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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Abu Dhabi Company for Onshore Petroleum Operations Ltd. (ADCO)

أدنوك
ADNOC
شركة بترول ابوظبي الوطنية

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

Presentation Outline

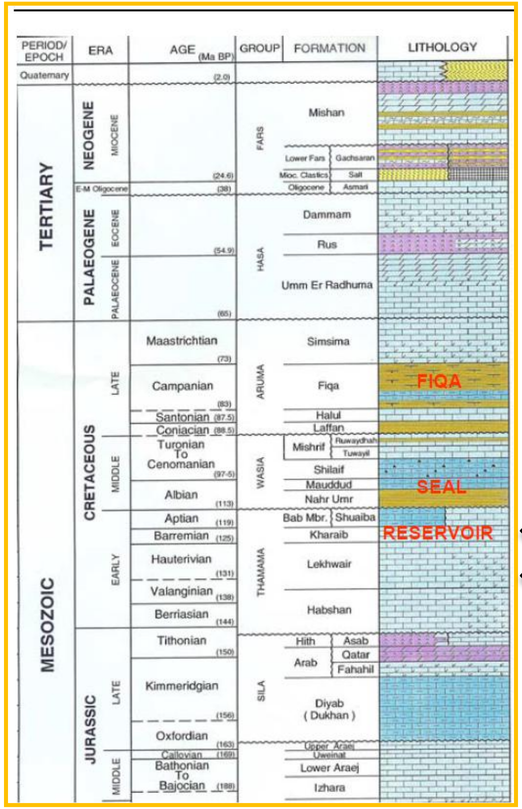
1. Objective
2. Definition of Geological and Geophysical Uncertainties
3. Geological Static Model (Base Case)
   a. Structural Framework
   b. Facies Modeling
   c. Petrophysical Modeling
4. Modeling Uncertainties in Realizations
5. Sensitivity Analysis
6. Conclusions

