Application of 3D-trend modelling feature in Petrel to obtain robust geological model and improve history matching accuracy in Pagardewa field.

BANGKITKAN ENERGI NEGERI

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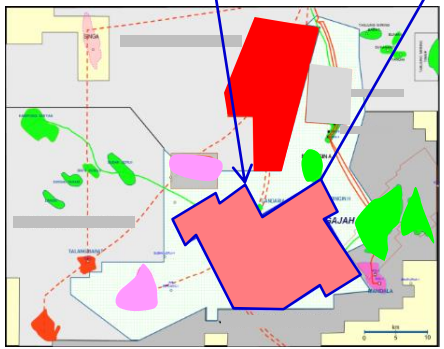
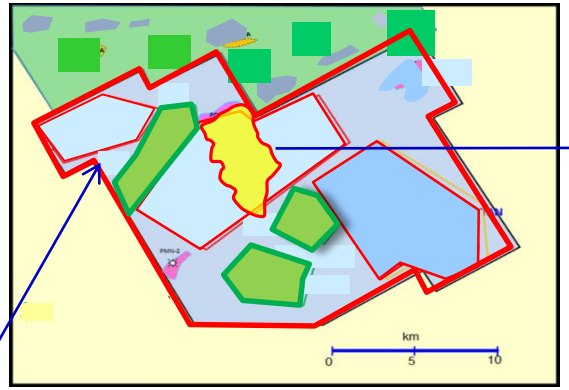
Highlights of Paku Gajah Area

Paku Gajah POD Complex: Phase-I (2012 – 2017)

- Located ± 60 km from Prabumulih City, South Sumatera.
- Total area of POD-I extent: 355 km^2.





: POD Pakugajah Phase-1 & POFD Kuang Phase-2

: POD Pakugajah Phase-2

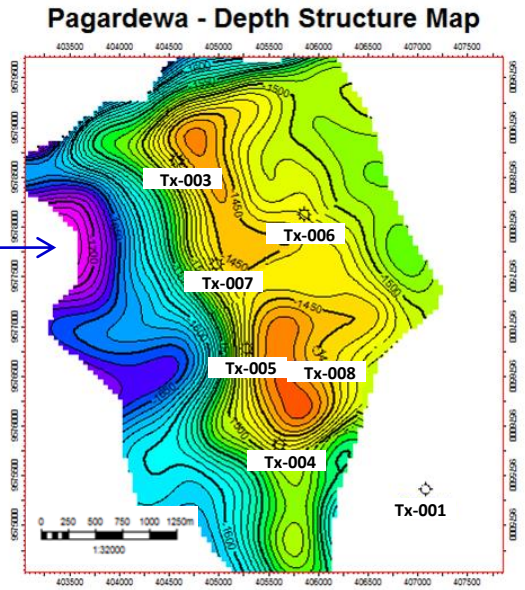
: Pagardewa Structure

Areal extent : 14.46 km

Current prod. (2019) : ± **16 mmscf** Gas & **99 bcpd** Condensate.

Cumulative prod. : **53.6 bscf** Gas & **857 mstb** Condensate*

**(per 31 July, 2019).*



Number of **productive wells**: 6

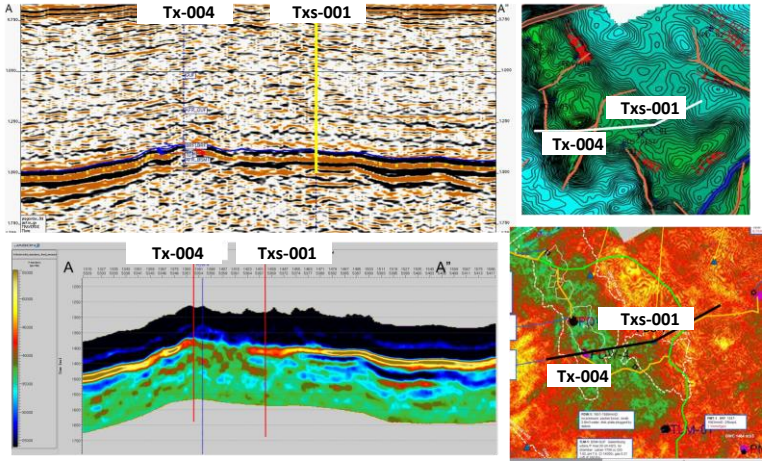
Reservoir : Baturaja Formation (BRF)

