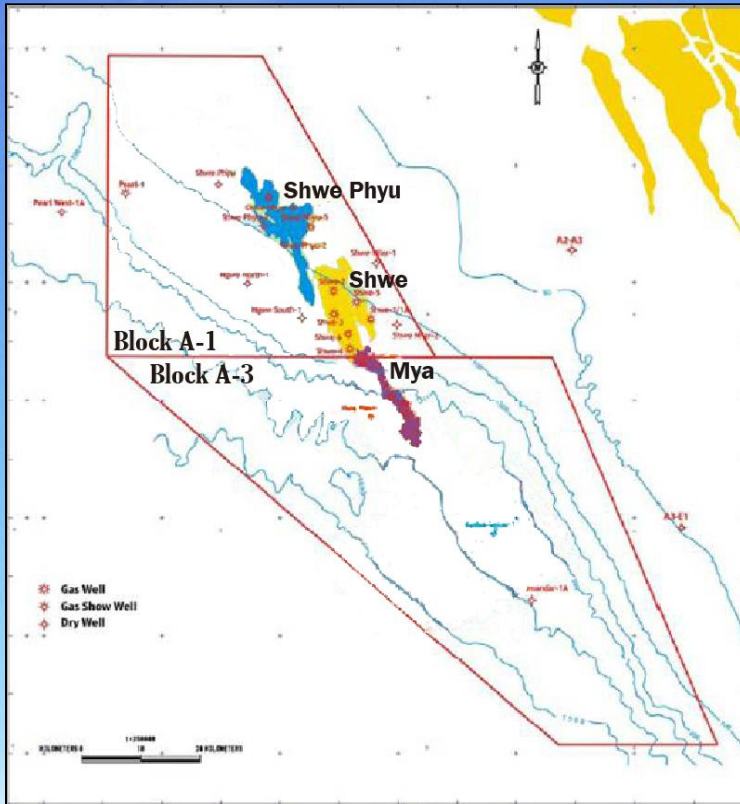
MYANMAR
A-3 (operator)



Blocks	A-1	A-3	AD-7
Participation	2000	2004	2007
Equity (%)	51	51	100
Acreage(km ²)	2,119	3,441	1,684
Partners	ONGC Videsh, GAIL, KOGAS, MOGE		

Study Area

Gas fields and Reserves



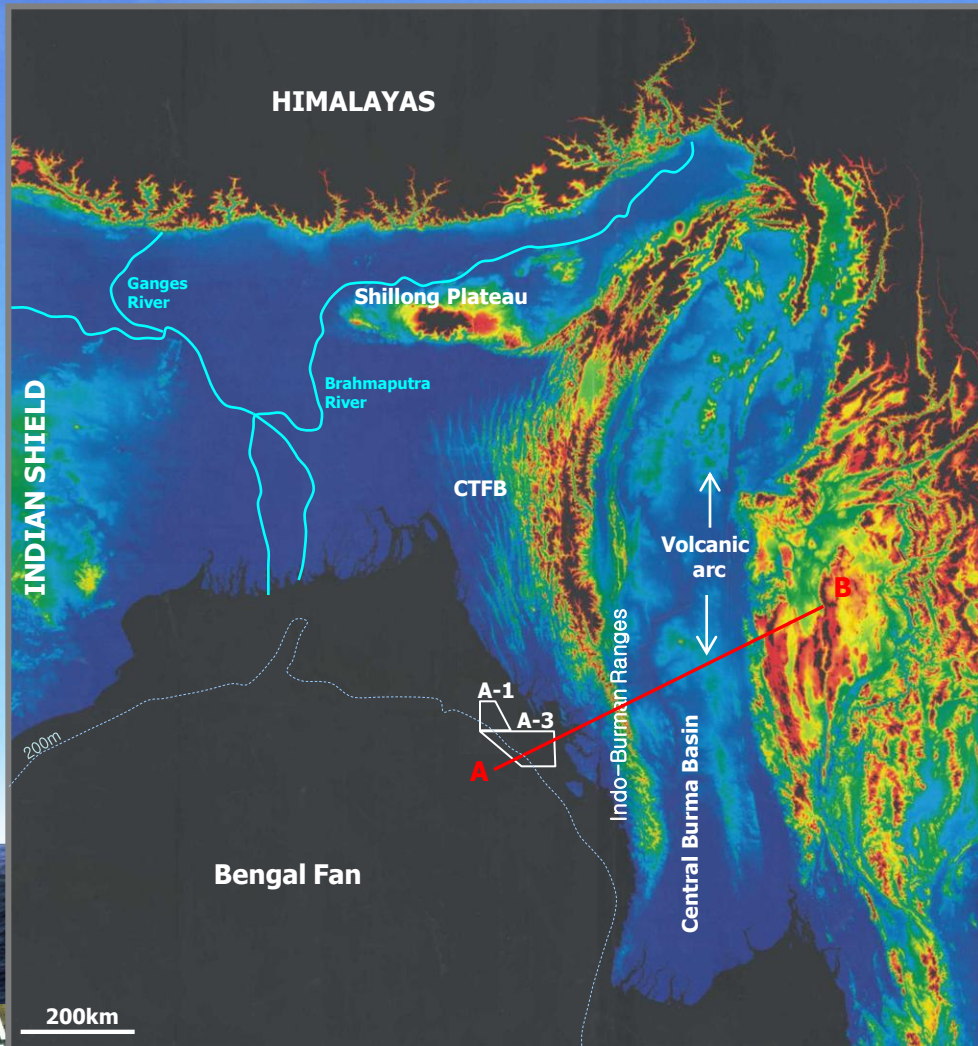
Resource Certification

Block	Gas Fields	Recoverable Reserves (TCF)
A-1	Shwe	2.87 ~ 4.67
	Shwe Phyu	0.38 ~ 0.91
A-3	Mya	1.28 ~ 2.16
Total		4.53 ~ 7.74

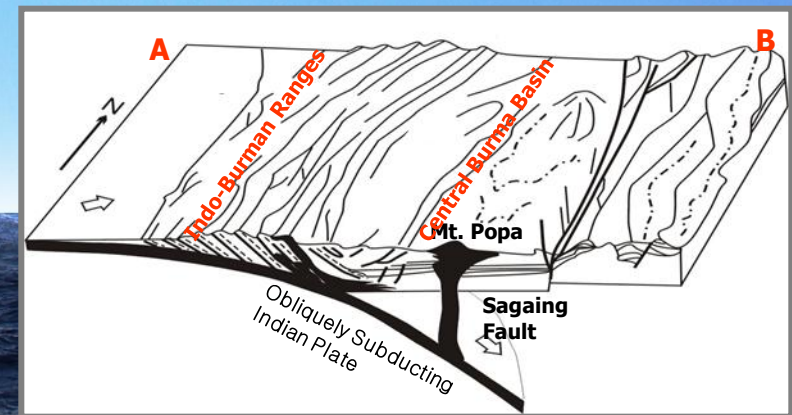
- Auditor : Gaffney, Cline & Associates (GCA)

