Reducing the Uncertainty of Static Reservoir Model in a Carbonate Platform, through the Implementation of an Integrated Workflow: Case A-Field, Abu Dhabi, UAE*

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Abstract

Predicting the spatial distribution of petrophysical properties within heterogeneous reservoirs is affected by significant uncertainties when based only on well information. However, integrating additional constraints, such as 3D seismic data and sedimentary concepts, can significantly improve the accuracy of reservoir models and help reduce uncertainties on predictions away from wells.

The aim of this study is to build a reliable 3D geological static model using petrographic and sedimentary reports and current understanding of the sedimentary conceptual model for the field. These core interpretations provide a clear description of the facies architecture across the A-Field, serve as excellent reference during seismic stratigraphy interpretations, and lead into a more geological distribution of the petrophysical properties in the reservoir through the facies models.

In the area of interest, Reservoir 1 is dominated by skeletal peloidal packstone with common thin, interbedded good-reservoir-quality rudstone and algal unit in the upper part of the reservoir. Reservoir 2, on the other hand is dominated by foraminiferal algal peloidal packstones with thin units of floatstone.

An integrated approach for facies modeling was implemented in order to generate stochastic models of the facies associations capable of reproducing the natural transition through the sequences. This method was adopted to model the high-resolution

prograding pulses in the carbonate platform that were interpreted through cores description and facies association for both reservoirs.

The final 3D sedimentary-stratigraphic architecture is used as the main constraint to model the petrophysical properties for each reservoir. Under this approach, these models can account for the varying spatial continuity of reservoir properties honoring the different sedimentary facies. Facies-based property models preserve the facies- specific statistical distribution of the property, as well as its depositional direction. The facies-based, 3D petrophysical models provide an improved prediction of petrophysical properties distribution and reservoir heterogeneity. The permeability simulation based on facies and the cloud transform between porosity and permeability allows better control across the reservoir of spatial connectivity patterns that could be used for improved reservoir performance prediction as carried out in the present static model.

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AAPG
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EUROPEAN ASSOCIATION OF GEOSCIENTISTS & ENGINEERS
SEG
Society of Exploration Geophysicists
The international society of applied geophysics
ادارة المعارض العربية
Arabian Exhibition Management

Presentation Outline

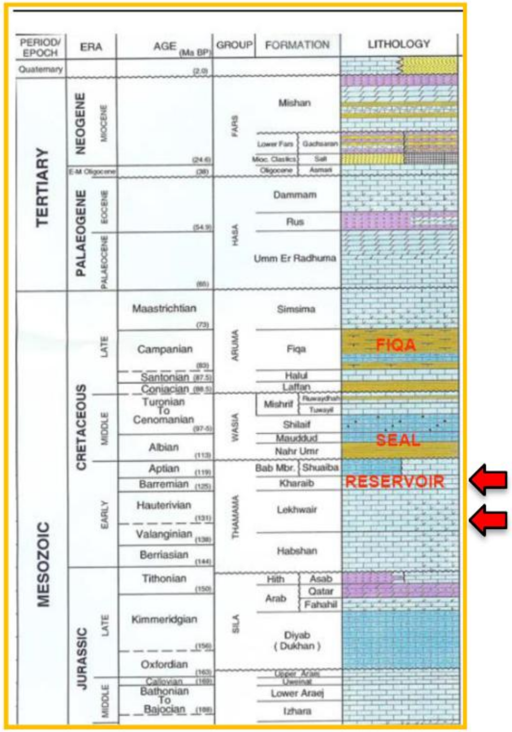
1. Objective
2. Definition of Geological and Geophysical Uncertainties
3. Geological Static Model (Base Case)
    a. Structural Framework
    b. Facies Modeling
    c. Petrophysical Modeling
4. Modeling Uncertainties in Realizations
5. Sensitivity Analysis
6. Conclusions

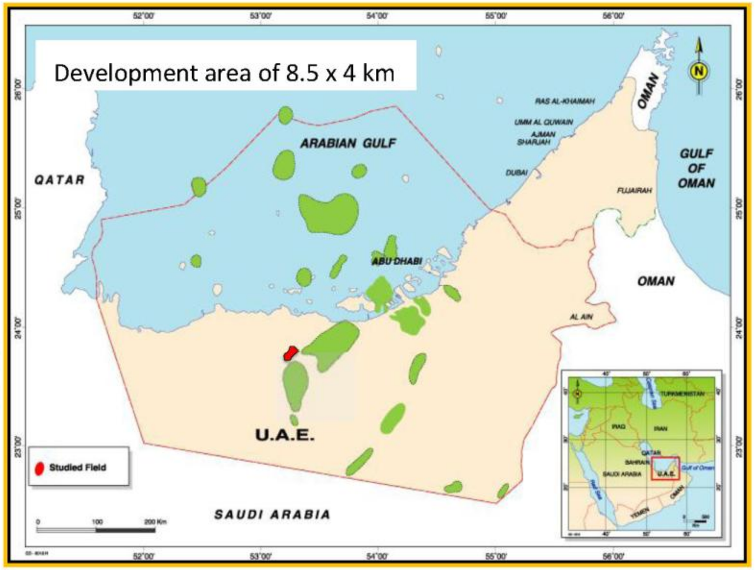
1. Objective

- Implementation of an Integrated Workflow in order to reduce the Uncertainty of Static Reservoir Model in a Carbonate Platform.

Overview

Field A




Development area of 8.5 x 4 km

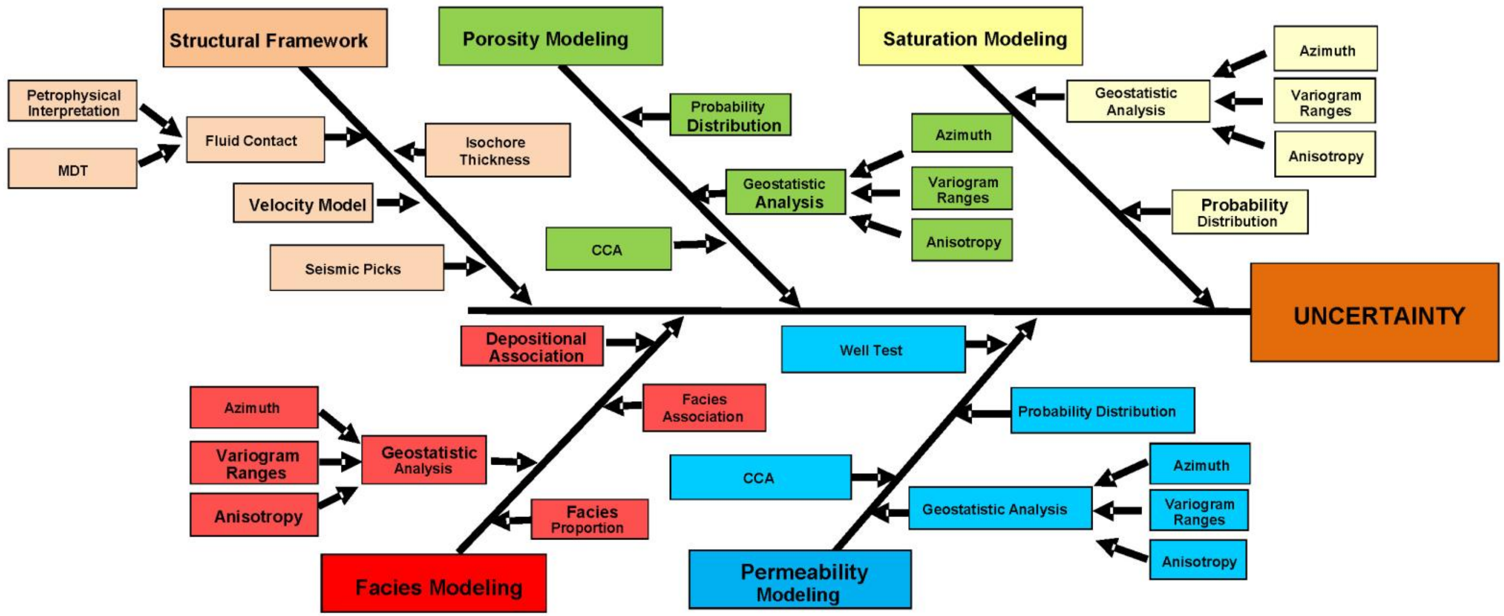
- Ø (%): R1: 18 - 27
  R2: 15 - 18
- K (mD): R1: 25 - 70
  R2: 5 - 10
- Thick (ft.): R1: 150
  R2: 20

Slightly elongated low-relief structure with a NNE-SSW trend located between two giant fields.

Presenter's notes: Currently two reservoirs are under production.