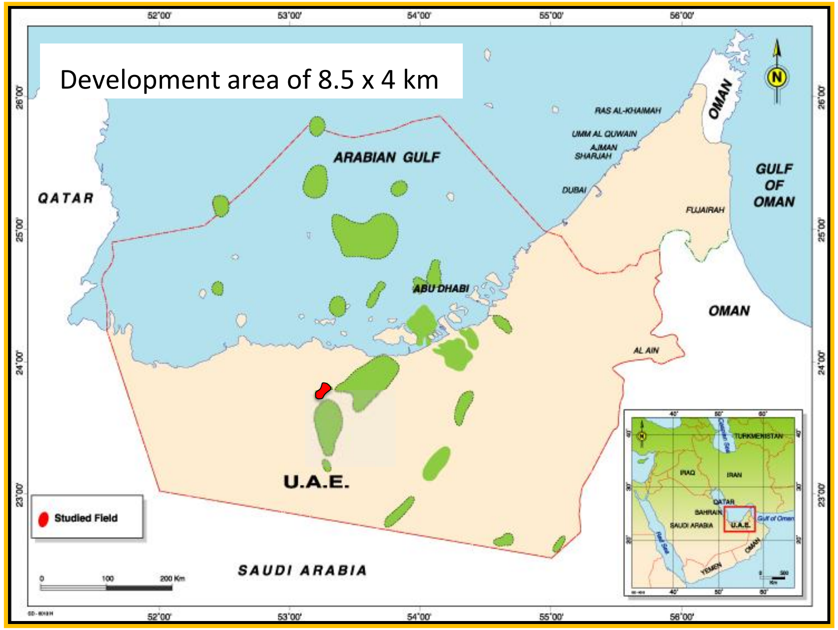
1. Objective

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

Overview

Field A





- Ø (%): R1: 18 - 27

  R2: 15 - 18

- K (mD): R1: 25 - 70

  R2: 5 - 10

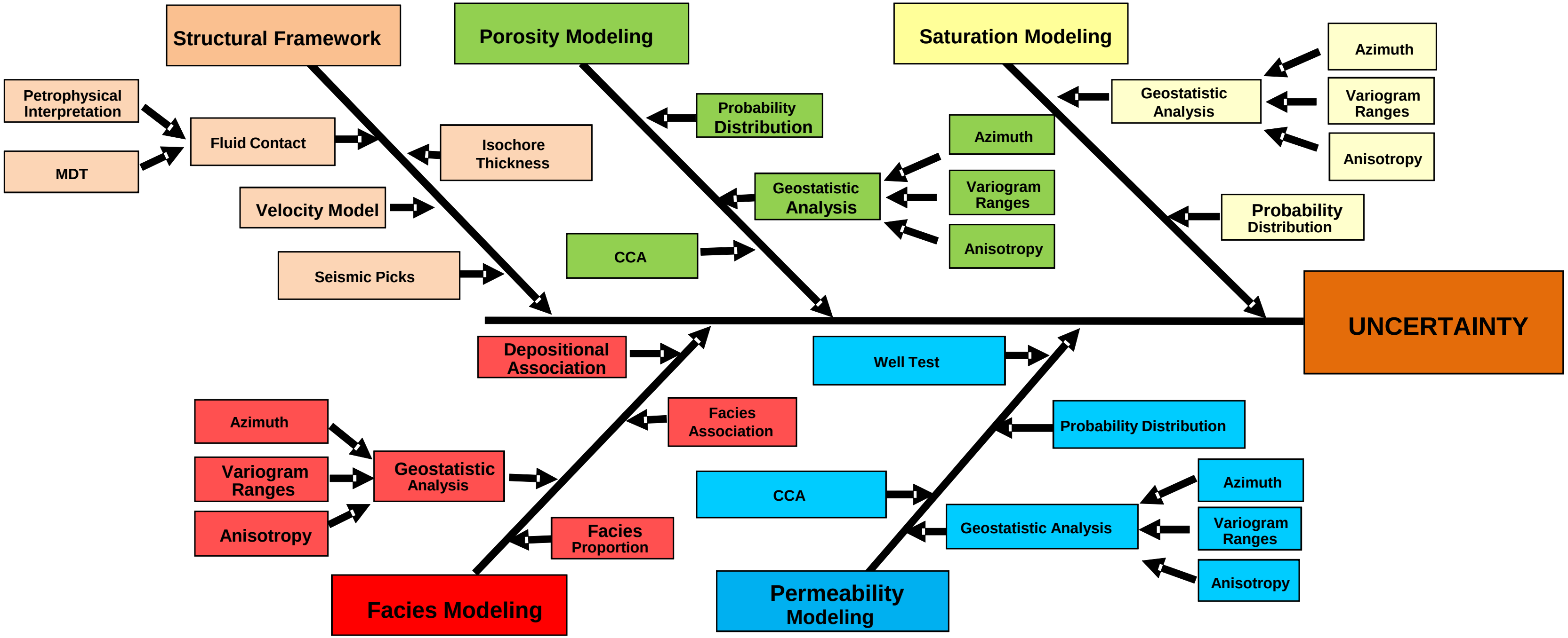
- Thick (ft.): R1: 150

  R2: 20

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

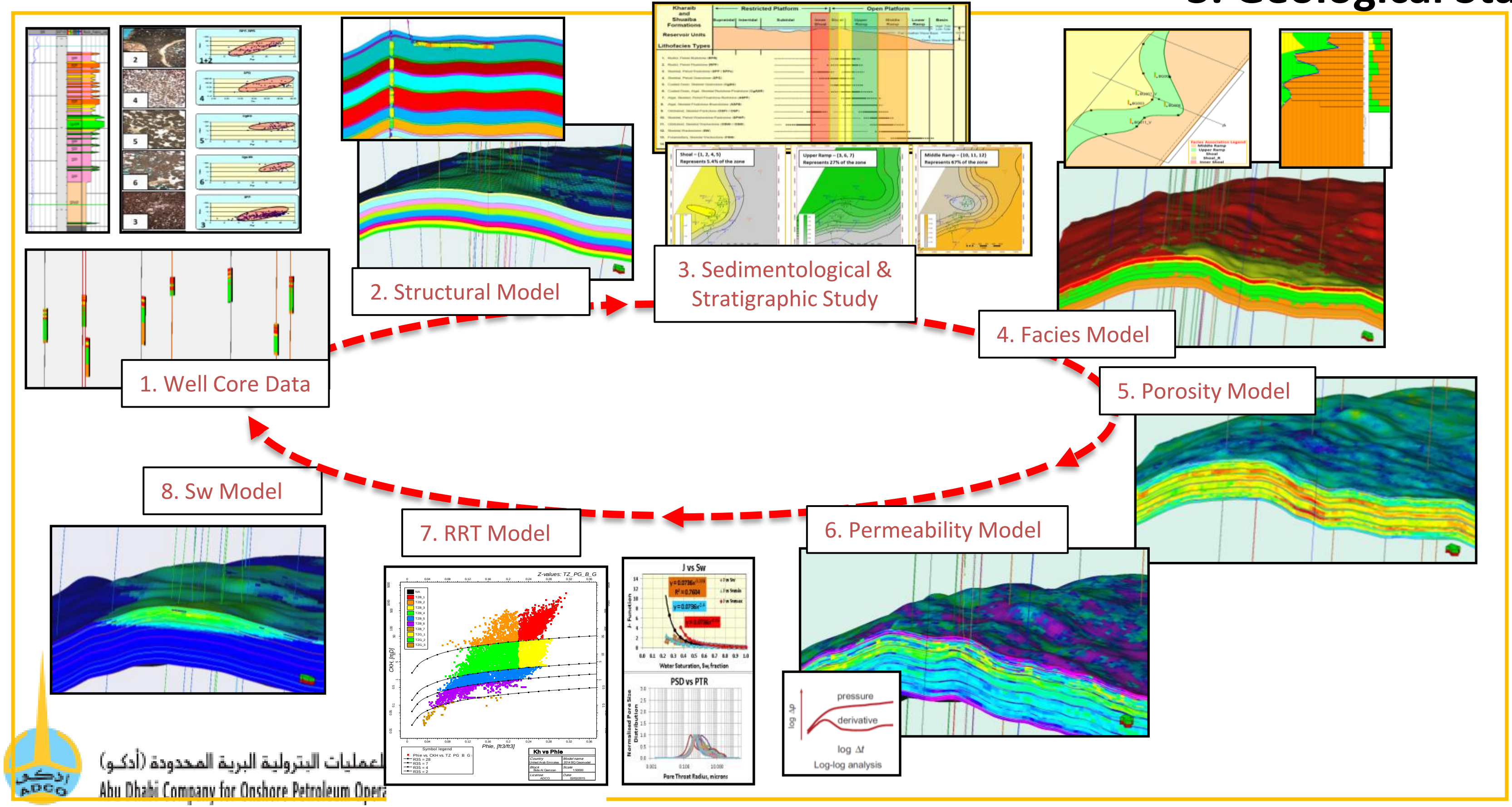
2. Definition of geological and geophysical uncertainties