Study Area

Regional Geology



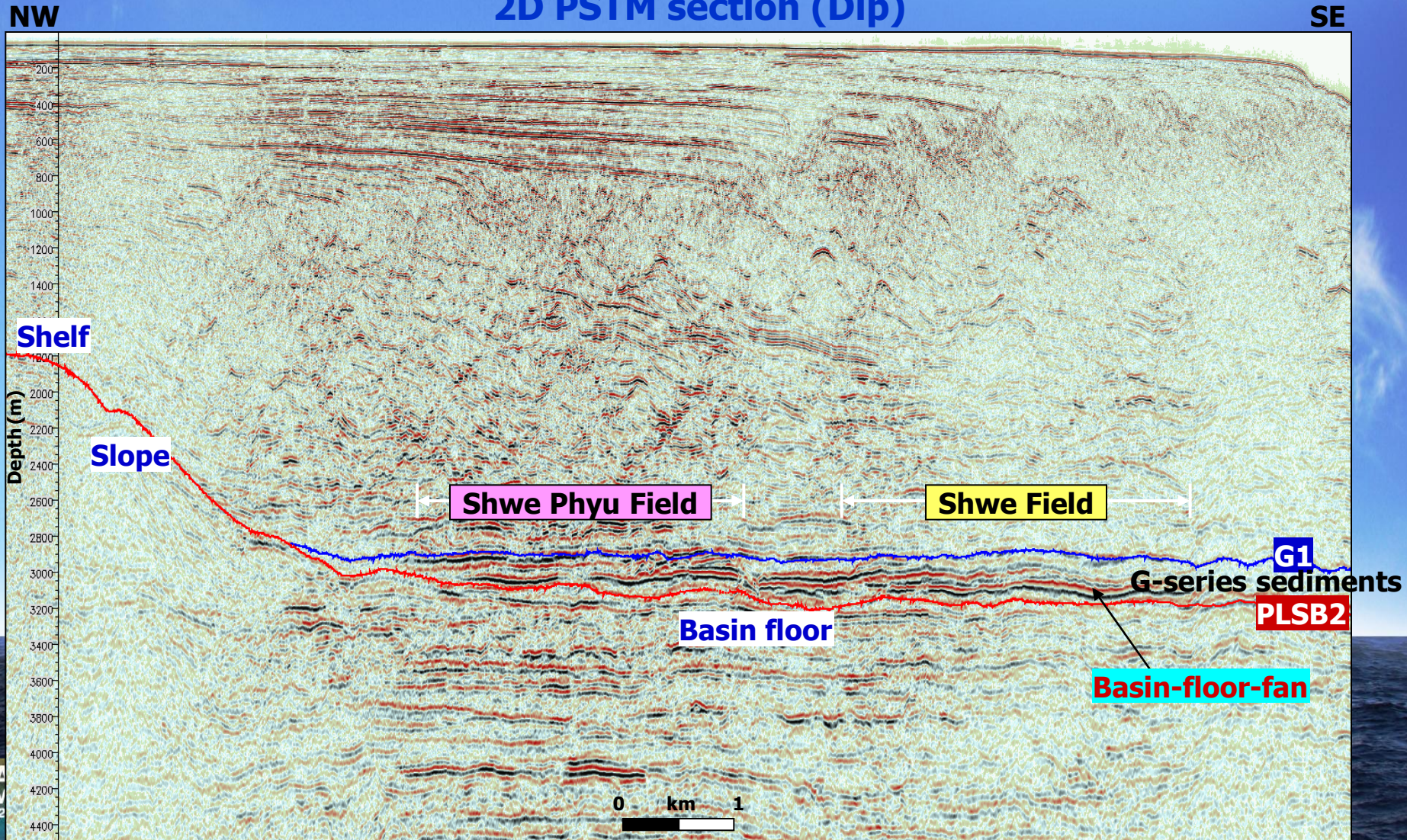
- **CTFB :**
Chittagong-Tripura Fold Belt
- **Indo-Burman Ranges:**
Accretionary prism by Bengal subduction
- **Central Burma Basin:**
Fore-arc and back-arc basin of Bengal subduction



Study Area

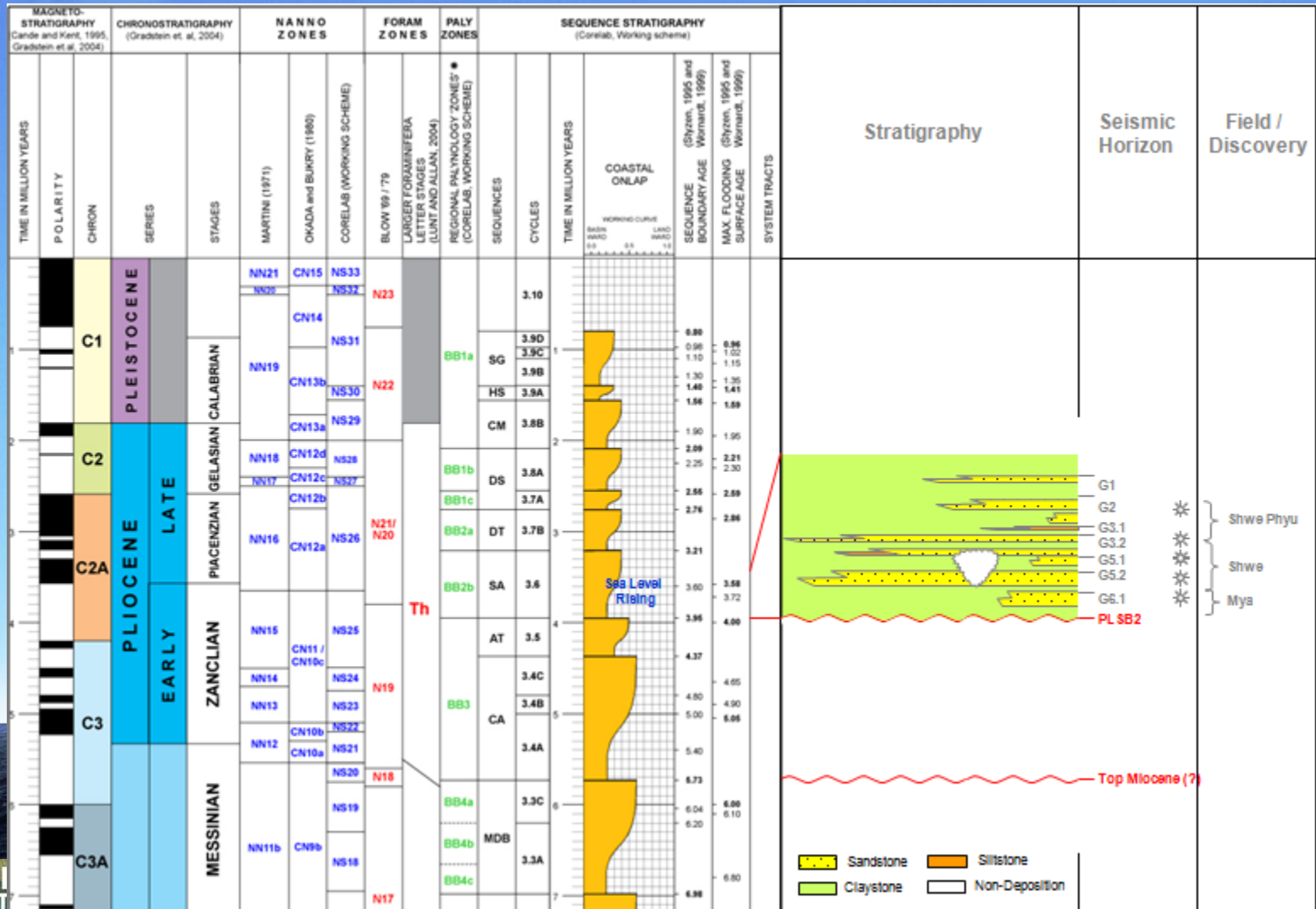
Seismic Stratigraphic Analysis

2D PSTM section (Dip)