Gross thickness : **55 – 110 m** (Avg. 72.5 m)

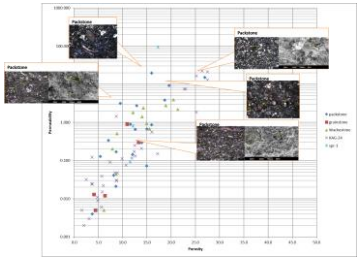
Porosity : **5 – 22 %**

Permeability : **0.001 – 150** mD

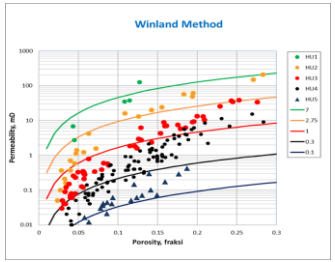
Geological setting, subsurface data, and modeling



Low-Relief carbonates plafform with gentle slope topograph

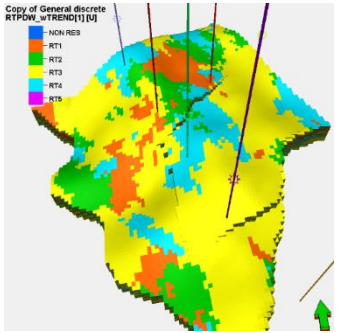


Lithology (core) and petrographic description

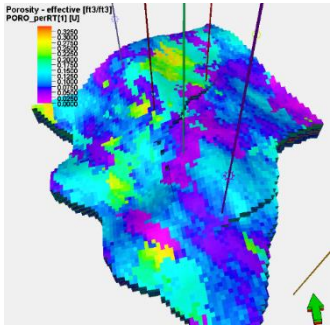


Rock types data (Winland; R35)

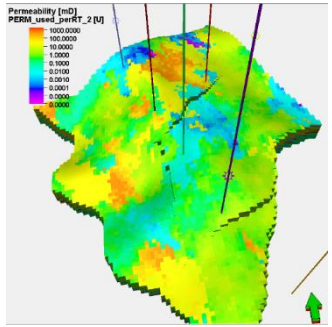
Previous modeling attempts



Facies model



Porosity model



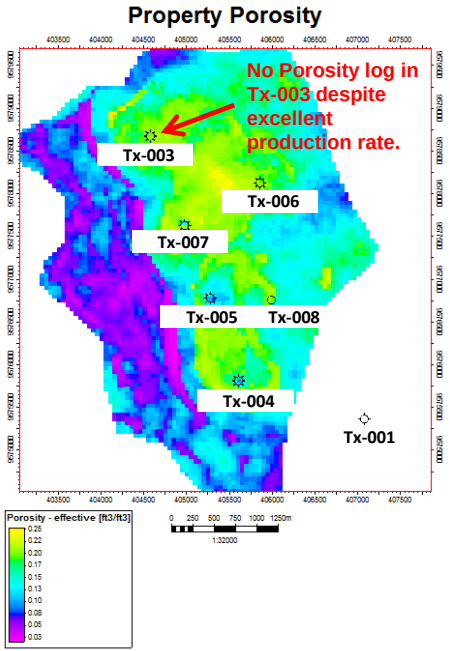
Permeability model

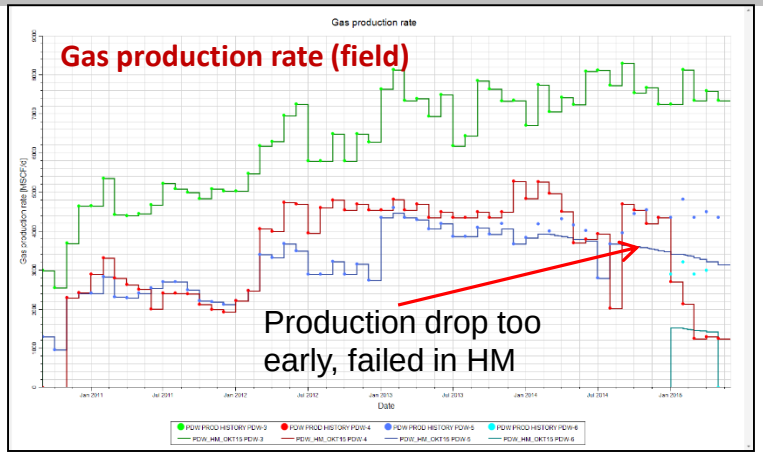
Facies / Rock Type driven: poorly defined reservoir body, loss in porous area, difficult to match volume and pressure, longer simulation runtime.