Fishbone Diagram



3. Geological Static Model

Workflow



3.a. Structural Uncertainty

Surfa s (Uncertainty during seismic Interpretation)

hastic Gaussian Map

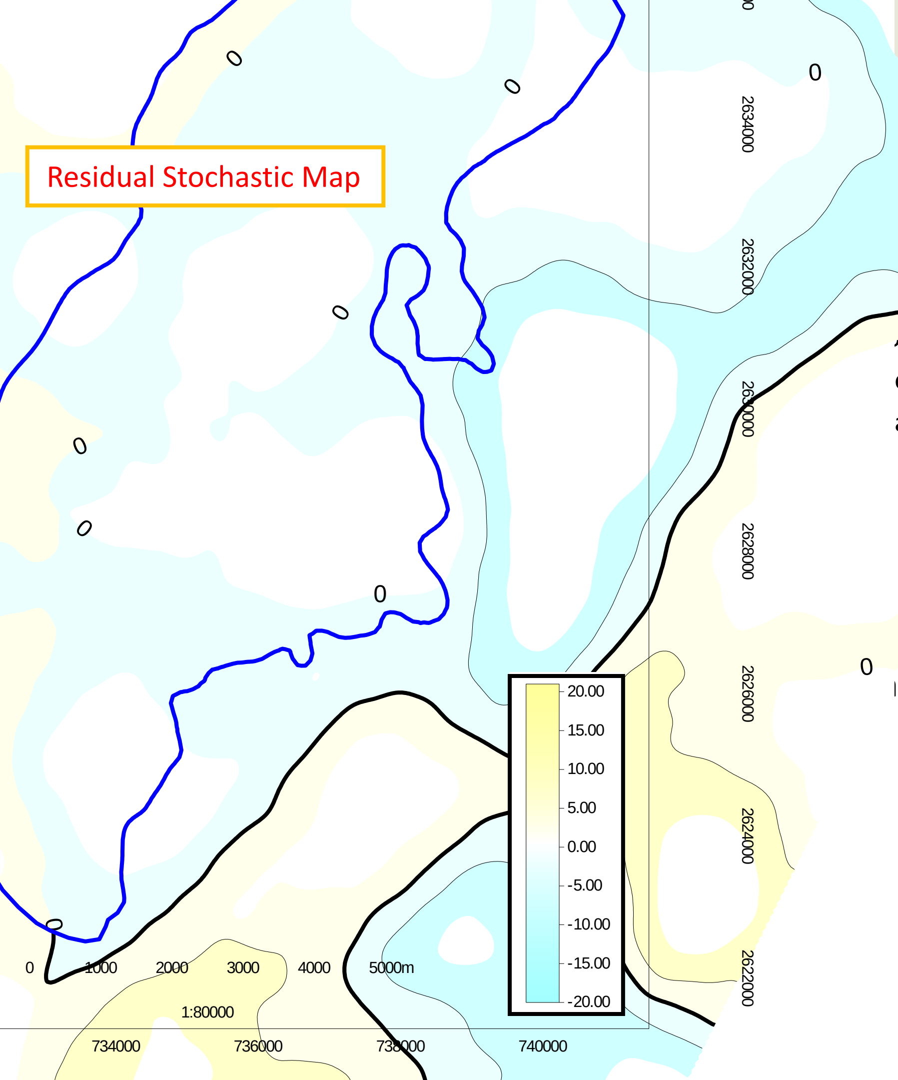
, va , (mean = 0 and std = 1)

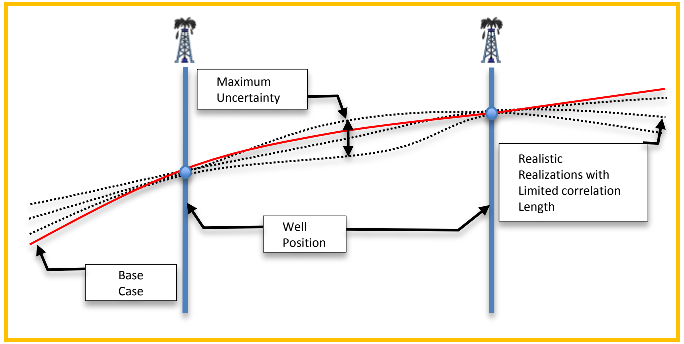
es smc with increasing distance from the wells