2. Definition of geological and geophysical uncertainties

Fishbone Diagram



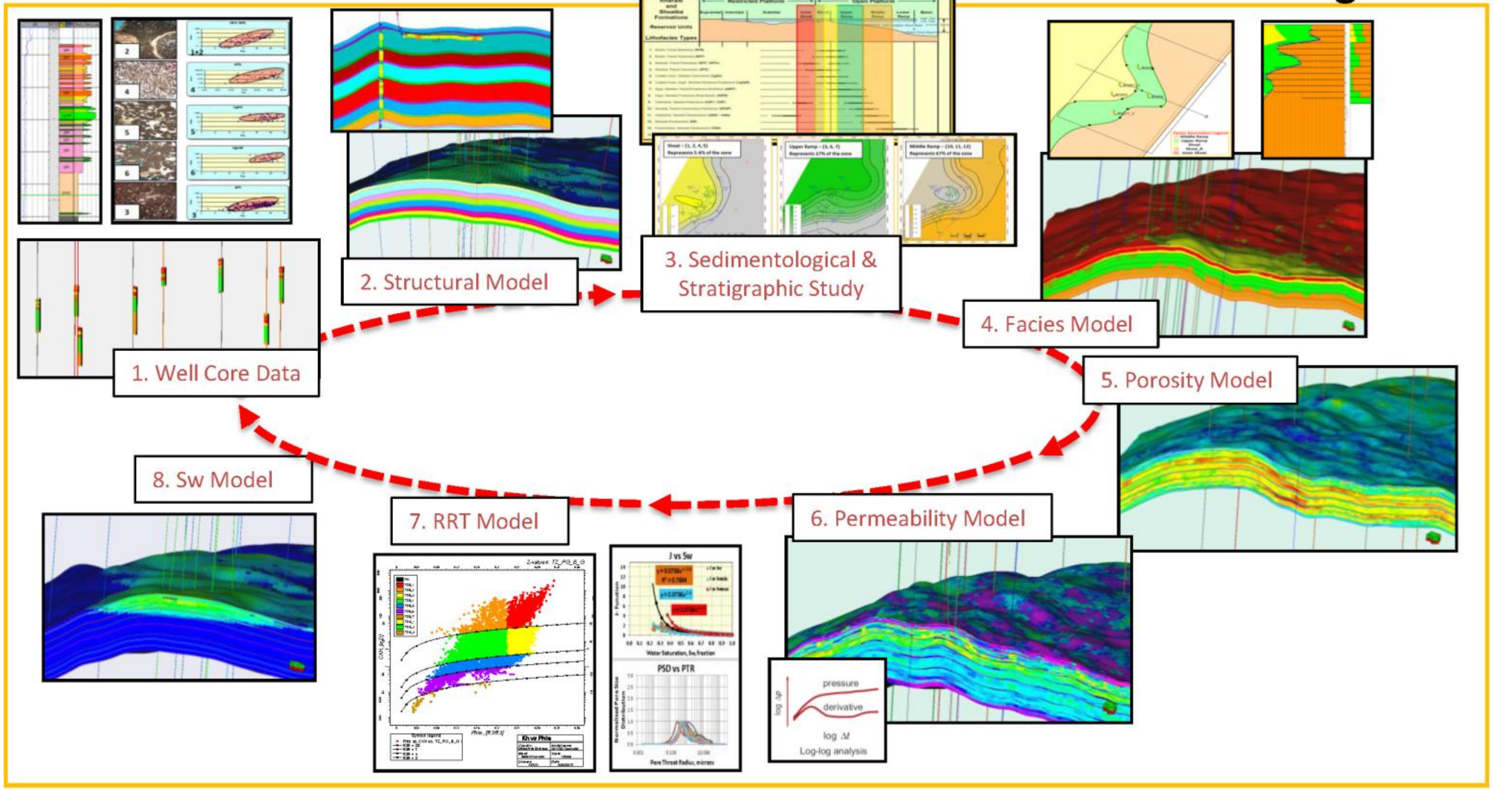
UNCERTAINTY

- **Structural Framework**
  - Fluid Contact
    - Petrophysical Interpretation
    - MDT
  - Isochore Thickness
  - Velocity Model
  - Seismic Picks
- **Porosity Modeling**
  - Probability Distribution
  - Geostatistic Analysis
    - Azimuth
    - Variogram Ranges
    - Anisotropy
  - CCA
- **Saturation Modeling**
  - Geostatistic Analysis
    - Azimuth
    - Variogram Ranges
    - Anisotropy
  - Probability Distribution
- **Facies Modeling**
  - Depositional Association
  - Facies Association
  - Geostatistic Analysis
    - Azimuth
    - Variogram Ranges
    - Anisotropy
  - Facies Proportion
- **Permeability Modeling**
  - Well Test
  - Probability Distribution
  - CCA
  - Geostatistic Analysis
    - Azimuth
    - Variogram Ranges
    - Anisotropy

Presenter’s notes: As it is humanly impossible to work with all variables in all processes related with all uncertainty analysis, the solution is concentrated only in the variables directly linked with the construction of the geological static model.

3. Geological Static Model

Workflow



1. Well Core Data

2. Structural Model

3. Sedimentological & Stratigraphic Study

4. Facies Model

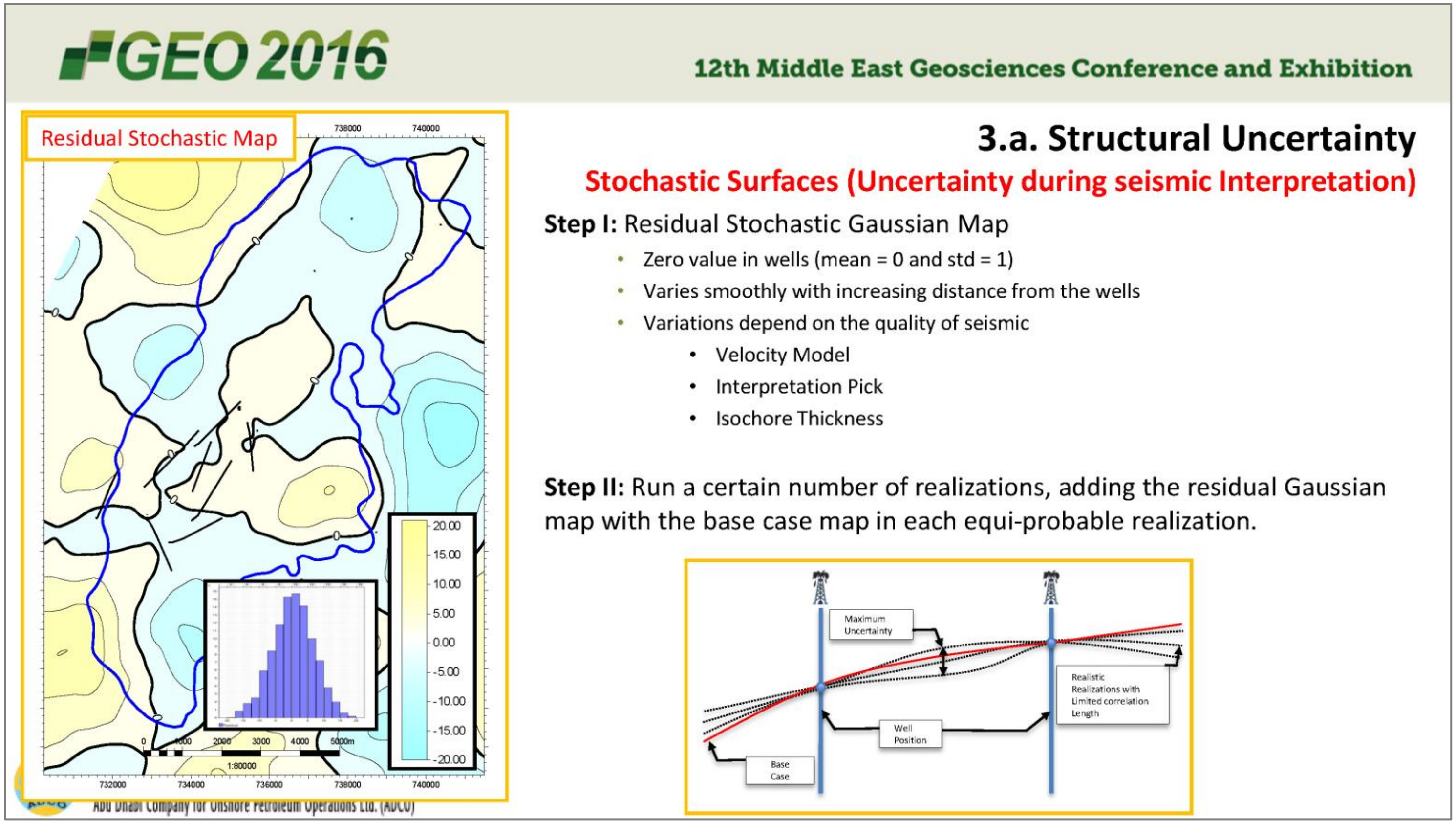
5. Porosity Model

6. Permeability Model

7. RRT Model

8. Sw Model

Presenter's notes: With the purpose to integrate the sedimentological knowledge, we build maps which were used during Facies Modeling and honor the sedimentology distribution according to the facies definition in well cores. PHIE and K models were built using the facies trends as a constrain. Water Saturation model was built using 3 different cases per J-Function in each RRT defined.