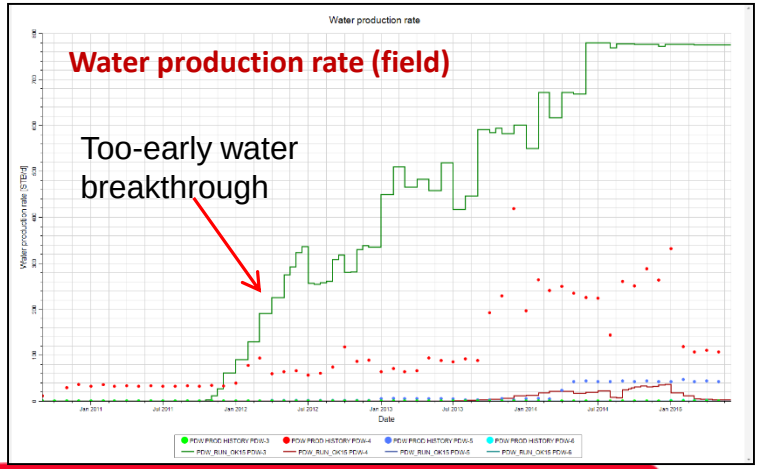
Using better algorithm i.e.: **Truncated Gaussian Simulation** (**TGS**) → better result: smooth property increment, nevertheless, still significant loss of porous area occurred.

Using trend from **Acoustic Impedance and other seismic surface attributes** was not successful in obtaining large Porous area.

Challenges in Reservoir Modeling







Some major challenges include:

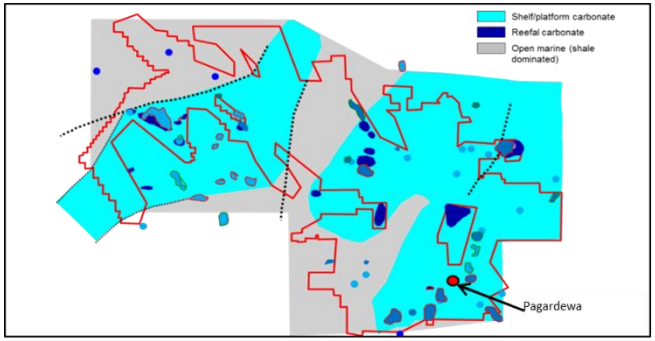
1. Maintain large porous area
2. Prevent early water breakthrough
3. Maintain smooth property increment away from wells

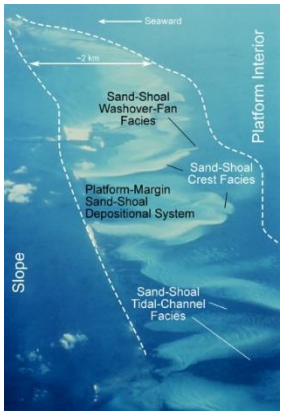
Problems Statement

- **Significant loss of porous area, how to obtain and preserve it better in our model ?**
  - Maintain porous area as optimum as possible by **creating trend** that will preserve it better.
  - Use **Variogram** + **3D trend concurrently** during facies and property modeling.

- **How to overcome pervasive water breakthrough from the area below HC contact?**
  - Create trend that will define clearly **Phreatic** vs. **Vadose** zone → lower porosity and permeability in the **phreatic** zone, hence, limiting the hydrodynamic of water.