ations d end on the quality of seismic

- Ve city Model
- erpretation Pick
- sochore Thickness

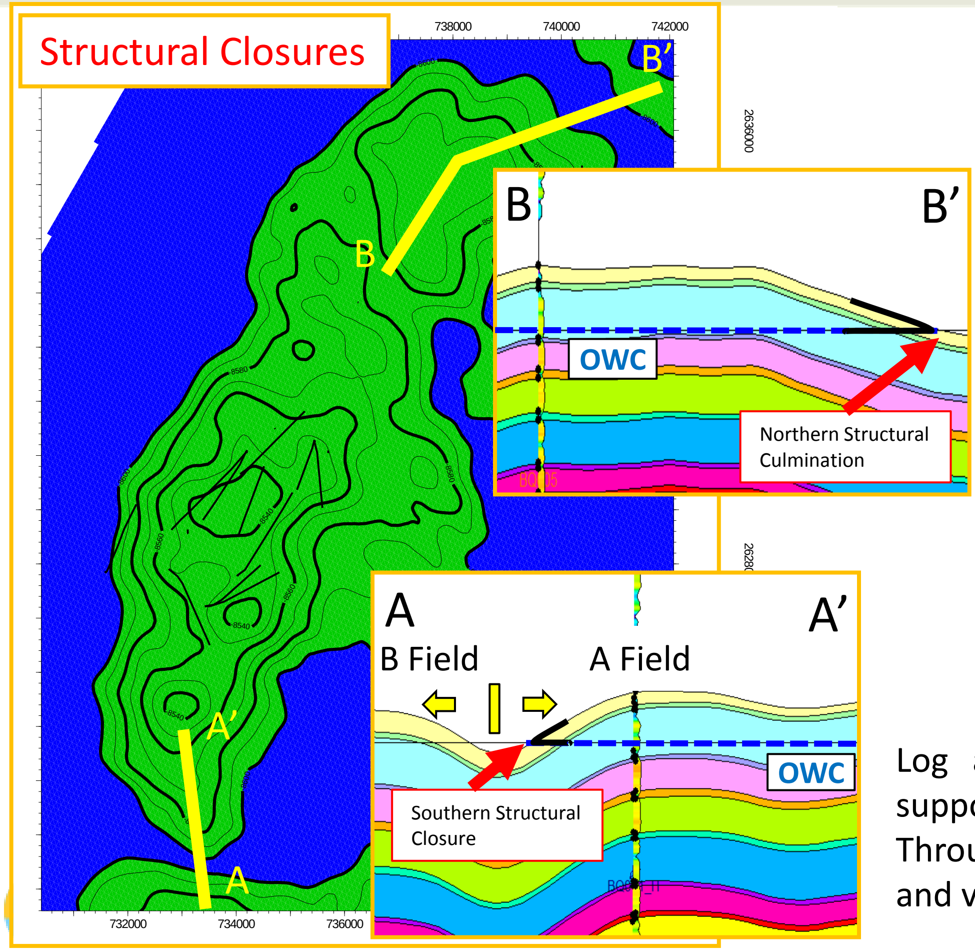
ı certain number of realizations, adding the residual Gaussian ıe base case map in each equi-probable realization.