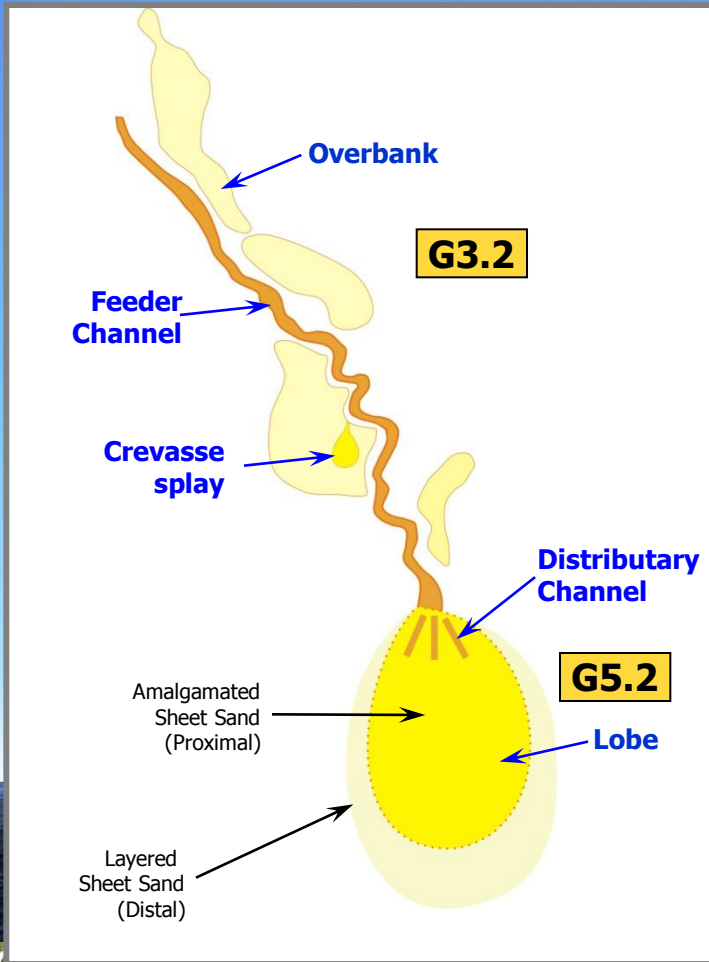
Study Area

Stratigraphic Column



Study Area

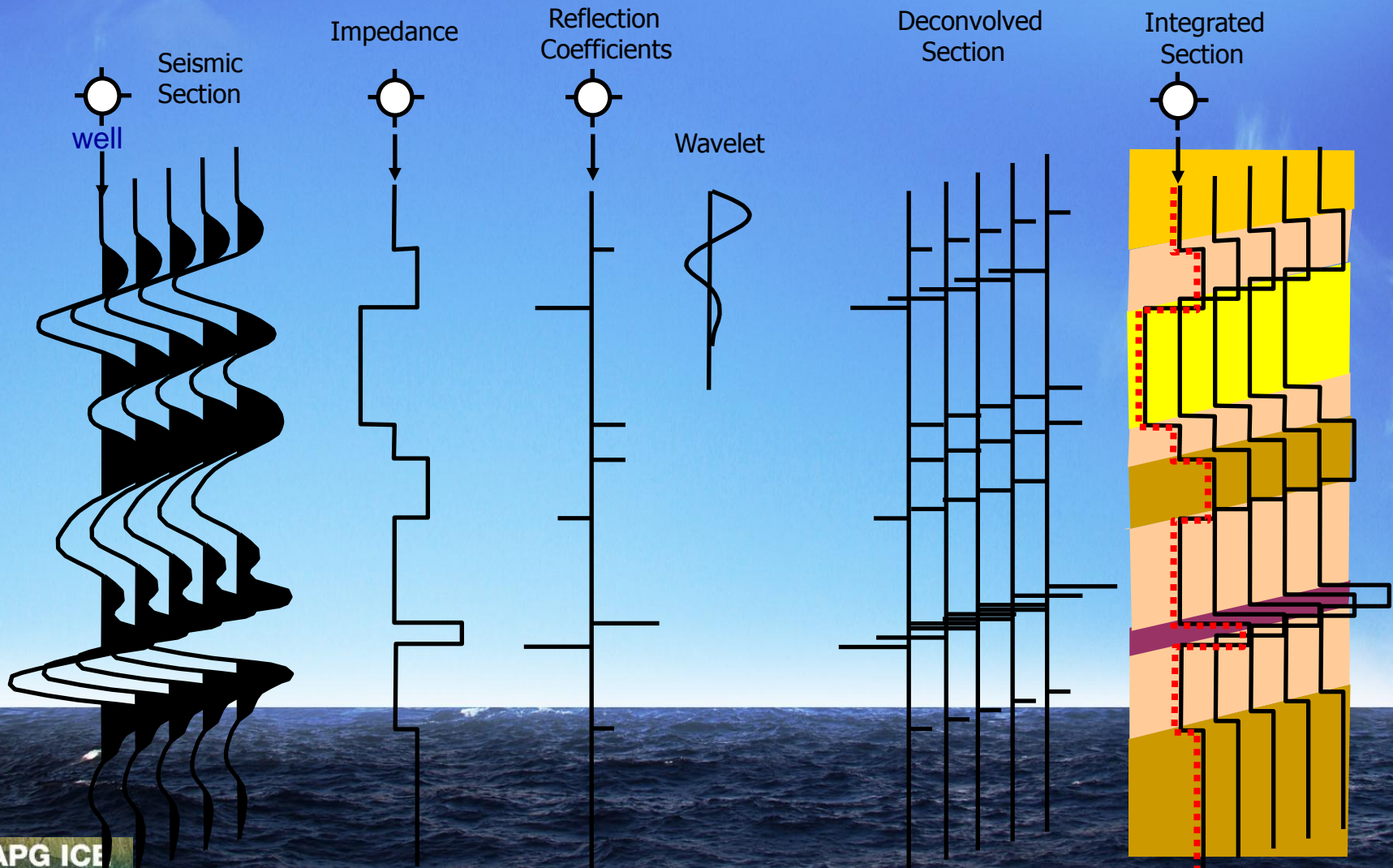
Conceptual Fan Depositional Model



- **Lobe deposit (G5.2)**
Proximal part : Amalgamated sand
Distal part : Layered sand
- **Channel – Overbank deposit (G3.2)**
Feeder & Distributary channels
Proximal & Distal overbank
Crevasse splays

Geostatistical Inversion

Seismic Inversion

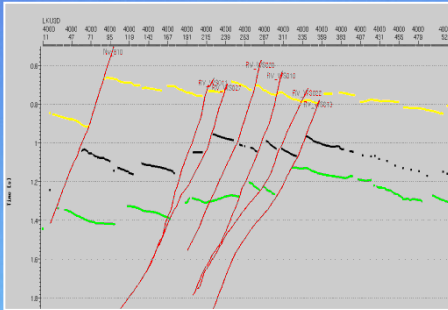


Geostatistical Inversion

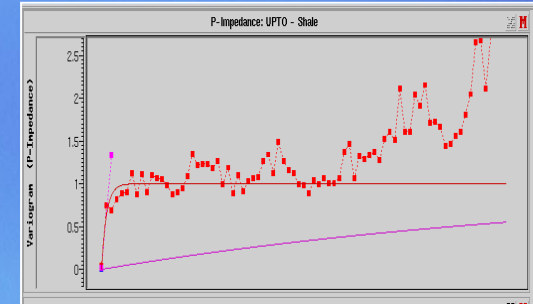
Seismic Inversion

Inversion type	Sparse Spike Inversion	Simultaneous Inversion	Geostatistical Inversion
Method	Deterministic		Stochastic
Input Data	Seismic (Post-stack), Well logs	Seismic with AVO, Well logs	Seismic with AVO, Well logs, Geostatistical data
Vertical Resolution (Sample rate)	4 ms	4 ms	1 ms
Inverted Properties	Zp	Zp, Zs, Rho	Zp, Zs, Rho
Co-simulated Petrophysical Properties	-	Porosity	Porosity, Permeability, Water saturation
Co-simulation Method	-	Empirical transforms	Multivariate statistics
Multiple Realizations	No	No	Yes