Resolving Reservoir Geometry: Porous Area



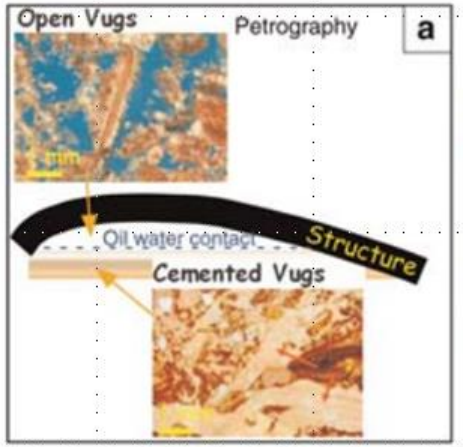


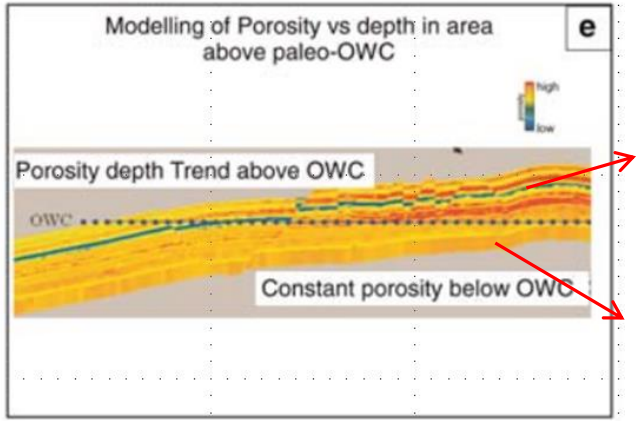
Example for analogues:

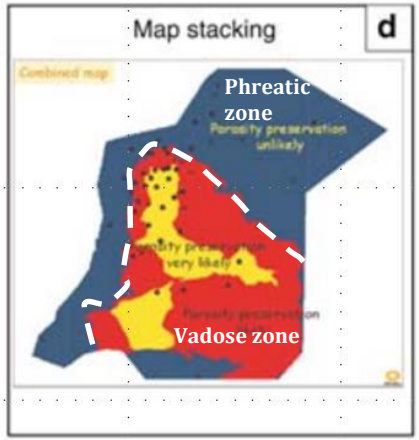
Recent carbonate shoals (platforms) in the Bahamas

- The abundant of micritic matrix & Neomorphism indicates Early diagenesis, in dominantly Phreatic setting (freshwater/marine).
- Change in porosity laterally may not be as heterogeneous as previously thought. **Need to maintain smooth increment of property away from wellbore.**
- The extent of porous & permeable facies are more than what could be resolved by Variogram or Seismic Attribute. **Need to increase the area of porous carbonate body.**

Resolving Early Water Breakthrough





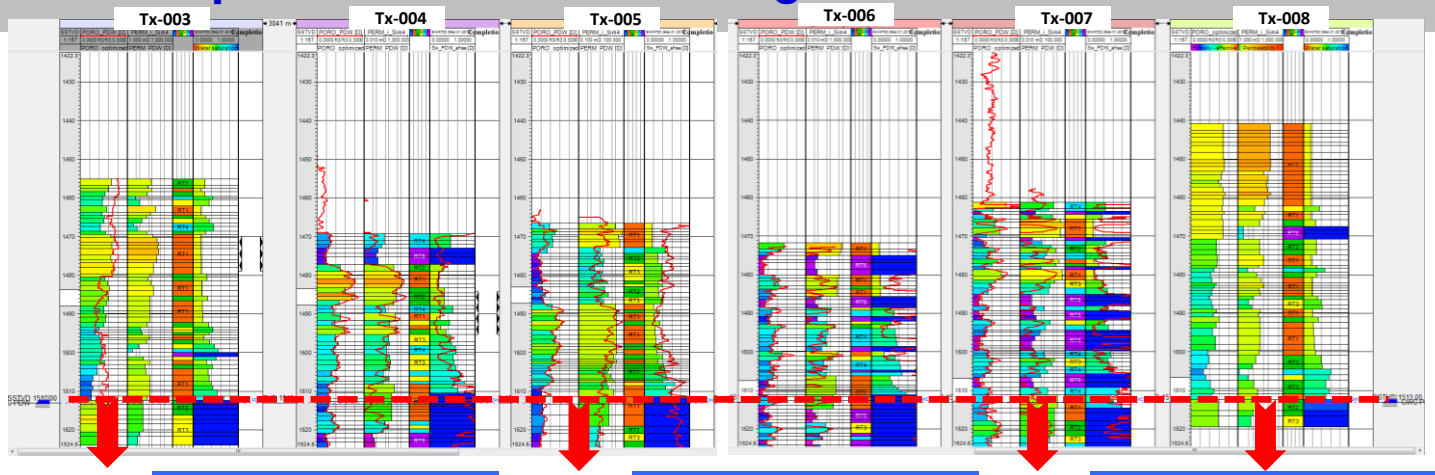


Inspiring work from: **Poppelreiter et.al., 2008.**

Realizing complex carbonate facies, diagenetic and fracture properties with standard reservoir modelling software

MICHAEL C. PÖPPELREITER[1], MARIA A. BALZARINI[2], BIRGER HANSEN[3] & RONALD NELSON[4]