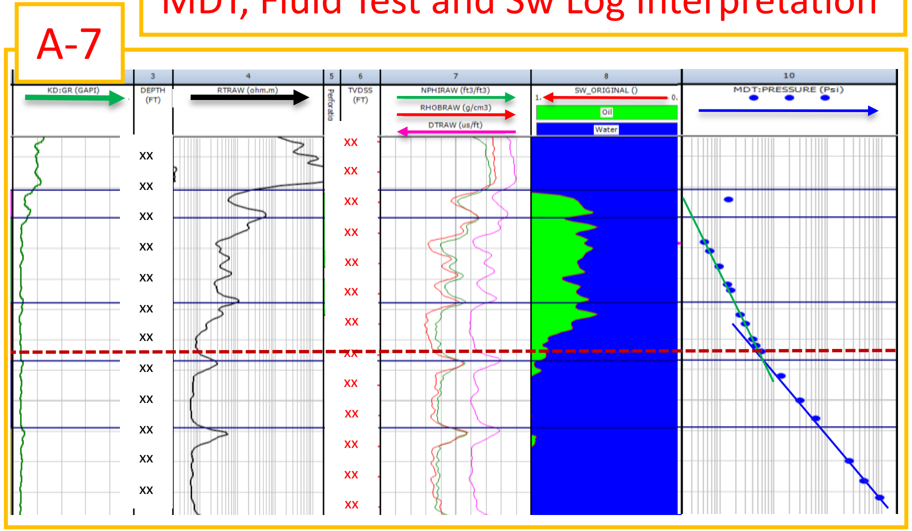


3.a. Structural Uncertainty

Structural Closures and Fluid Contacts



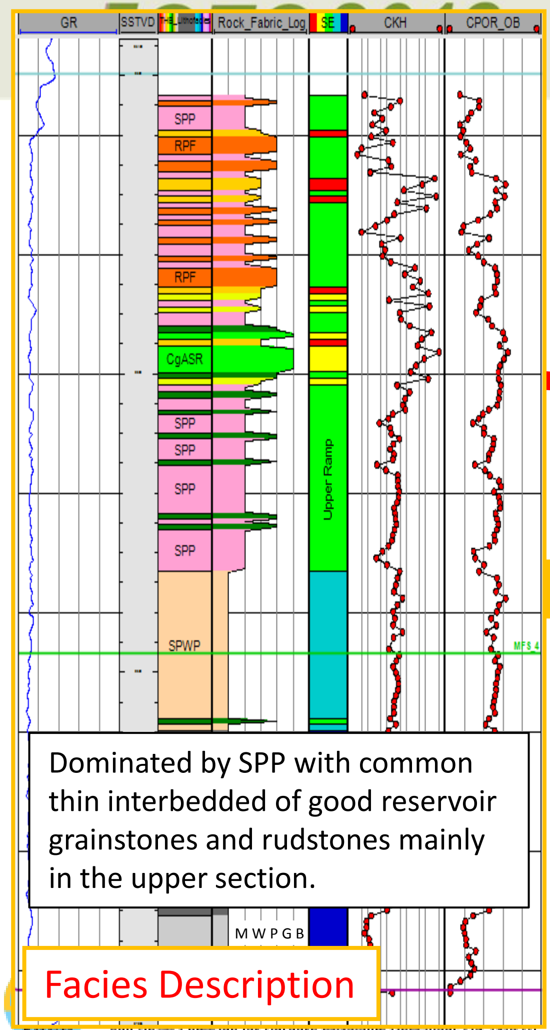
MDT, Fluid Test and Sw Log Interpretation



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.

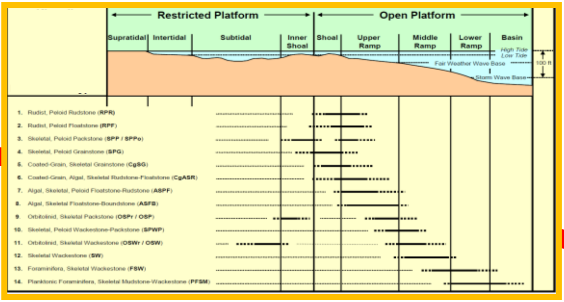
3.b. Facies Modeling

Facies, Facies Association, Depositional Environment



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

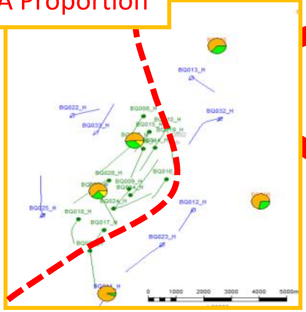
Facies Description

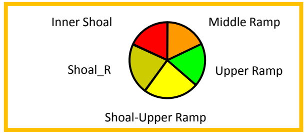


Sub Environments	Facies Association		Facies Petrel
	Main	Subordinates	
Inner Shoal	SPP (3)	OSPr (9), SPG (4)	Inner Shoal (3)
Shoal	CgSG (5), SPG (4)	RPR (1), RPF (2), SPP (3), CgASR (6)	Shoal_R (4, 5)
Shoal-Upper Ramp	RPR (1), RPF (2)	SPP (3), SPG (4), CgSG (5), CgASR (6), ASPF (7), ASFB (8)	Shoal-Upper 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)

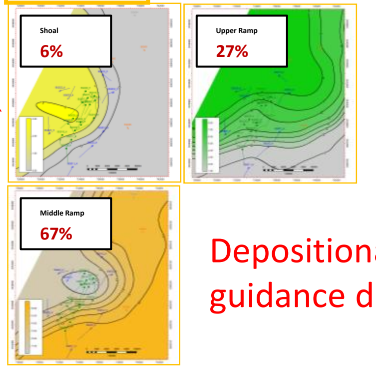
Facies Association

FA Proportion





FA Maps



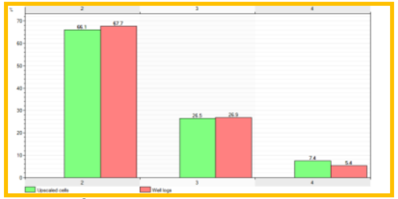
- The depositional trend.
- Boundary of facies.
- Estimate and propose fluid flow trend.
- As a guidance to define layer cake / clinoform structures, etc.