3.a. Structural Uncertainty

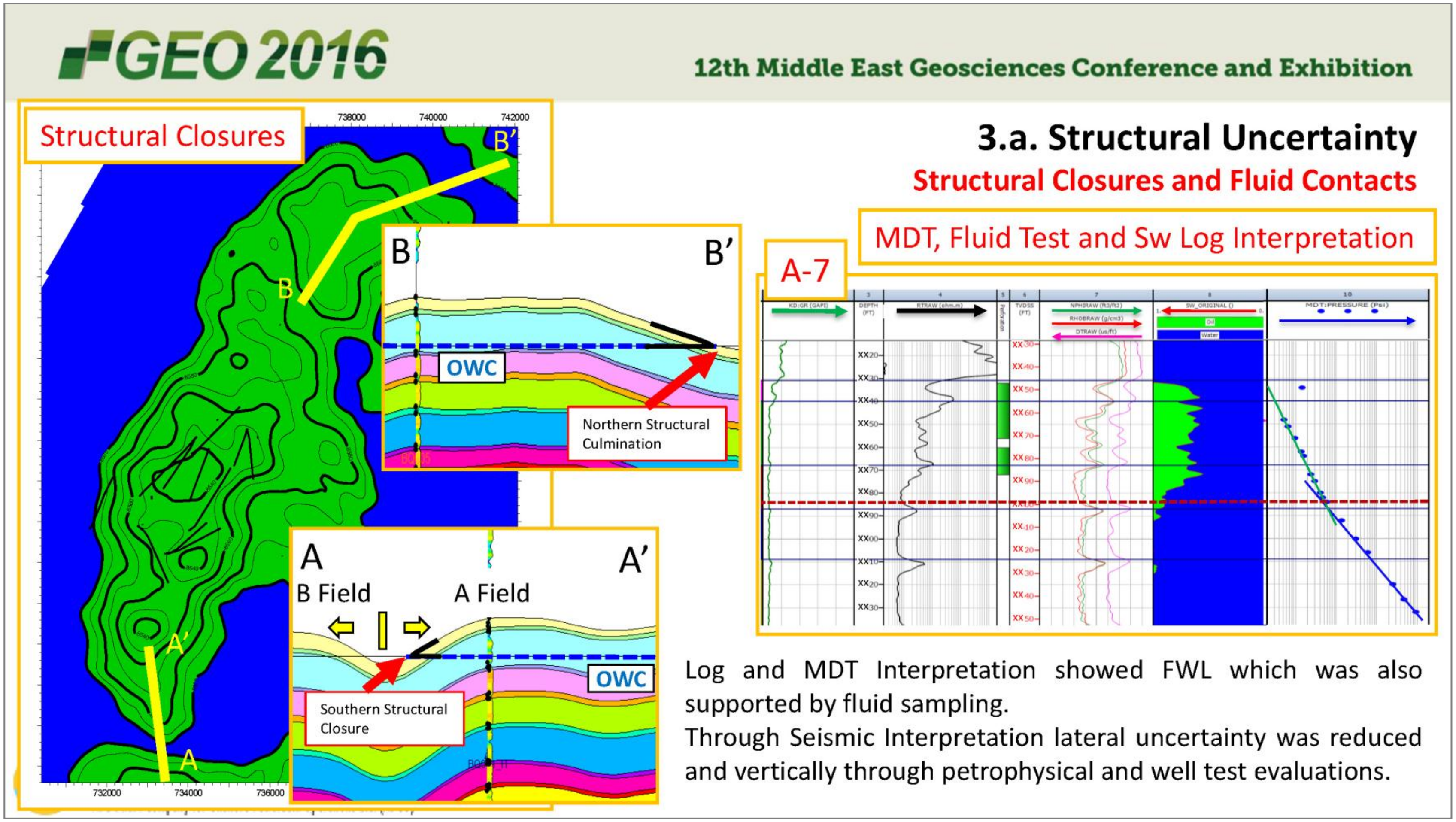
Stochastic Surfaces (Uncertainty during seismic Interpretation)

Step I: Residual Stochastic Gaussian Map

- Zero value in wells (mean = 0 and std = 1)
- Varies smoothly with increasing distance from the wells
- Variations depend on the quality of seismic
    - Velocity Model
    - Interpretation Pick
    - Isochore Thickness

Step II: Run a certain number of realizations, adding the residual Gaussian map with the base case map in each equi-probable realization.

Presenter's notes: We can summarize the uncertainty taking into consideration the vertical seismic resolution and the distance between the wells; such information allowed generating a residual stochastic Gaussian map which has the following characteristics: Zero value in wells, as we move away from the wells; the uncertainty rises gradually to achieve the maximum uncertainty; such location has no control points and generally is located downdip from the flank of crest. Residual stochastic maps are particularly useful for incorporating realistic lateral variations, such as increased uncertainty away from well data and downdip. This uncertainty is very critical because it affects directly the reservoir thickness. We can make the mistake of overestimating or underestimating the volume. These maps can be based on well miss-ties, analysis of stacking velocities and general time interpretation uncertainty, usually defined by small time shifts of interpreted horizons. The time shift can either be a constant or can vary laterally to reflect varying quality of the seismic response or increasing uncertainty across major faults.



3.a. Structural Uncertainty

Structural Closures and Fluid Contacts

Structural Closures

MDT, Fluid Test and Sw Log Interpretation

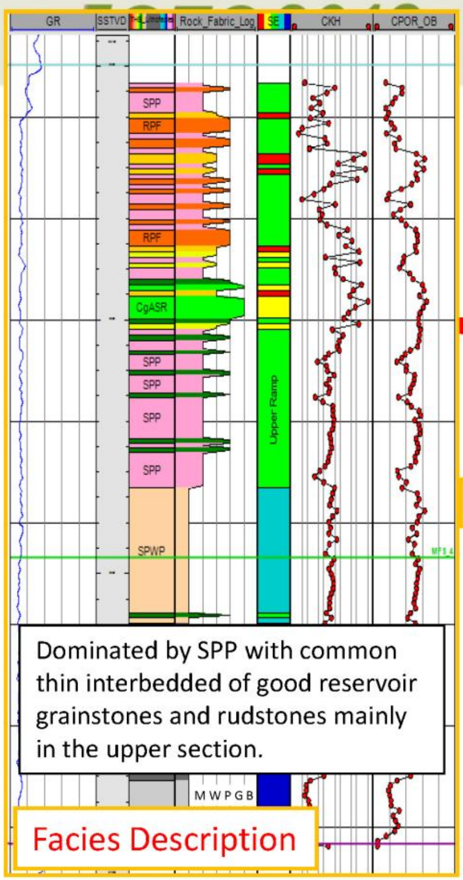
A-7

Log and MDT Interpretation showed FWL which was also supported by fluid sampling.
Through Seismic Interpretation lateral uncertainty was reduced and vertically through petrophysical and well test evaluations.

Presenter's notes: As other structural uncertainties, the structural closures were defined with the help of the geophysicist and petrophysiicists; the spill points were identified through seismic horizon interpretation and confirmed with log response in the northern and southern area, showing the disconnection between nearby fields in the intersections A and B. The fluids contact was confirmed using reliable MDT data, integrated with petrophysical evaluation and fluid sampling. In this way, we are closing the uncertainty laterally mainly through seismic interpretation and vertically through petrophysical and well test evaluations.

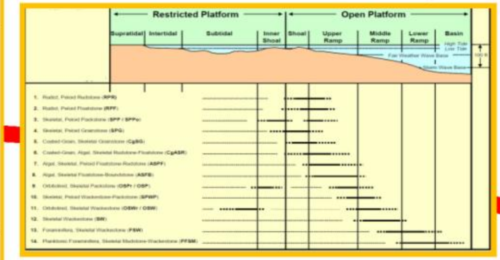
3.b. Facies Modeling

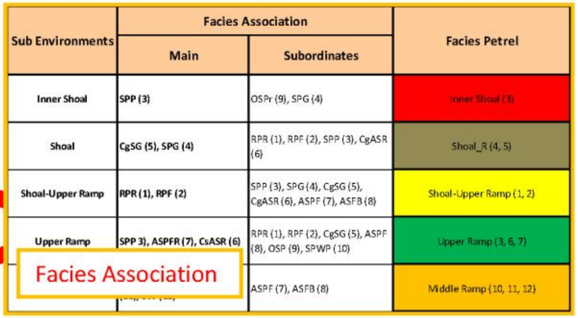
Facies, Facies Association, Depositional Environment



Dominated by SPP with common thin interbedded of good reservoir grainstones and rudstones mainly in the upper section.

Facies Description

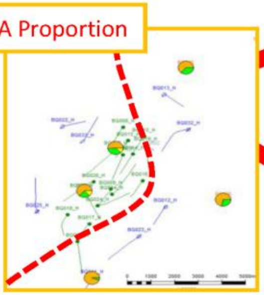


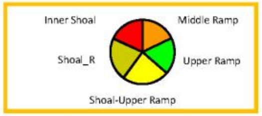


Sub Environments	Facies Association		Facies Petrel
	Main	Subordinates	
Inner Shoal	SPP (3)	OSPr (9), SPG (4)	Inner Shoal (3)
Shoal	CgSG (5), SPG (4)	RPR (1), RPF (2), SPP (3), CgASR (6)	Shoal_R (4, 5)
Shoal-Upper Ramp	RPR (1), RPF (2)	SPP (3), SPG (4), CgSG (5), CgASR (6), ASPF (7), ASFB (8)	Shoal-Upper Ramp (1, 2)
Upper Ramp	SPP 3), ASPFR (7), CsASR (6)	RPR (1), RPF (2), CgSG (5), ASPF (8), OSP (9), SPWP (10)	Upper Ramp (3, 6, 7)
[illegible]	[illegible]	ASPF (7), ASFB (8)	Middle Ramp (10, 11, 12)

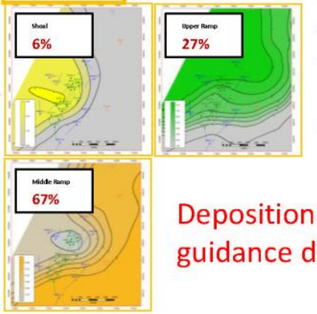
Facies Association

FA Proportion





FA Maps



- The depositional trend.
- Boundary of facies.
- Estimate and propose fluid flow trend.
- As a guidance to define layer cake / clinoform structures, etc.

Depositional sedimentary trend is used as guidance during 3D modeling

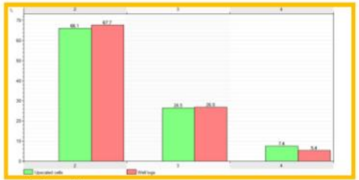
Presenter's notes: The 14 facies with their own descriptions and petrophysical properties (mainly porosity and permeability). During Facies association interpretation, the facies were joined according to their depositional sub-environment interpreted—resulting in 5 Facies associations. The same ones were independently mapped according their proportion in each zone.

Depositional trend is used as guidance during variogram calculation. Propose fluid flow direction: fluids move faster through the same facies with same petrophysical parameters. Average porosity (18 to 27%) and permeability (25 to 70 mD).