Geostatistical Inversion Input

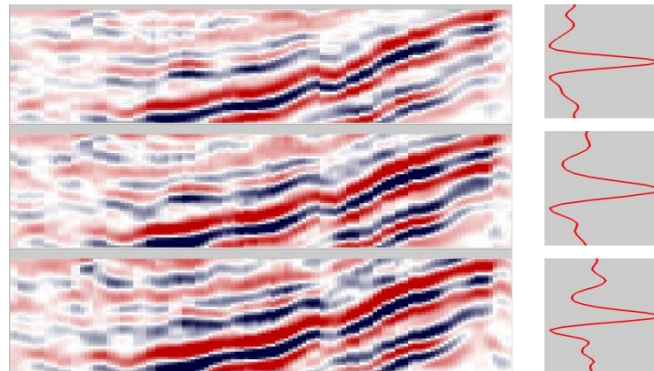


Variogram

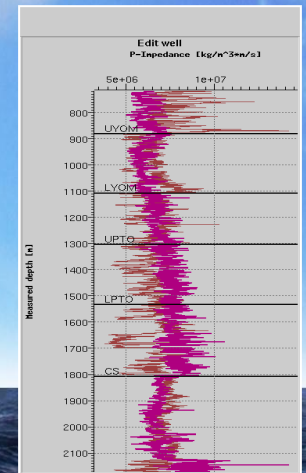
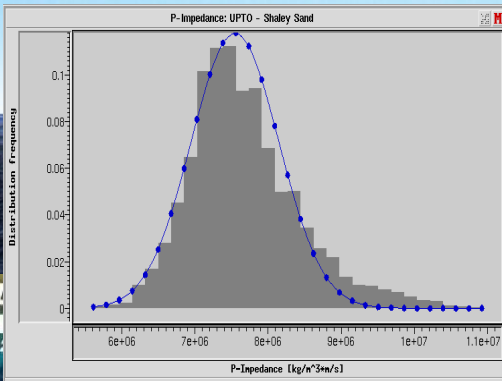