Depositional sedimentary trend is used as guidance during 3D modeling

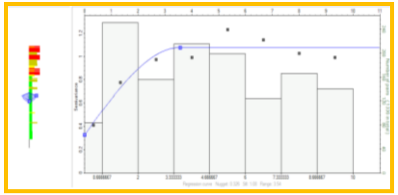
3.b. Facies Modeling

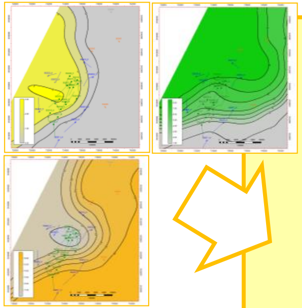
3D Model Algorithm - Intersection

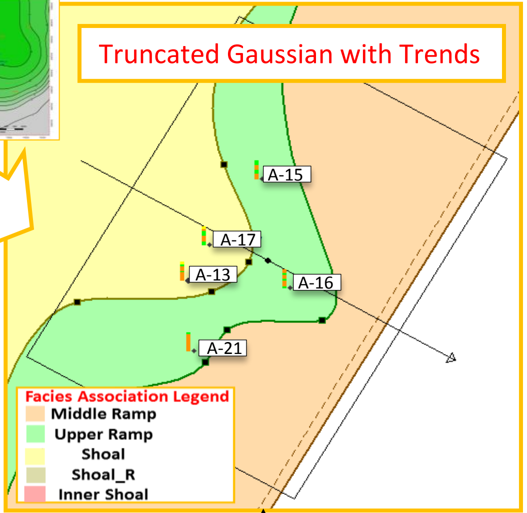
Distribution



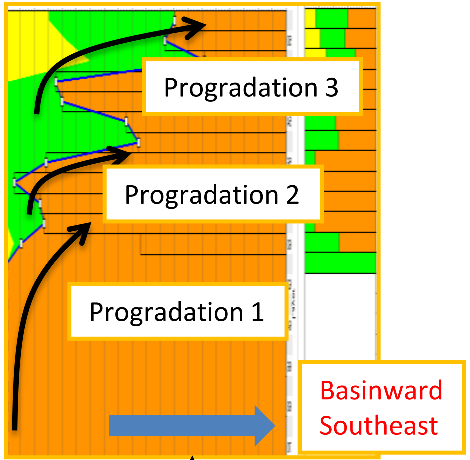
Variograms

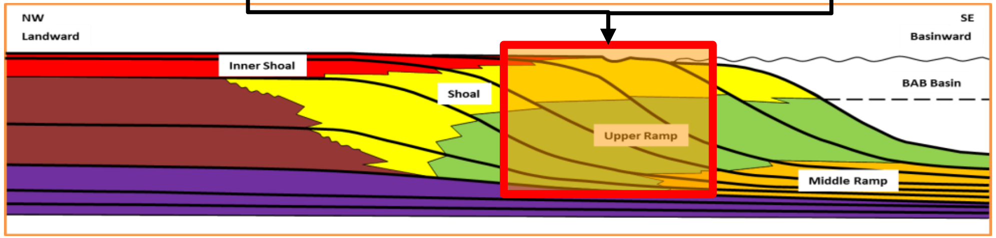






Vertical Proportion Curve





Histogram shows good relationship between upscaled and log data.

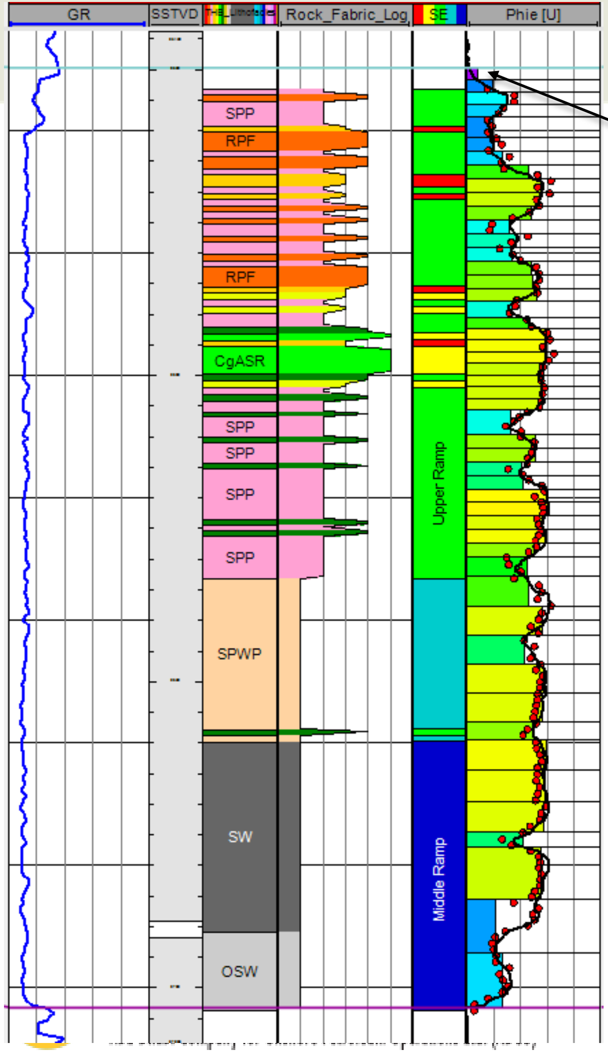
Variograms were defined to know the spatial relationship between wells.

VPC avoids vertical stationary distribution.