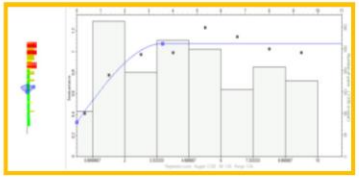
3.b. Facies Modeling

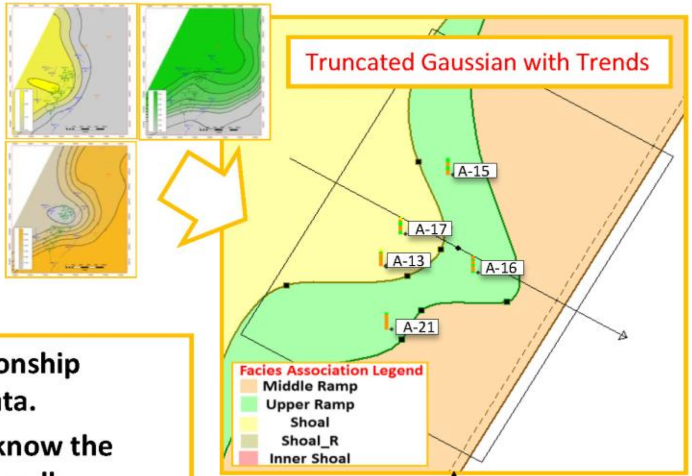
3D Model Algorithm - Intersection

Distribution

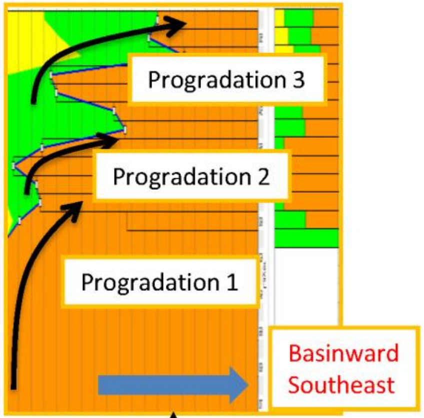


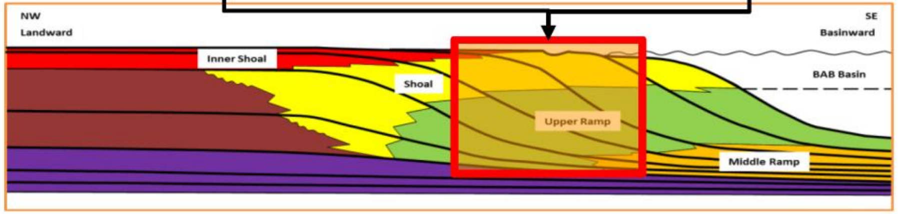
Variograms





Vertical Proportion Curve



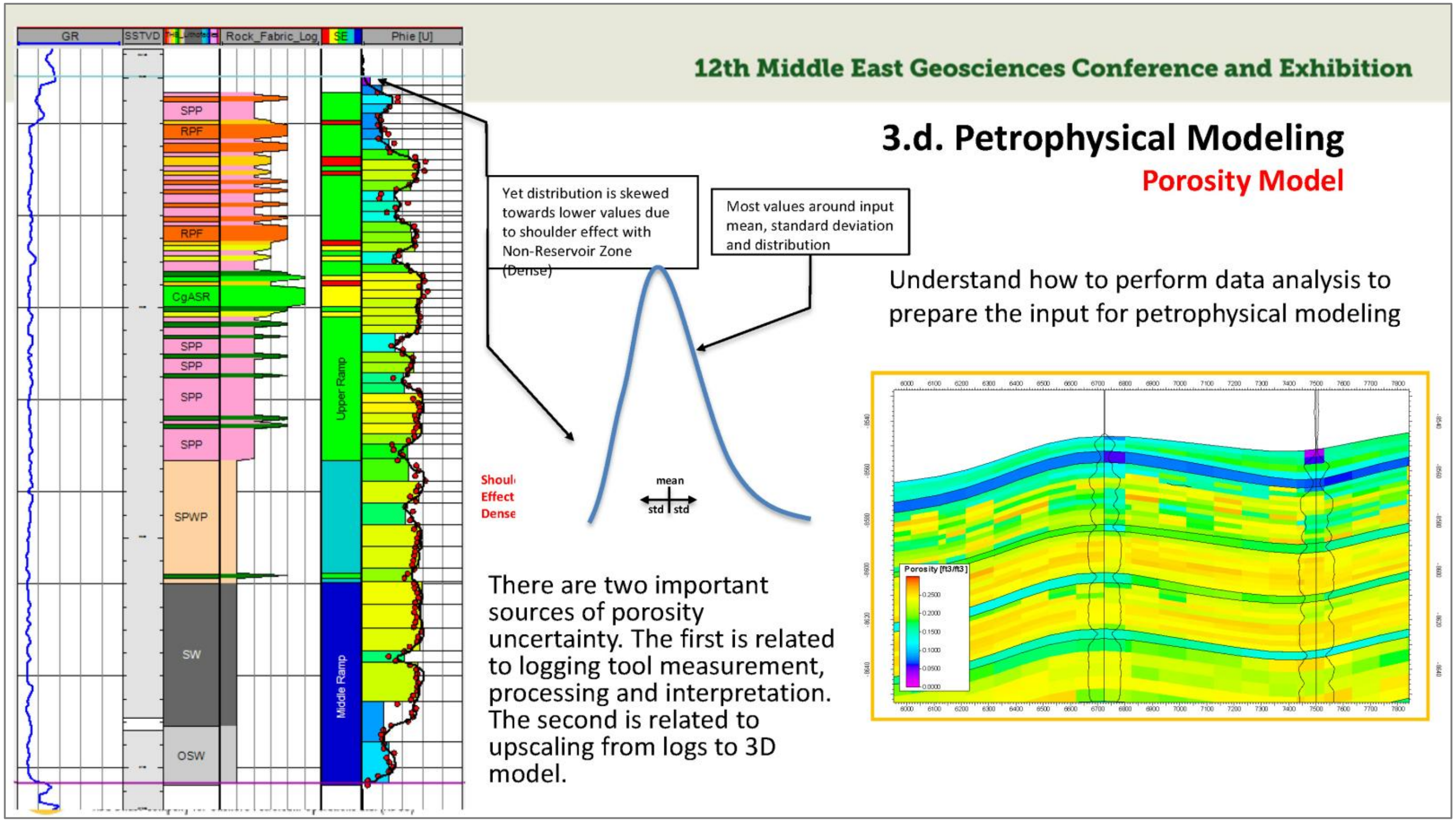


Histogram shows good relationship between upscaled and log data.

Variograms were defined to know the spatial relationship between wells.

VPC avoids vertical stationary distribution.

Presenter's notes: The methods used TGT and FA maps, were to mimic the areal distribution of Facies Association mapped. Vertically, VPC was estimated in order to avoid the vertical stationary position of facies and allowing the progradation of the platform over the carbonate ramp. As we move away from the cores, the uncertainty rises.



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3.d. Petrophysical Modeling

Porosity Model

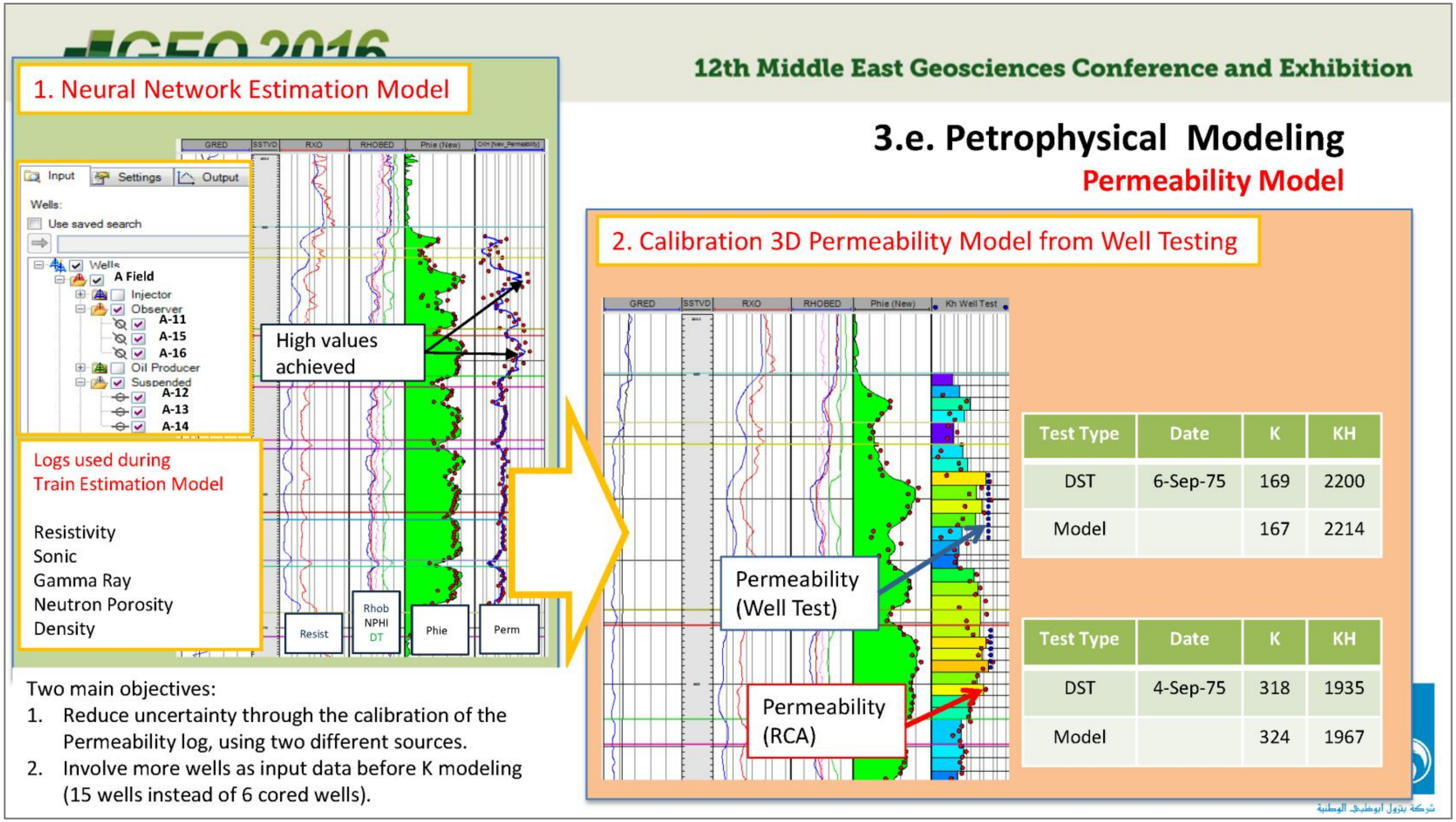
Yet distribution is skewed towards lower values due to shoulder effect with Non-Reservoir Zone (Dense)