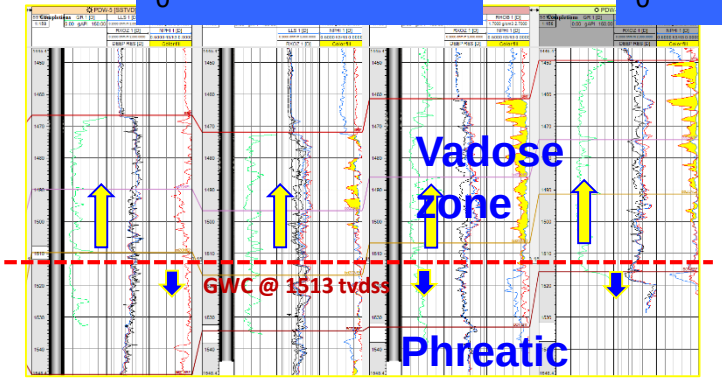
Proposed solution: isolating Phreatic from Vadose

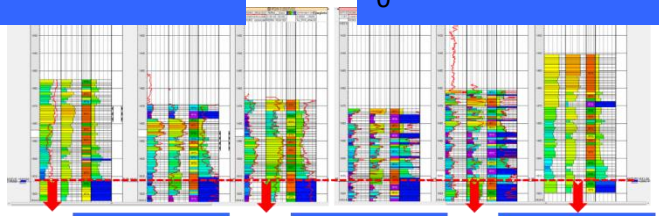


Free-water level / height= 0

Free-water level / height= 0

Free-water level / height= 0





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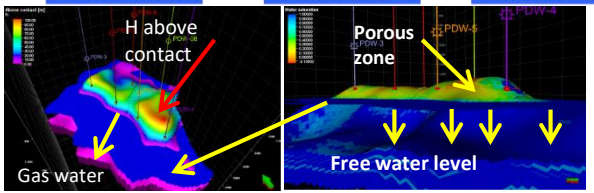


Adaptive Workflow using Petrel's 3D Trend modeling tool

Estimate depth of free water level (FWL) at well log

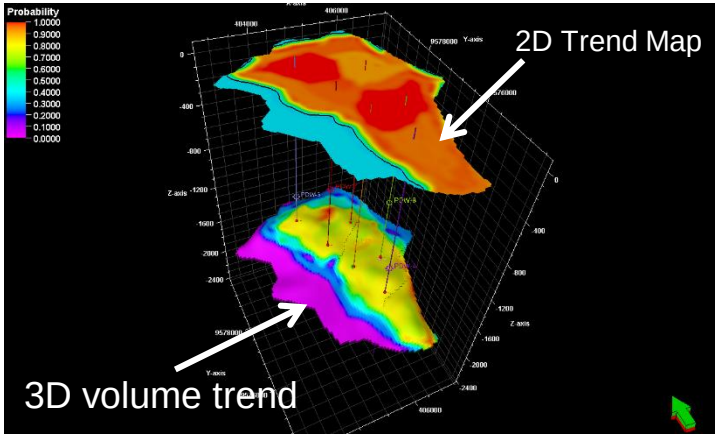
Create Height above FWL on 3D model

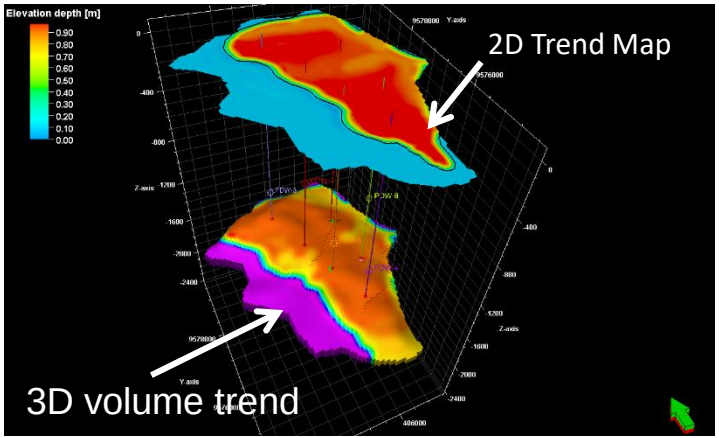
Plot the limit of porous vs non-porous area on 3D model