Structural model,
defining stratigraphic grid

Seismic stacks and wavelets



Histogram

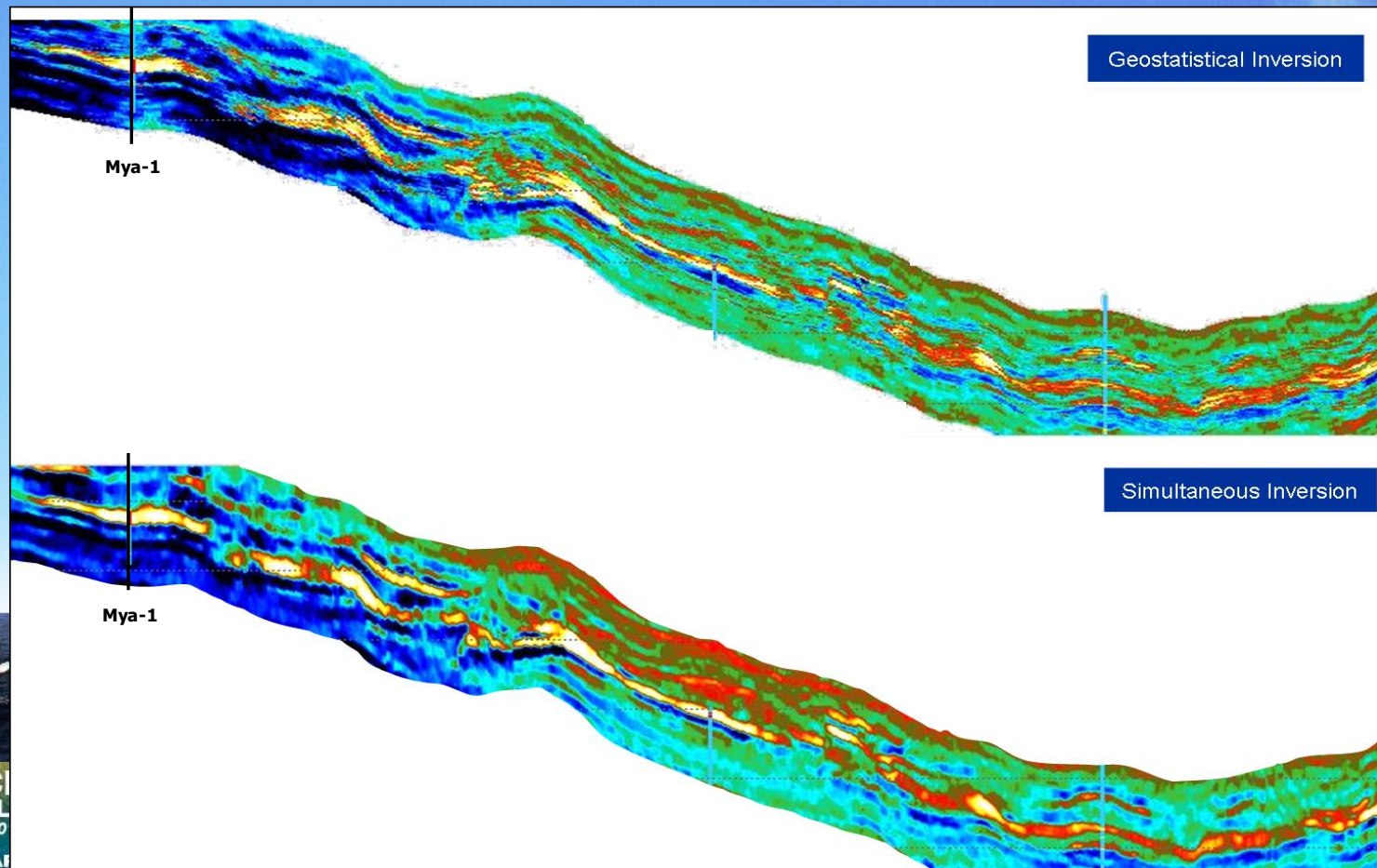


Well logs

Geostatistical Inversion

Output: High Vertical Resolution

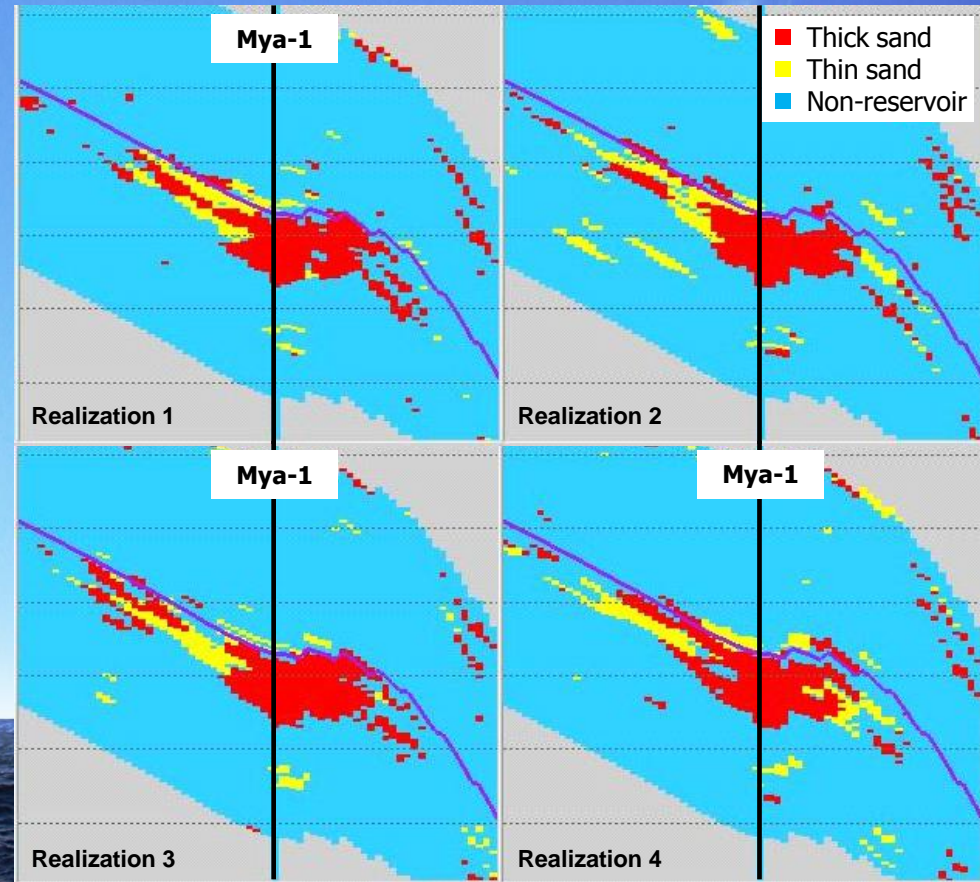
- About 4 times higher than seismic resolution
- Vertical variogram model from well logs controls high frequencies



Geostatistical Inversion

Output: Multiple Realizations

- Multiple realizations that honor all known information
- Each output realization comprises
 - A lithofacies model
 - Shale, wet sand, thin sand, thick sand and etc.
 - A petrophysical model
 - Porosity, Sw, permeability and etc.



Geostatistical Inversion

Summary

▪ Advantage

- Predicted discrete/ continuous property volumes are much more detailed.
- Multiple realizations consistent with all input data including geostatistics are possible.
- Well data have a greater impact on results.

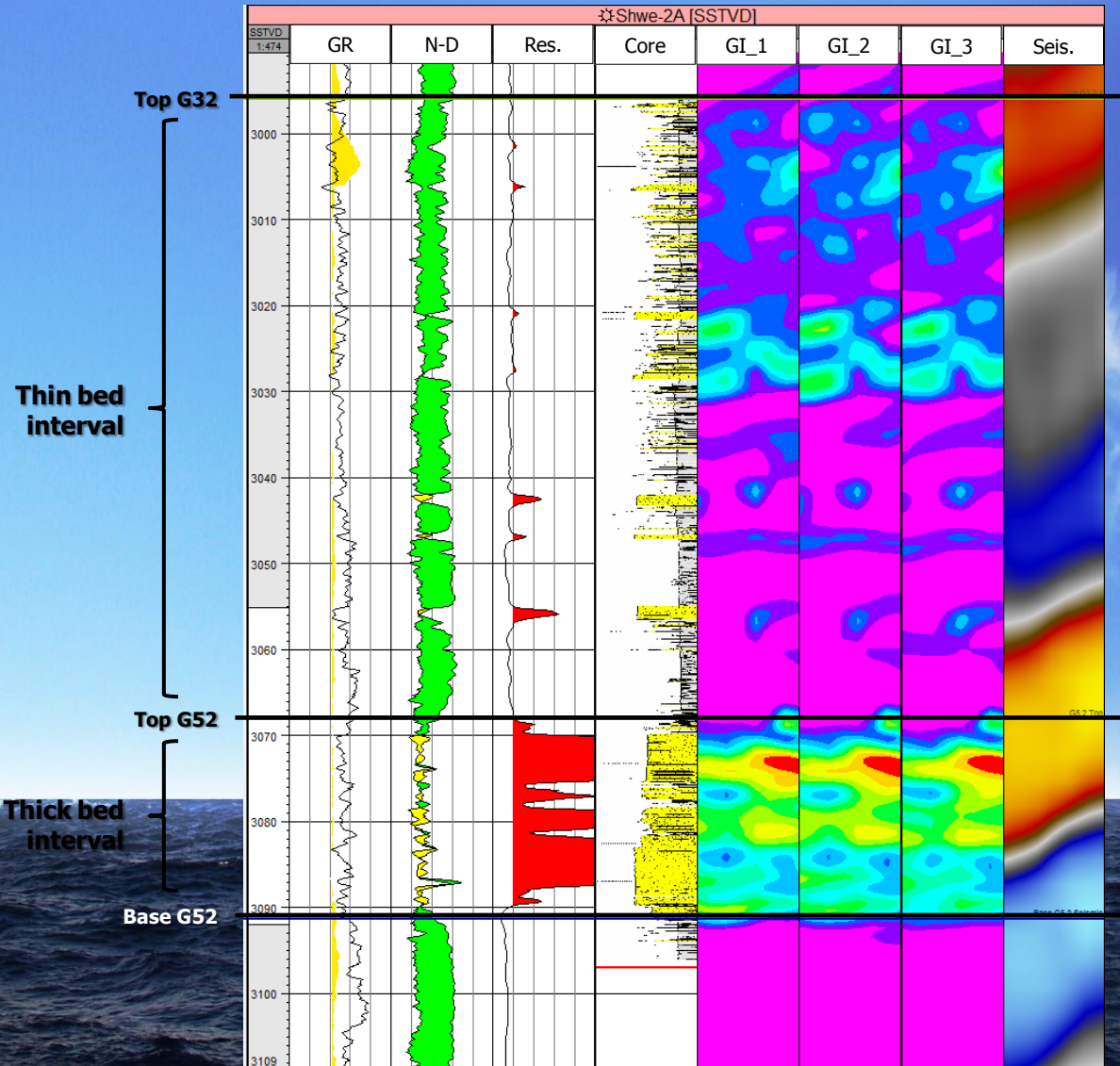
▪ Disadvantage

- Seismic data have a less significant impact on results than well data.
- Known geostatistics may not be representative of true geostatistics.
- Good results are more subjective.
- Long turn-around time due to long computation time

Geological Modeling with GI

Comparison among well logs and GI realizations

- GI can capture geological details better than seismic with reasonable certainty.
- Each realizations are slightly different around well location.
- G32 interval does not capture geological details as good as in G52 interval.
- However, it is difficult to define the core facies from inversion results.