Most values around input mean, standard deviation and distribution

Understand how to perform data analysis to prepare the input for petrophysical modeling

There are two important sources of porosity uncertainty. The first is related to logging tool measurement, processing and interpretation. The second is related to upscaling from logs to 3D model.

Presenter's notes: As shown in porosity and during the upscaling, very low values were considered from the adjacent zone; therefore the distribution is skewed toward low values. The shoulder effect is inherent uncertainty due of vertical resolution of logs, calibration of logs or definition of well tops; it is more pronounced between reservoir and non-reservoir zones, but it also needs to be considered within reservoir zones. Reservoir model porosities were derived from log porosities calibrated to core measurements. Resulting uncertainty was obtained by considering an aerial distribution of porosities. The porosities considered are vertical averages over reservoir thickness. Porosity is a key component of reservoir Pore Volume and hence of the resource base for the field. Since the porosity defines the volumes of moveable fluids in the reservoir, measurements of the effective porosity of the reservoir rock are also required.



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3.e. Petrophysical Modeling

Permeability Model

1. Neural Network Estimation Model

Logs used during Train Estimation Model

- Resistivity
- Sonic
- Gamma Ray
- Neutron Porosity
- Density

Two main objectives:

1. Reduce uncertainty through the calibration of the Permeability log, using two different sources.
2. Involve more wells as input data before K modeling (15 wells instead of 6 cored wells).

2. Calibration 3D Permeability Model from Well Testing

Test Type	Date	K	KH
DST	6-Sep-75	169	2200
Model		167	2214

Test Type	Date	K	KH
DST	4-Sep-75	318	1935
Model		324	1967

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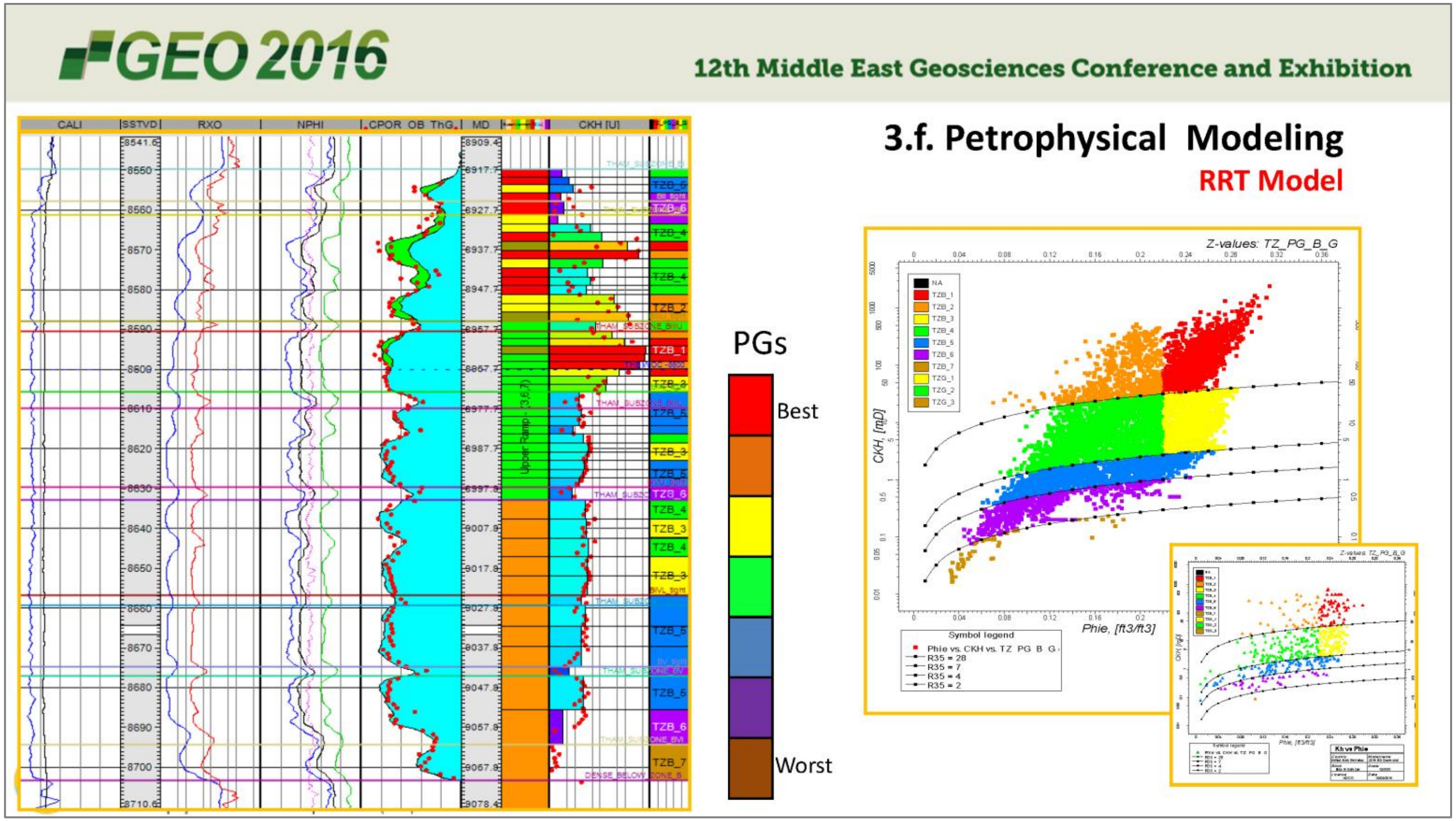
Presenter's notes: To work with RCA K data, it was necessary to build a continuous curve. As a first step, A neural network model was constructed using 5 logs as input data and K values as guidance; for that, 2 wells were used as blind test, to QC the K estimation. As a second step, model the synthetic permeability for all wells; permeability was interpreted from well test and used to calibrate the log with two main objectives:

1. Reduce uncertainty through the calibration of the Permeability log, using two different sources. 2. Involve more wells as input data before K modeling--15 wells instead of 6 cored wells.



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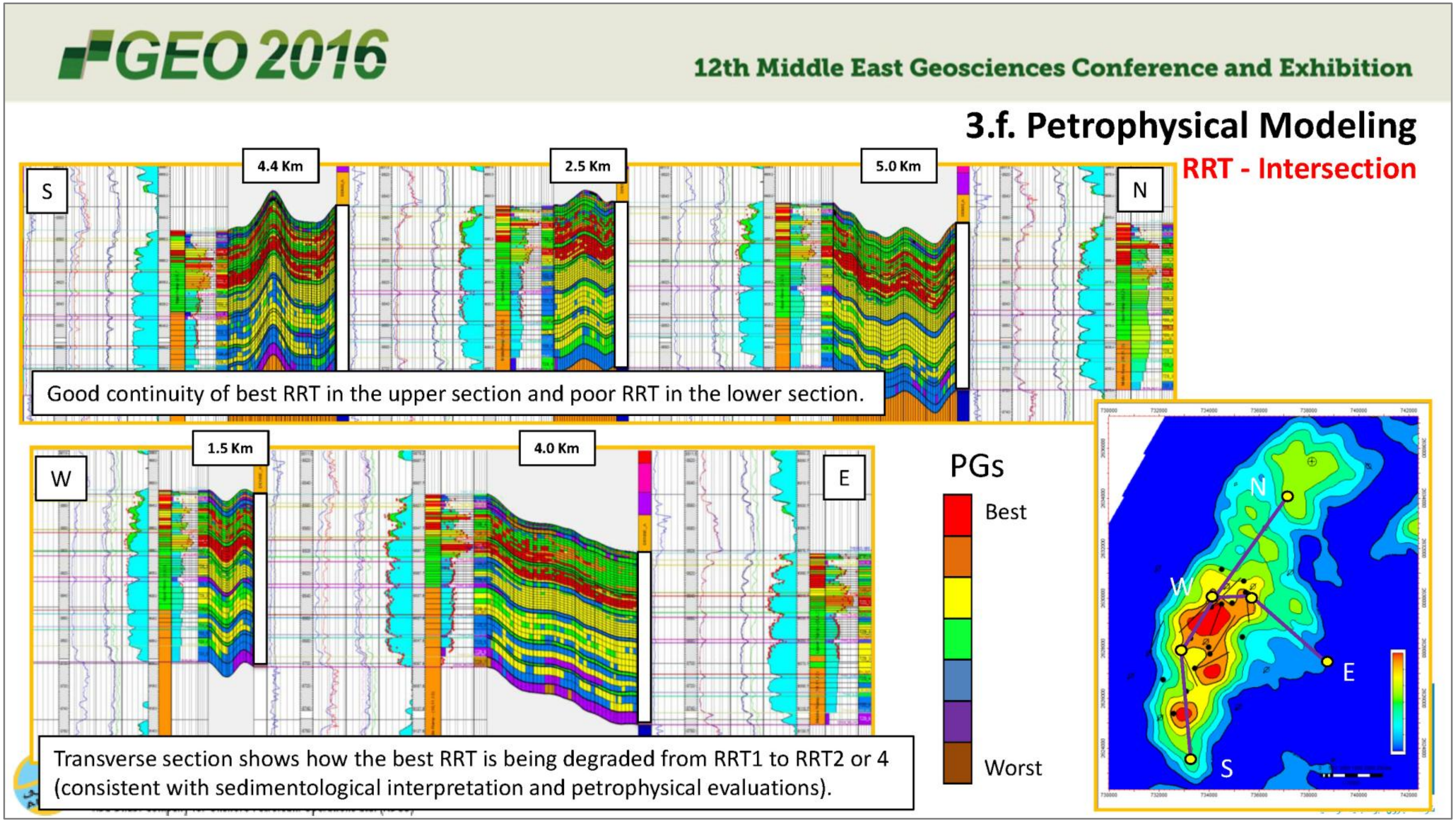
3.f. Petrophysical Modeling