Create 2D trend Map, assign value (manually) from **0** to **1**

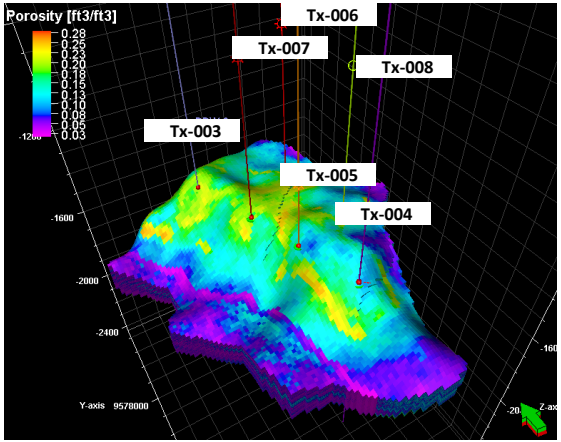
Convert 2D map into 3D Property, use **Linear Combination**

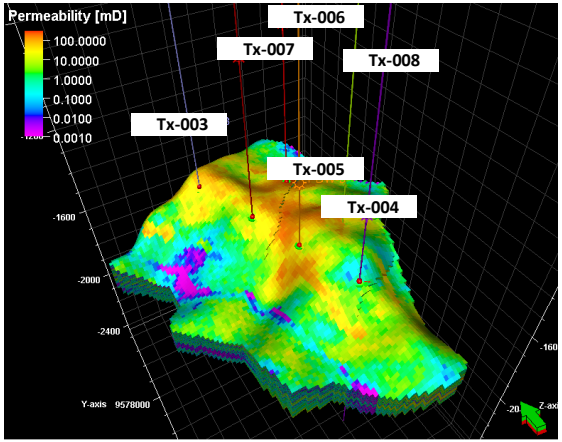
Use 3D trend as Trend in Property & Facies modeling