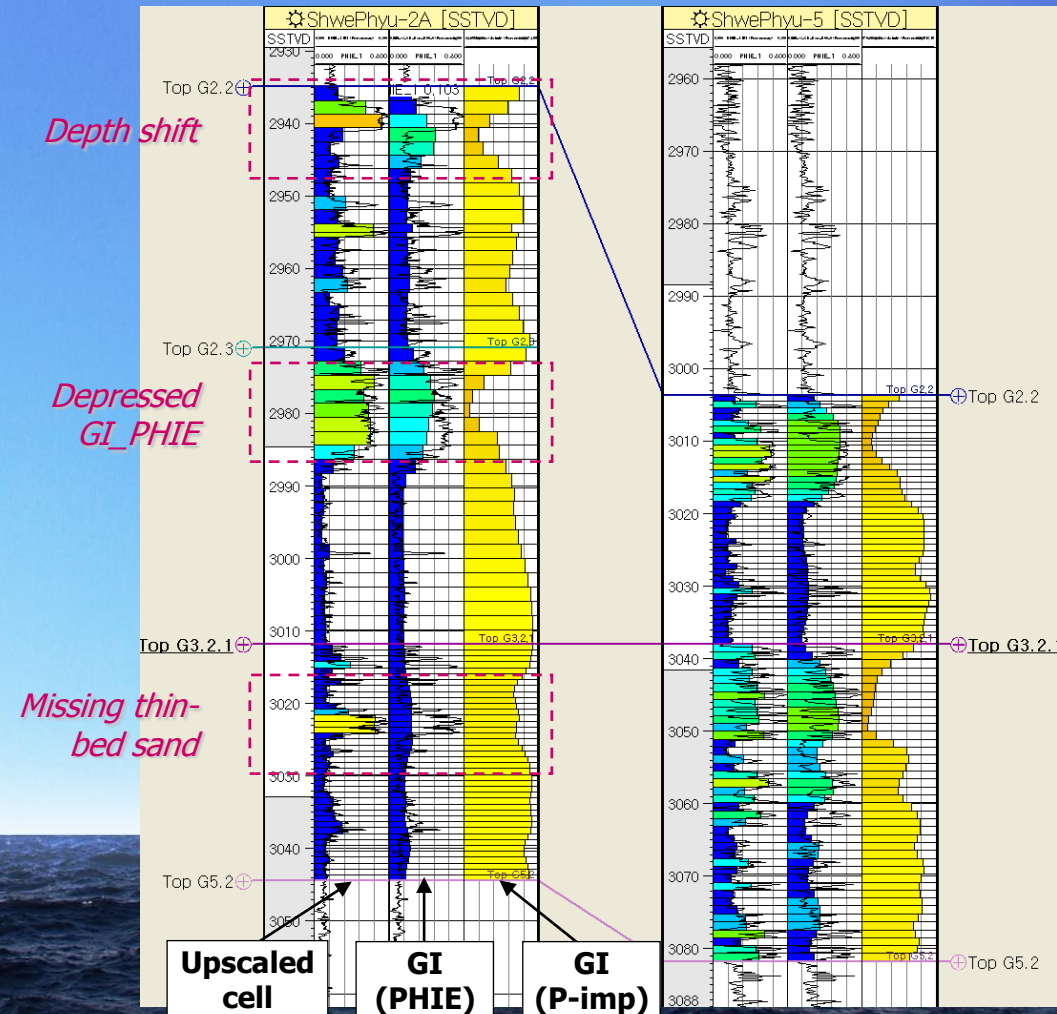


Geological Modeling with GI

Correlation between well logs and GI

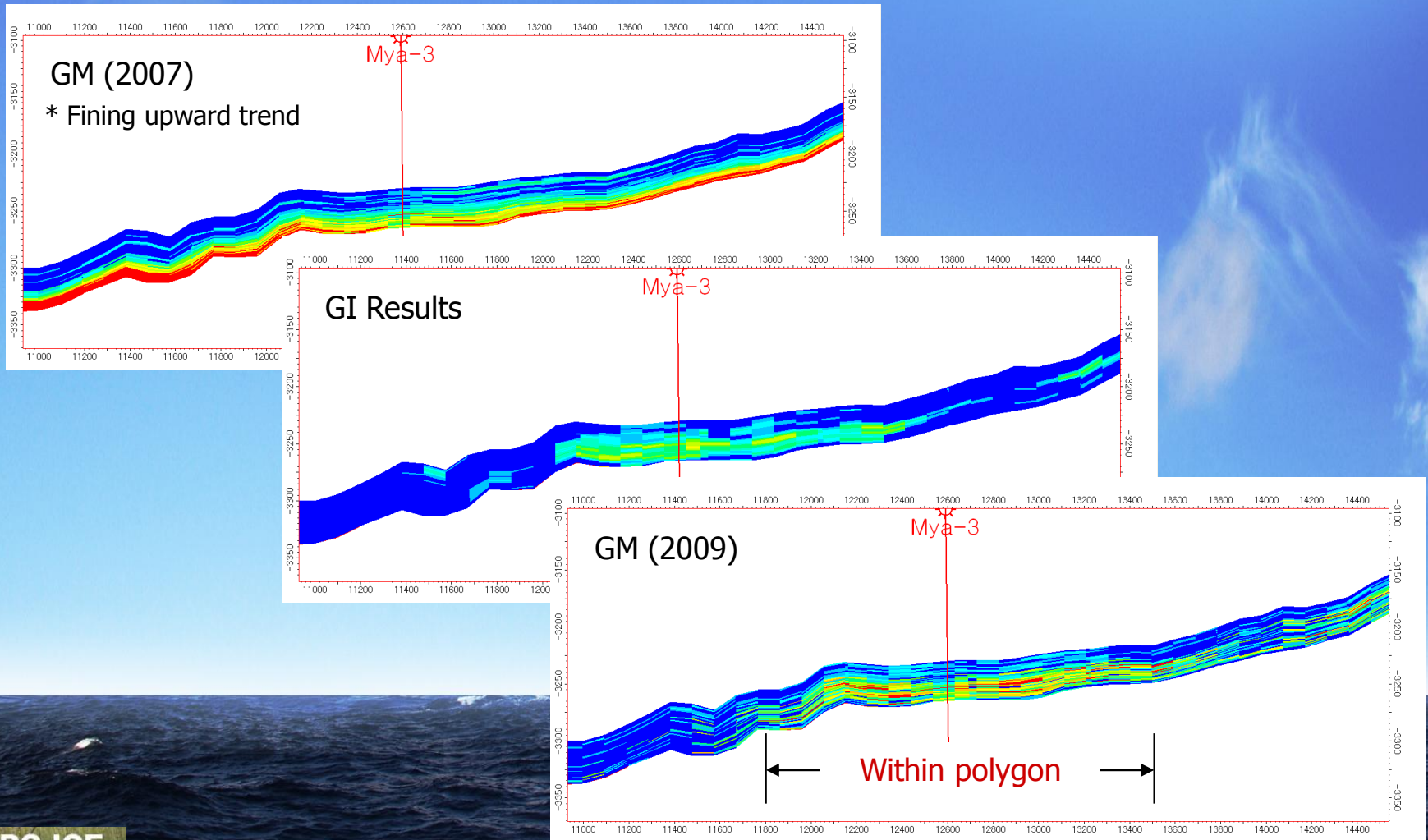
- Generally GI results (PHIE, P-imp) showed a good match with well properties (PHIE and NTG).
- However, it was difficult to use GI results directly into geological model.
- Therefore, GI results were used as a trend for property modeling.