RRT Model

Presenter's notes: The final result after use of Permeability and Porosity (RCA) to compute Empirical Winland R35 equation, validated with MICP and joined with samples according to their response in terms of Mercury Saturation vs. PTS and Mercury Saturation vs. Pc. The well presents two zones with high permeability, which is captured by one RRT, and the RRTs are decreasing gradually in terms of quality downward.

1. Permeability, Porosity 2. Compute the Pore Throat Size base on Empirical Winland R35 Equation. 3. R35 Validation Using MICP.

4. Generation Flow Units based on PTS and normalized cumulative Flow Capacity.



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3.f. Petrophysical Modeling

RRT - Intersection

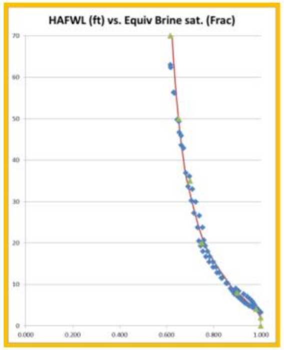
Good continuity of best RRT in the upper section and poor RRT in the lower section.

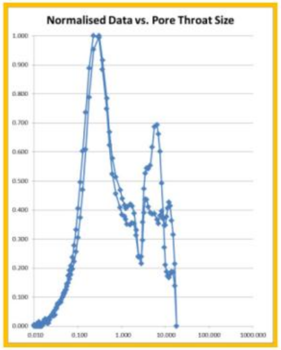
Transverse section shows how the best RRT is being degraded from RRT1 to RRT2 or 4 (consistent with sedimentological interpretation and petrophysical evaluations).

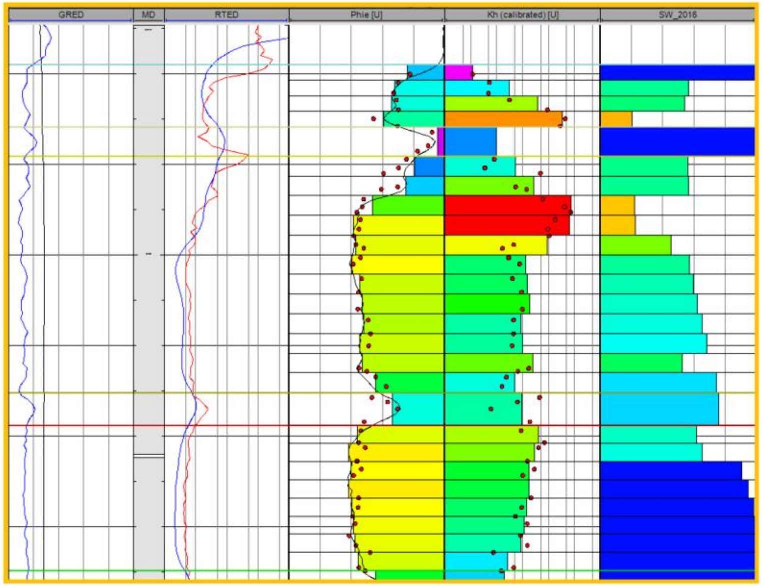
Presenter's notes: Longitudinal and transverse intersections show the lateral variation of RRT. From south to north there is good continuity of best RRT in the upper section and poor RRT in the lower section, whilst in the transverse section (W-E) the best RRT is being degraded from RRT1 to RRT2 or 4, consistent with the sedimentological interpretation and petrophysical evaluations.

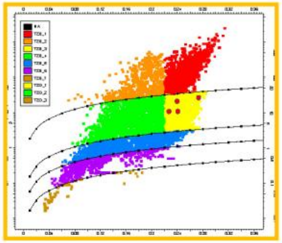
3.g. Petrophysical Modeling

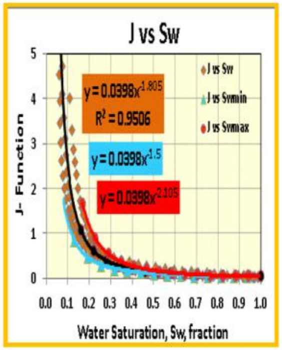
SW Model





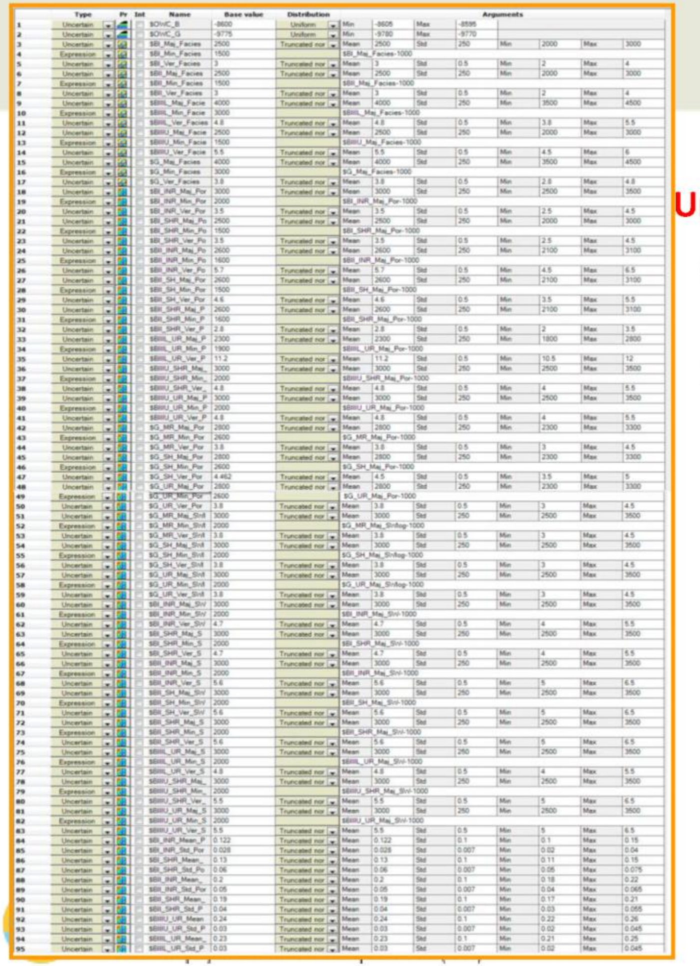






PC property assigned to Transverse section shows how the best RRT are being degraded from RRT1.

Presenter's notes: Having generated the RRT, Pc property is calculated and 3 different SW equations (Min, Mean and Max) are calculated for each RRT, trying to match the model with current SW log interpretation.