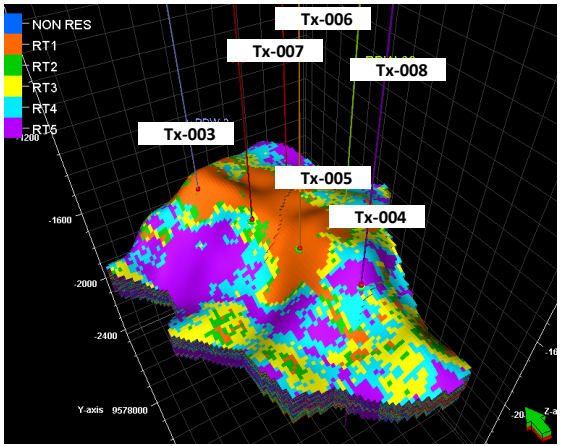


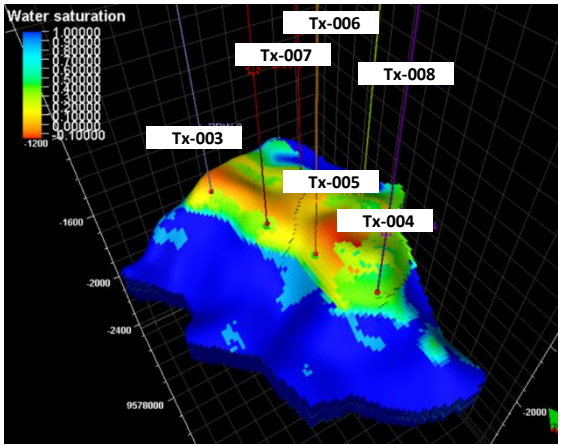


Results: Static Reservoir Properties







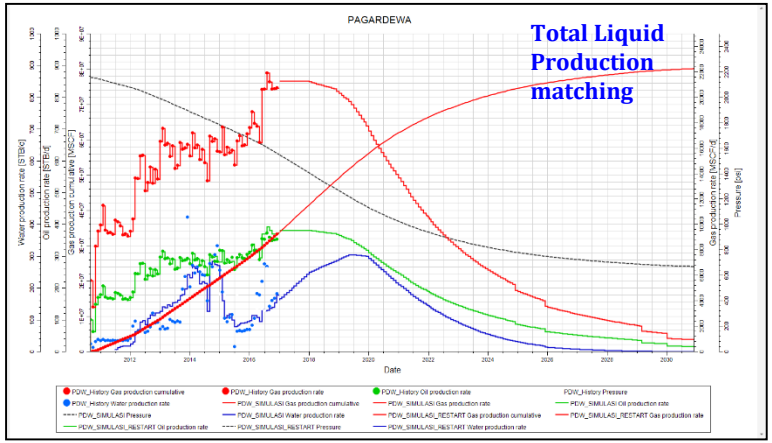


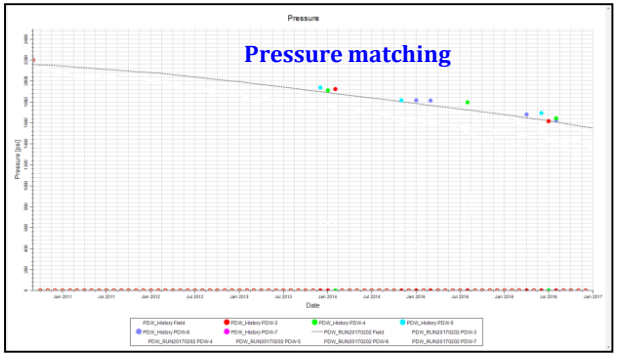
More homogeneous facies and property model have been obtained in Pagardewa Structure.

The **smooth change in facies and porosity- permeability** has been able to optimize porous and permeable distribution area throughout the structure.

Utilization of 3D Trend modelling tool has been proven to be useful in maintaining **accurate property distribution**, **porous area**, and **reduce hydrodynamic** of water below HC contact.

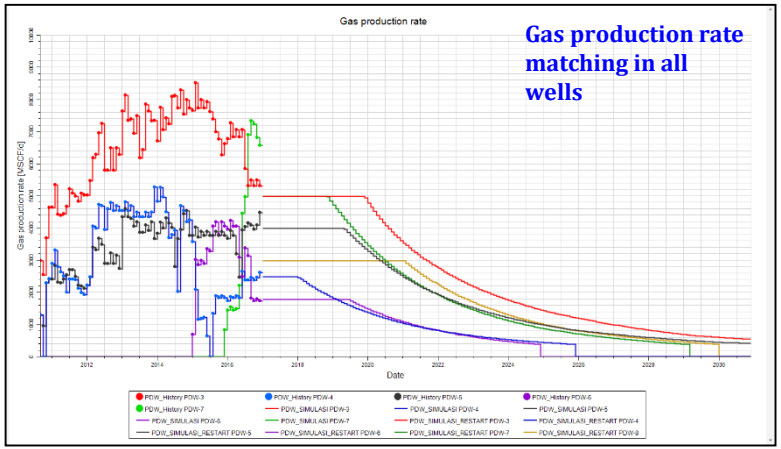
Results: Dynamic Simulation





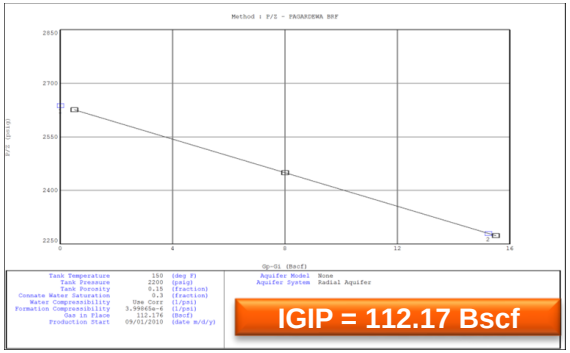
Results after running Dynamic Simulation and History matching show good agreement on Static Volumetric vs. Dynamic Volume.

There is also reasonably good level of matching in Pressure and Production Rate in all wells and the whole field.



Volume matching: static & dynamic

No	Struktur	IGIP, Bscf MBAL	IGIP, Bscf Statik	IGIP, Bscf Dinamik
A	POP			
1	Pagardewa	112.17	113.70	114.23



Conclusion

- **Implementing fundamental concepts of carbonate sedimentology and how the diagenesis works has brought significant impact in improving level of accuracy of the geological model**. This has been tested and verified during reservoir simulation and history matching processes.
- What's more important, is **to bring all the concepts into a suitable/unique workflow that is technically feasible to be executed by software,** and can be easily replicated by other workers or other field with reasonably similar case.
- An enhanced modelling tool that may resembles specific reservoir body and enable geoscientists to build **unique geometry of porous body** and inserting particular diagenetic information (i.e. carbonates setting), may be the next 'big leap' in the competitive world of commercial earth-modeling software.

TERIMA KASIH

BANGKITKAN ENERGI NEGERI