Corr. Coeff. (G6.0 + G6.1)		GI results			
		P imp	PHIE_0	PHIE_1	PHIE_2
Well Data	NTG	-0.5995	0.6718	0.6120	0.6197
	PHIE	-0.6684	0.8061	0.7360	0.7556



Geological Modeling with GI

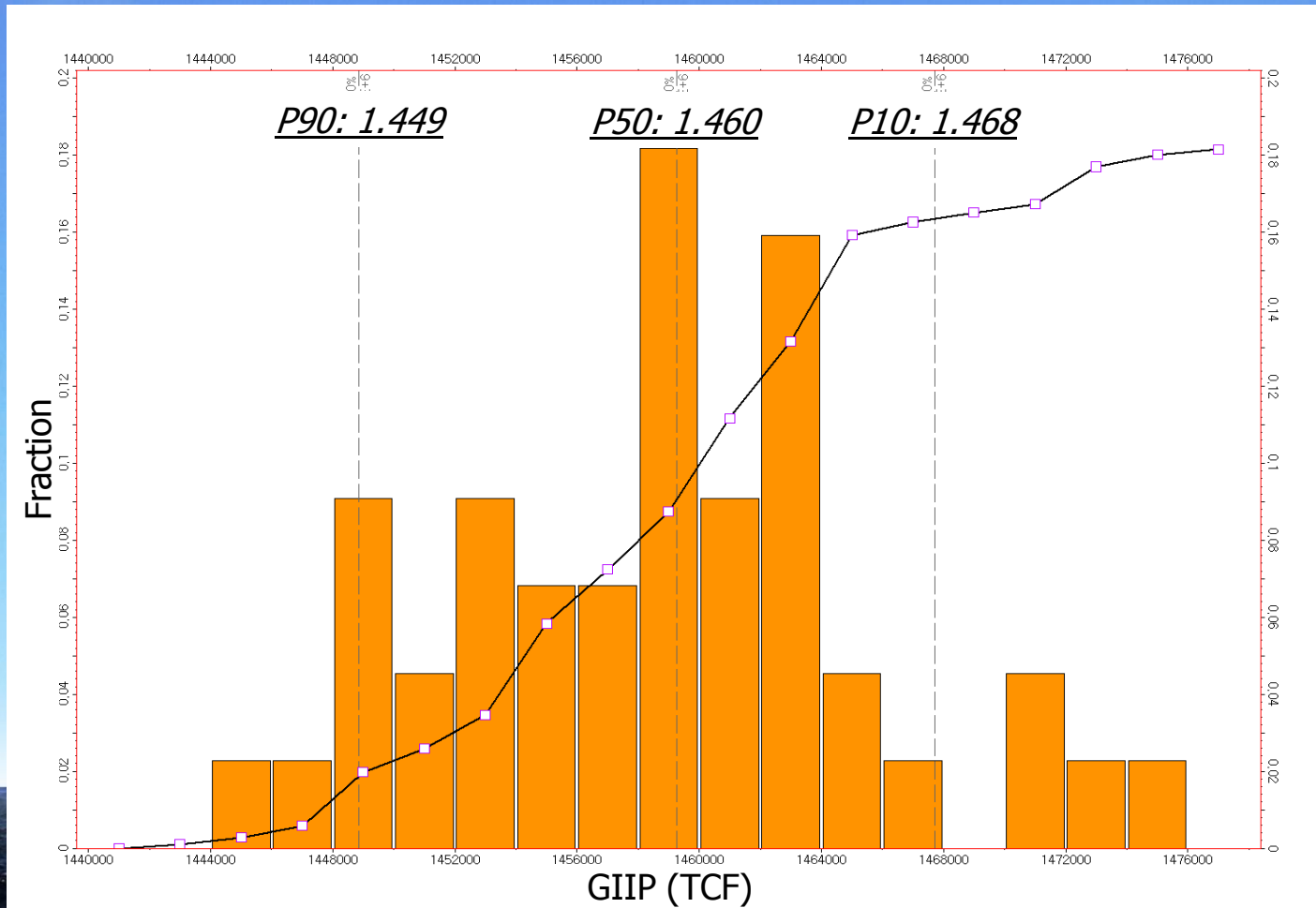
Property model improvement



Vertical trend in a porosity model has been greatly improved after using GI as a property trend.

Geological Modeling with GI

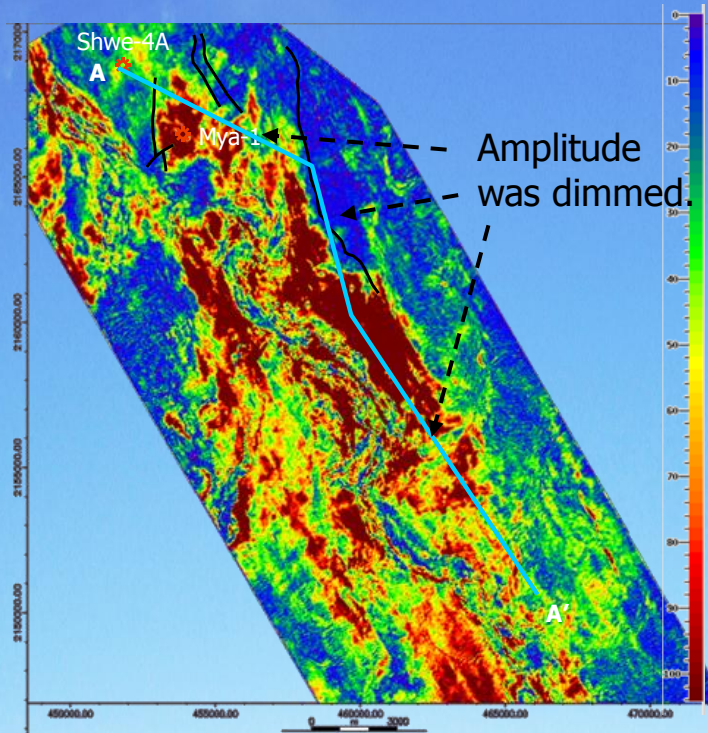
Uncertainty analysis with multiple realizations



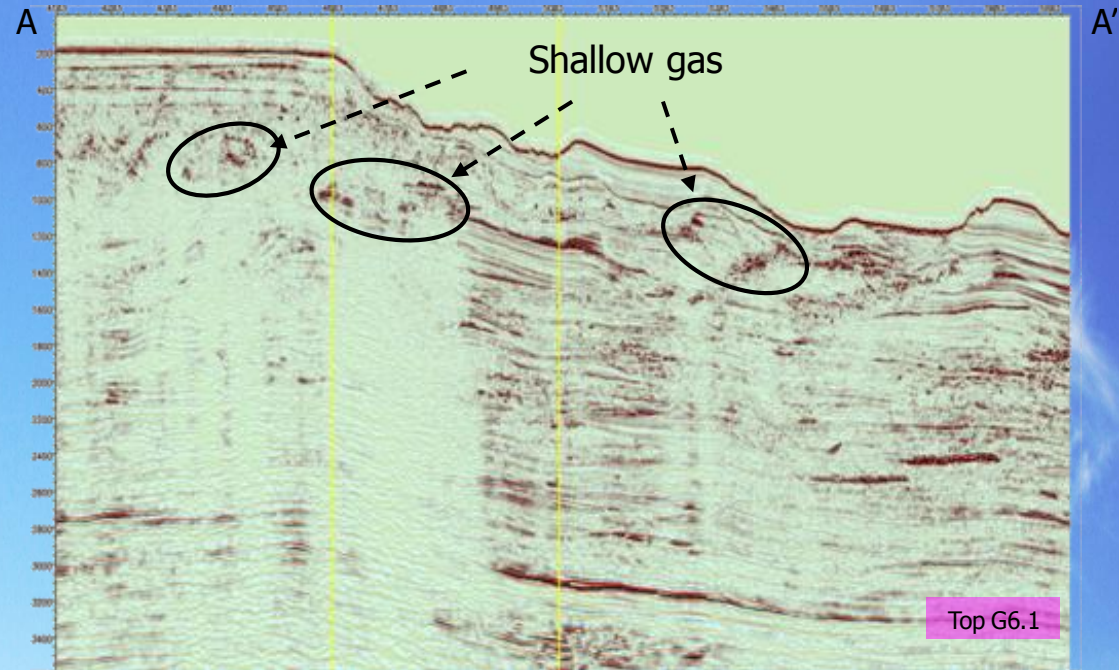
45 GI_PHIE multiple realizations were used to evaluate the uncertainty in GIIP and those impacts in GIIP was not so significant.