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2	Uncertain		☐	$OWC_G	-9775	Uniform	Min	-9780	Max	-9770				
3	Uncertain		☐	$BI_Maj_Facies	2500	Truncated nor	Mean	2500	Std	250	Min	2000	Max	3000
4	Expression		☐	$BI_Min_Facies	1500		$BI_Maj_Facies-1000							
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6	Uncertain		☐	$BII_Maj_Facies	2500	Truncated nor	Mean	2500	Std	250	Min	2000	Max	3000
7	Expression		☐	$BII_Min_Facies	1500		$BII_Maj_Facies-1000							
8	Uncertain		☐	$BII_Ver_Facies	3	Truncated nor	Mean	3	Std	0.5	Min	2	Max	4
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19	Expression		☐	$BI_INR_Min_Por	2000		$BI_INR_Maj_Por-1000							
20	Uncertain		☐	$BI_INR_Ver_Por	3.5	Truncated nor	Mean	3.5	Std	0.5	Min	2.5	Max	4.5
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22	Expression		☐	$BI_SHR_Min_Po	1500		$BI_SHR_Maj_Por-1000							
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29	Uncertain		☐	$BII_SH_Ver_Por	4.6	Truncated nor	Mean	4.6	Std	0.5	Min	3.5	Max	5.5
30	Uncertain		☐	$BII_SHR_Maj_P	2600	Truncated nor	Mean	2600	Std	250	Min	2100	Max	3100
31	Expression		☐	$BII_SHR_Min_P	1600		$BII_SHR_Maj_Por-1000							
32	Uncertain		☐	$BII_SHR_Ver_P	2.8	Truncated nor	Mean	2.8	Std	0.5	Min	2	Max	3.5
33	Uncertain		☐	$BIIIL_UR_Maj_P	2300	Truncated nor	Mean	2300	Std	250	Min	1800	Max	2800
34	Expression		☐	$BIIIL_UR_Min_P	1900		$BIIIL_UR_Maj_Por-1000							
35	Uncertain		☐	$BIIIL_UR_Ver_P	11.2	Truncated nor	Mean	11.2	Std	0.5	Min	10.5	Max	12
36	Uncertain		☐	$BIIIU_SHR_Maj_	3000	Truncated nor	Mean	3000	Std	250	Min	2500	Max	3500
37	Expression		☐	$BIIIU_SHR_Min_	2000		$BIIIU_SHR_Maj_Por-1000							
38	Uncertain		☐	$BIIIU_SHR_Ver_	4.8	Truncated nor	Mean	4.8	Std	0.5	Min	4	Max	5.5
39	Uncertain		☐	$BIIIU_UR_Maj_P	3000	Truncated nor	Mean	3000	Std	250	Min	2500	Max	3500
40	Expression		☐	$BIIIU_UR_Min_P	2000		$BIIIU_UR_Maj_Por-1000							
41	Uncertain		☐	$BIIIU_UR_Ver_P	4.8	Truncated nor	Mean	4.8	Std	0.5	Min	4	Max	5.5
42	Uncertain		☐	$G_MR_Maj_Por	2800	Truncated nor	Mean	2800	Std	250	Min	2300	Max	3300
43	Expression		☐	$G_MR_Min_Por	2600		$G_MR_Maj_Por-1000							
44	Uncertain		☐	$G_MR_Ver_Por	3.8	Truncated nor	Mean	3.8	Std	0.5	Min	3	Max	4.5
45	Uncertain		☐	$G_SH_Maj_Por	2800	Truncated nor	Mean	2800	Std	250	Min	2300	Max	3300
46	Expression		☐	$G_SH_Min_Por	2600		$G_SH_Maj_Por-1000							
47	Uncertain		☐	$G_SH_Ver_Por	4.462	Truncated nor	Mean	4.5	Std	0.5	Min	3.5	Max	5
48	Uncertain		☐	$G_UR_Maj_Por	2800	Truncated nor	Mean	2800	Std	250	Min	2300	Max	3300
49	Expression		☐	$G_UR_Min_Por	2600		$G_UR_Maj_Por-1000							
50	Uncertain		☐	$G_UR_Ver_Por	3.8	Truncated nor	Mean	3.8	Std	0.5	Min	3	Max	4.5
51	Uncertain		☐	$G_MR_Maj_Swl	3000	Truncated nor	Mean	3000	Std	250	Min	2500	Max	3500
52	Expression		☐	$G_MR_Min_Swl	2000		$G_MR_Maj_Swlog-1000							
53	Uncertain		☐	$G_MR_Ver_Swl	3.8	Truncated nor	Mean	3.8	Std	0.5	Min	3	Max	4.5
54	Uncertain		☐	$G_SH_Maj_Swl	3000	Truncated nor	Mean	3000	Std	250	Min	2500	Max	3500
55	Expression		☐	$G_SH_Min_Swl	2000		$G_SH_Maj_Swlog-1000							
56	Uncertain		☐	$G_SH_Ver_Swl	3.8	Truncated nor	Mean	3.8	Std	0.5	Min	3	Max	4.5
57	Uncertain		☐	$G_UR_Maj_Swl	3000	Truncated nor	Mean	3000	Std	250	Min	2500	Max	3500
58	Expression		☐	$G_UR_Min_Swl	2000		$G_UR_Maj_Swlog-1000							
59	Uncertain		☐	$G_UR_Ver_Swl	3.8	Truncated nor	Mean	3.8	Std	0.5	Min	3	Max	4.5
60	Uncertain		☐	$BI_INR_Maj_Sw	3000	Truncated nor	Mean	3000	Std	250	Min	2500	Max	3500
61	Expression		☐	$BI_INR_Min_Sw	2000		$BI_INR_Maj_Sw-1000							
62	Uncertain		☐	$BI_INR_Ver_Sw	4.7	Truncated nor	Mean	4.7	Std	0.5	Min	4	Max	5.5
63	Uncertain		☐	$BI_SHR_Maj_S	3000	Truncated nor	Mean	3000	Std	250	Min	2500	Max	3500
64	Expression		☐	$BI_SHR_Min_S	2000		$BI_SHR_Maj_Sw-1000							
65	Uncertain		☐	$BI_SHR_Ver_S	4.7	Truncated nor	Mean	4.7	Std	0.5	Min	4	Max	5.5
66	Uncertain		☐	$BII_INR_Maj_S	3000	Truncated nor	Mean	3000	Std	250	Min	2500	Max	3500
67	Expression		☐	$BII_INR_Min_S	2000		$BII_INR_Maj_Sw-1000							
68	Uncertain		☐	$BII_INR_Ver_S	5.6	Truncated nor	Mean	5.6	Std	0.5	Min	5	Max	6.5
69	Uncertain		☐	$BII_SH_Maj_Sw	3000	Truncated nor	Mean	3000	Std	250	Min	2500	Max	3500
70	Expression		☐	$BII_SH_Min_Sw	2000		$BII_SH_Maj_Sw-1000							
71	Uncertain		☐	$BII_SH_Ver_Sw	5.6	Truncated nor	Mean	5.6	Std	0.5	Min	5	Max	6.5
72	Uncertain		☐	$BII_SHR_Maj_S	3000	Truncated nor	Mean	3000	Std	250	Min	2500	Max	3500
73	Expression		☐	$BII_SHR_Min_S	2000		$BII_SHR_Maj_Sw-1000							
74	Uncertain		☐	$BII_SHR_Ver_S	5.6	Truncated nor	Mean	5.6	Std	0.5	Min	5	Max	6.5
75	Uncertain		☐	$BIIIL_UR_Maj_S	3000	Truncated nor	Mean	3000	Std	250	Min	2500	Max	3500
76	Expression		☐	$BIIIL_UR_Min_S	2000		$BIIIL_UR_Maj_Sw-1000							
77	Uncertain		☐	$BIIIL_UR_Ver_S	4.8	Truncated nor	Mean	4.8	Std	0.5	Min	4	Max	5.5
78	Uncertain		☐	$BIIIU_SHR_Maj_	3000	Truncated nor	Mean	3000	Std	250	Min	2500	Max	3500
79	Expression		☐	$BIIIU_SHR_Min_	2000		$BIIIU_SHR_Maj_Sw-1000							
80	Uncertain		☐	$BIIIU_SHR_Ver_	5.5	Truncated nor	Mean	5.5	Std	0.5	Min	5	Max	6.5
81	Uncertain		☐	$BIIIU_UR_Maj_S	3000	Truncated nor	Mean	3000	Std	250	Min	2500	Max	3500
82	Expression		☐	$BIIIU_UR_Min_S	2000		$BIIIU_UR_Maj_Sw-1000							
83	Uncertain		☐	$BIIIU_UR_Ver_S	5.5	Truncated nor	Mean	5.5	Std	0.5	Min	5	Max	6.5
84	Uncertain		☐	$BI_INR_Mean_P	0.122	Truncated nor	Mean	0.122	Std	0.1	Min	0.1	Max	0.15
85	Uncertain		☐	$BI_INR_Std_Por	0.028	Truncated nor	Mean	0.028	Std	0.007	Min	0.02	Max	0.04
86	Uncertain		☐	$BI_SHR_Mean_	0.13	Truncated nor	Mean	0.13	Std	0.1	Min	0.11	Max	0.15
87	Uncertain		☐	$BI_SHR_Std_Po	0.06	Truncated nor	Mean	0.06	Std	0.007	Min	0.05	Max	0.075
88	Uncertain		☐	$BII_INR_Mean_	0.2	Truncated nor	Mean	0.2	Std	0.1	Min	0.18	Max	0.22
89	Uncertain		☐	$BII_INR_Std_Por	0.05	Truncated nor	Mean	0.05	Std	0.007	Min	0.04	Max	0.065
90	Uncertain		☐	$BII_SHR_Mean_	0.19	Truncated nor	Mean	0.19	Std	0.1	Min	0.17	Max	0.21
91	Uncertain		☐	$BII_SHR_Std_P	0.04	Truncated nor	Mean	0.04	Std	0.007	Min	0.03	Max	0.055
92	Uncertain		☐	$BIIIU_UR_Mean	0.24	Truncated nor	Mean	0.24	Std	0.1	Min	0.22	Max	0.26
93	Uncertain		☐	$BIIIU_UR_Std_P	0.03	Truncated nor	Mean	0.03	Std	0.007	Min	0.02	Max	0.045
94	Uncertain		☐	$BIIIL_UR_Mean_	0.23	Truncated nor	Mean	0.23	Std	0.1	Min	0.21	Max	0.25
95	Uncertain		☐	$BIIIL_UR_Std_P	0.03	Truncated nor	Mean	0.03	Std	0.007	Min	0.02	Max	0.045

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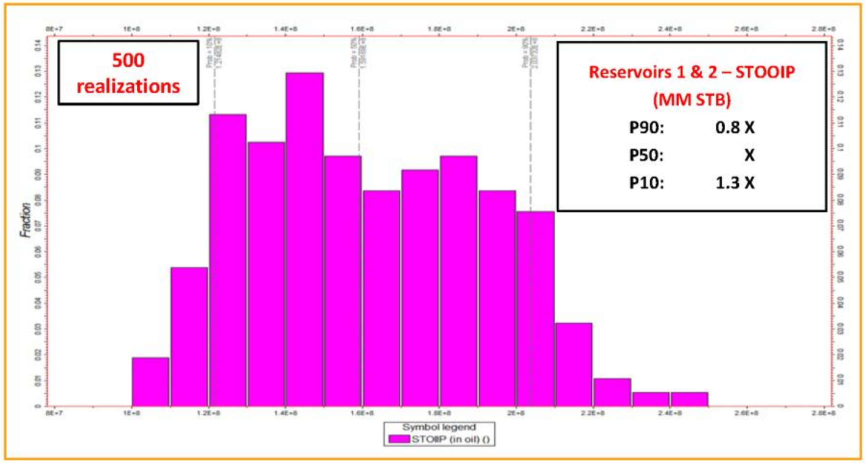
4. Modeling Uncertainties in Realizations

Uncertainty Variables, Distribution and Monte Carlo Simulation

95 variables were defined to run uncertainty model in:

Structural Framework, Facies, Porosity, Permeability , RRT, Sw Models.