3.d. Petrophysical Modeling

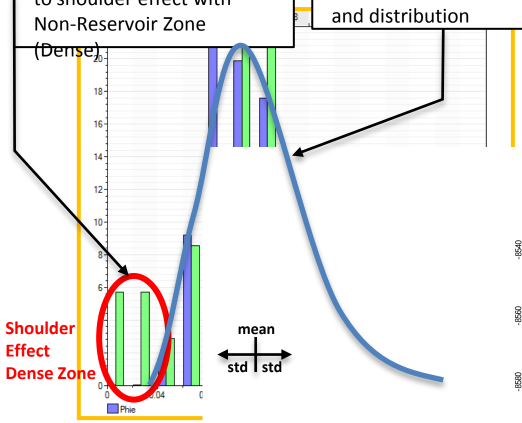
Porosity Model

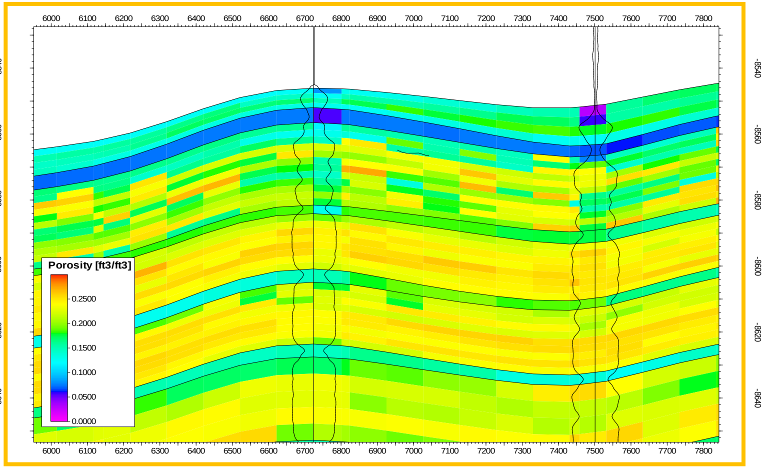
Understand how to perform data analysis to prepare the input for petrophysical modeling



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



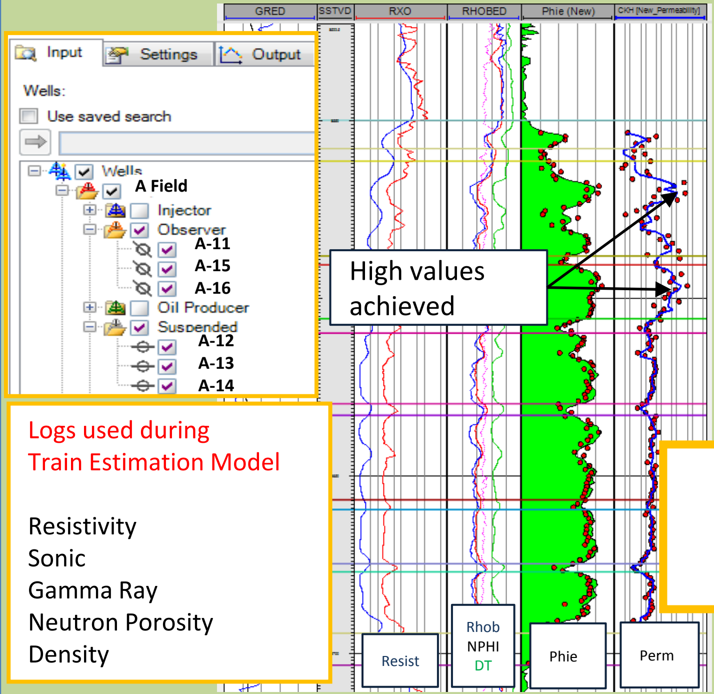


There are two important sources of porosity uncertainty. The first is related to logging tool measurement, processing and interpretation. The second is related to upscaling from logs to 3D model.