Discussion

GI: Dimming Compensation



PSHM amplitude

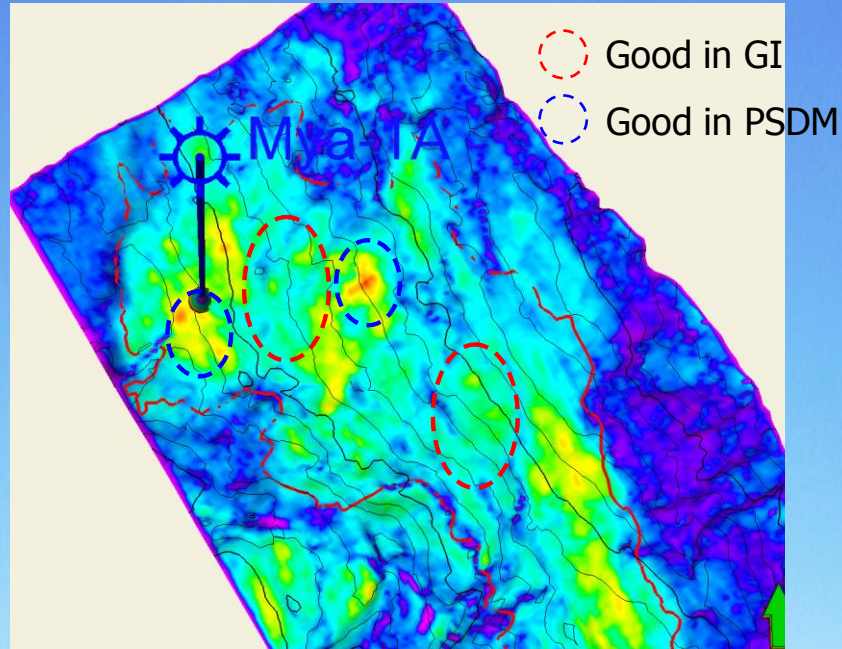


Seismic section

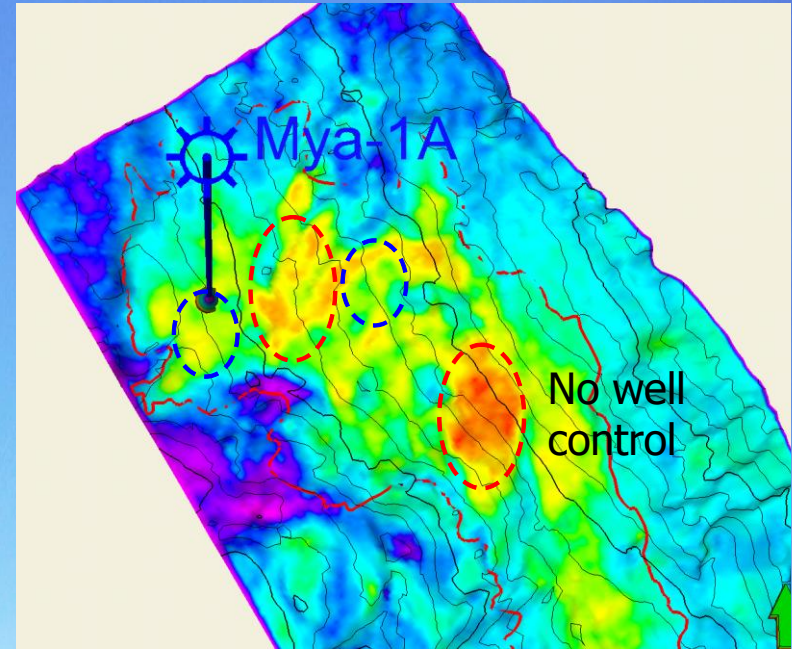
- *Seismic amplitude of Mya field is dimmed due to shallow gas effect.*
- *In order to improve seismic data quality, we have applied dimming compensation with lateral varying wavelet (LVW).*

Discussion

GI: Dimming Compensation



PSDM amplitude



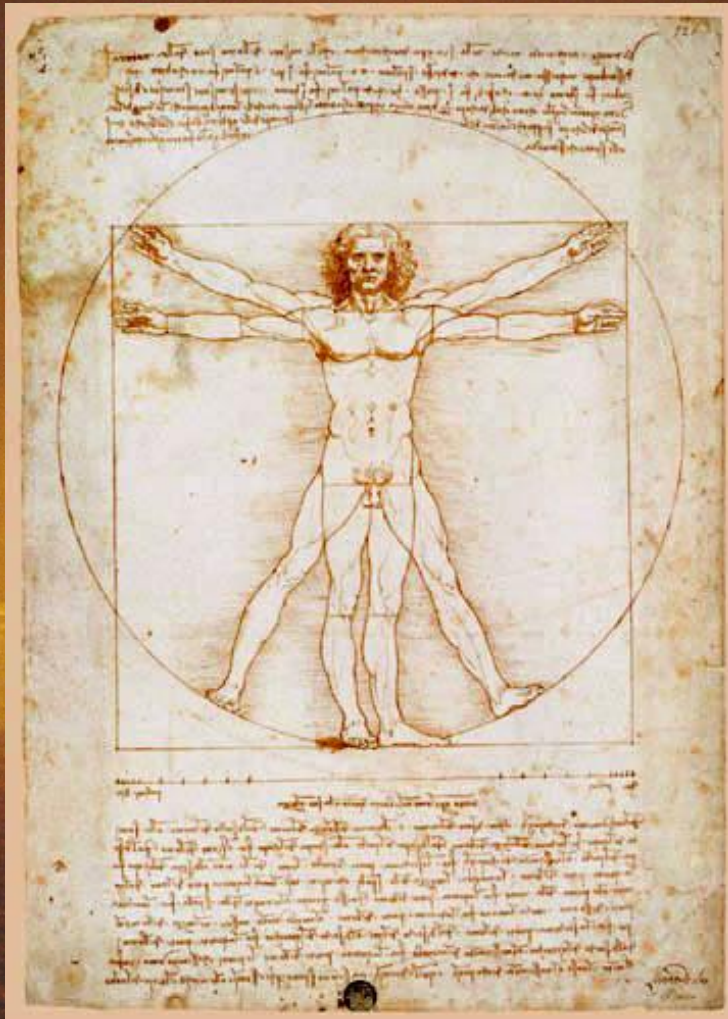
GI (Effective porosity)

- *GI trend is different from PSDM trend in Mya field due to the dimming compensation and well data influence.*
- *Especially there was bull's eye where there is no well control.*
- *We have to QC carefully when applying dimming compensation.*

Conclusion

- There are many difficulties in reservoir characterization due to resolution differences between seismic and well data.
- In order to overcome those difficulties, we applied Geostatistical Inversion which can provide us high vertical resolution results and multiple realizations.
- GI results gives us a higher confidence as a property guidance than seismic and improved geological models significantly.
- GI results should be QCed carefully because there were some trends which may not have a geological meaning.

(The 1st Gas Discovery Well in Block A-1, Offshore Myanmar)



Thank you !