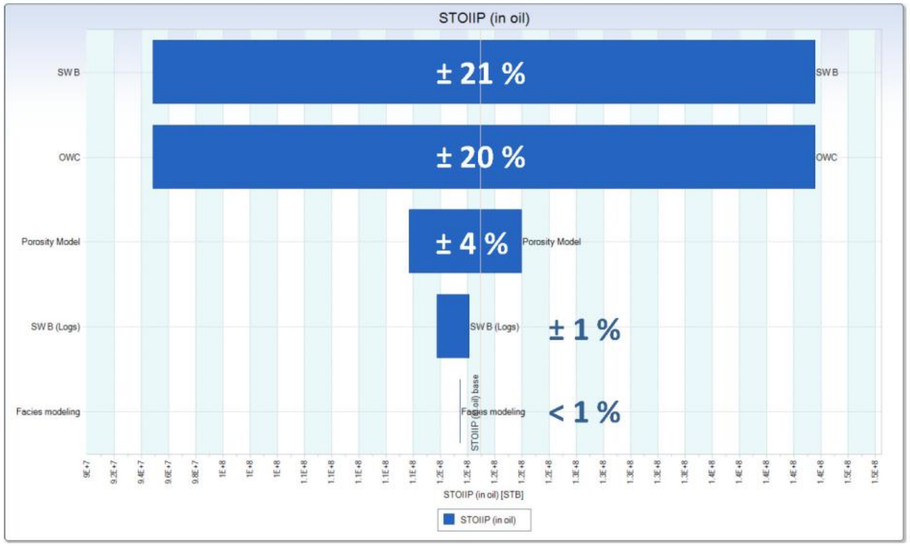
Reservoirs 1 & 2 – STOOIP (MM STB)

P90:	0.8 X
P50:	X
P10:	1.3 X

Presenter's notes: The aim of Uncertainty Analysis is to generate several models, each of them linked to a given probability of occurrence. These models, after being processed by a particular transfer function, must generate a variable distribution curve of interest with the following characteristics: The smallest possible standard deviation as long as the actual value (unknown) is within the limits of this curve.

5. Sensitivity Model

Tornado Plot



Finally, OWC and SW Model mainly in Reservoir 1 has more influence in the changes of the volume.

Sw ranges are between:
0.88X – 1.15X MMSTB

OWC in R-1 ranges are between:
0.9X – 1.1X MMSTB

Phie Model ranges are between:
0.98X – 1.02X MMSTB

Presenter's notes: Implementation of Sensitivity analysis of case model, using uncertain parameter, yields the tornado chart, where it is confirmed that oil-water Contact (WOC) and petrophysical parameters (porosity and water saturation model) have largest impact on our original oil-in-place calculation. Tornado charts are great to visually summarize information and more precisely the impact of various plotted parameters. They are excellent decision-support tools for that reason. The results can be shown in histograms in which probability level of 10%, probability level of 50% (reality-oriented model) and probability level of 90% have been identified and CDF curve can be depicted. In this way we can study performance (influence) (*Presenter's notes continued on next slide*)

(*Presenter's notes continued from previous slide*)

of that parameter on the amount of oil. It is necessary to rapidly know what actions are required to reduce their uncertainty to an acceptable level. From a reservoir modeling point of view, that would mean: (i) refining the interpretation, (ii) refining the model, or (iii) gathering more data because interpretation and modeling uncertainty cannot be refined any further with existing information.

4. Sensitivity analysis

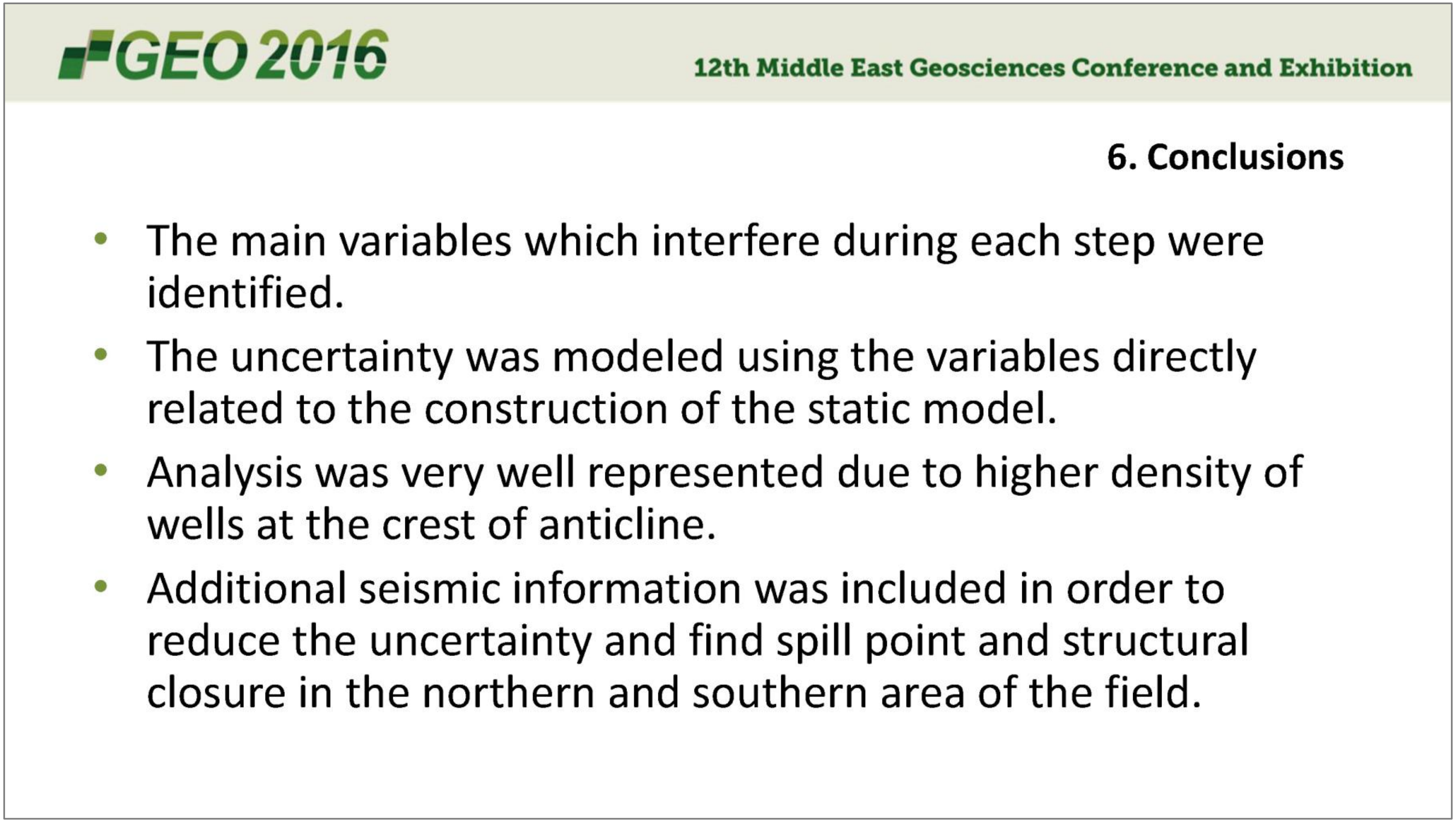
Design sensitivity analysis plays a critical role in inverse and identification studies, as well as numerical optimization, and reliability analyses. Before Uncertainty analysis to determine most influenced uncertain parameters, it is important to make sensitivity analysis. Sensitivity analysis is frequently performed to gain a better understanding of the influence of variables or parameters on the distributions of uncertainty. The purpose of sensitivity analysis is to identify those parameters and/or processes that strongly influence simulated results of the given model, and further analyze the trends of these correlations. Tornado chart is sensitivity analysis result and shows the major elements. Petrel offers two separate sensitivity tasks in the Uncertainty and optimization process:

4.1 Sensitivity by variable (Uncertain, SEED)

The variable-based sensitivity of the given model is determined by successively selecting one variable at a time from the set of all uncertain variables, and changing its value while keeping the others fixed at their Base values. This is done for each uncertain variable in turn, so the total No. of runs thus equals to the number of uncertain or SEED variables multiplied by the No. of samples per variable that has been entered by the user. Note that Expression-type variables are not directly sampled to test their sensitivity because they may depend on other $-variables that are tested.

4.2 Sensitivity by process

The process-based sensitivity of the given model is determined by altering the variables of one process at a time. This differs from Sensitivity by variable as several parameters may be defined within a single process. When this task is chosen, the total No. of runs equals to the number of parameterized processes multiplied by the value entered in the No. of samples. If multiple variables are defined in one process, all these variables will be active together.



6. Conclusions

- The main variables which interfere during each step were identified.
- The uncertainty was modeled using the variables directly related to the construction of the static model.
- Analysis was very well represented due to higher density of wells at the crest of anticline.
- Additional seismic information was included in order to reduce the uncertainty and find spill point and structural closure in the northern and southern area of the field.

Presenter’s notes: The uncertainty related directly to the static model is basically derived from our lack of knowledge of values between wells.

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