3.e. Petrophysical Modeling

Permeability Model

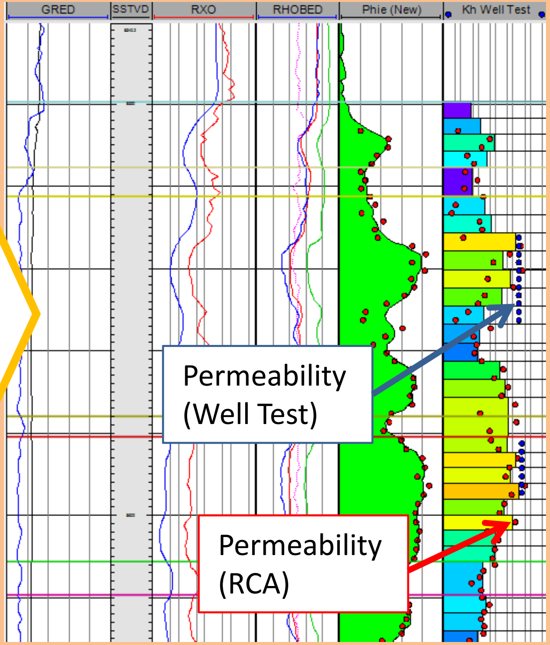
1. Neural Network Estimation Model



Logs used during Train Estimation Model

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

2. Calibration 3D Permeability Model from Well Testing



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

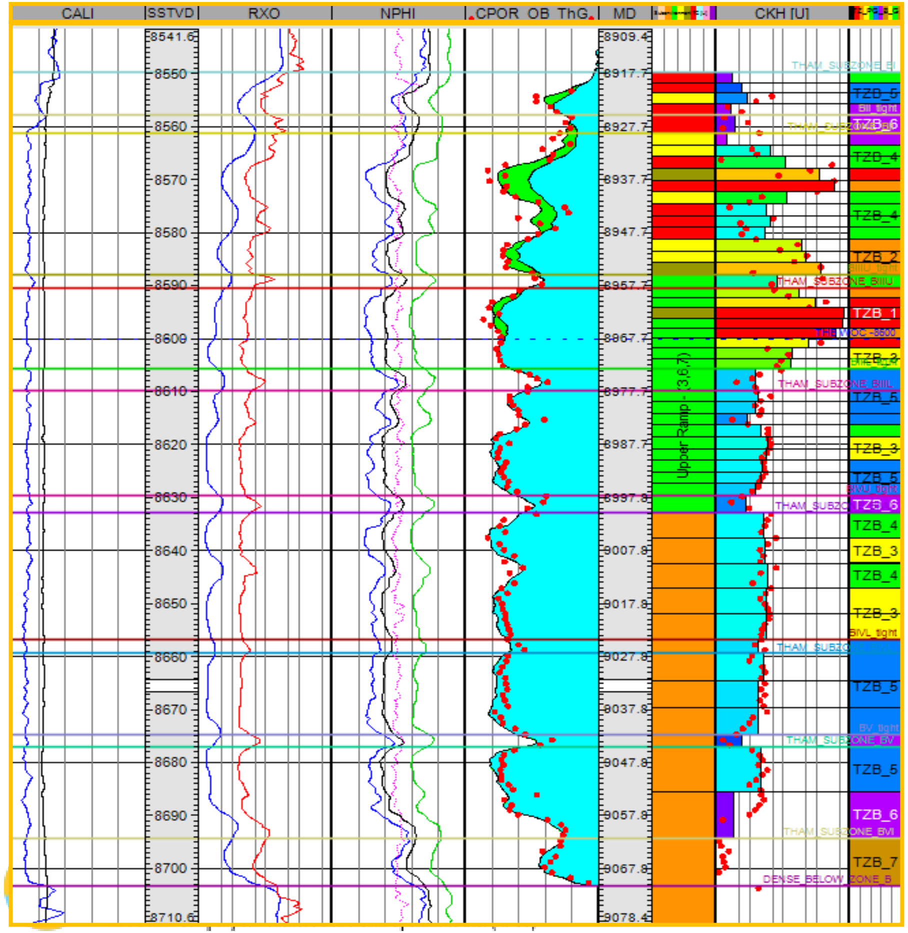
Test Type	Date	K	KH
DST	4-Sep-75	318	1935
Model		324	1967

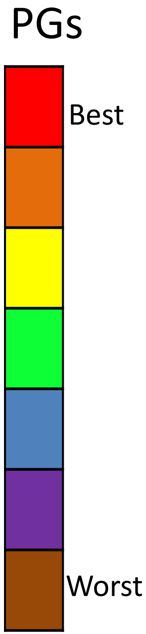
Two main objectives:

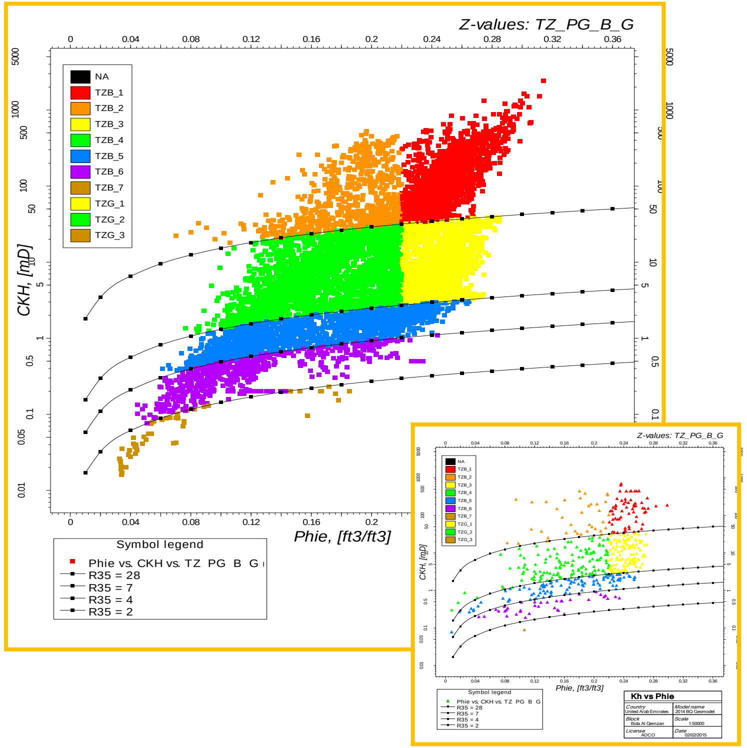
1. Reduce uncertainty through the calibration of the Permeability log, using two different sources.
2. Involve more wells as input data before K modeling (15 wells instead of 6 cored wells).

3.f. Petrophysical Modeling

RRT Model

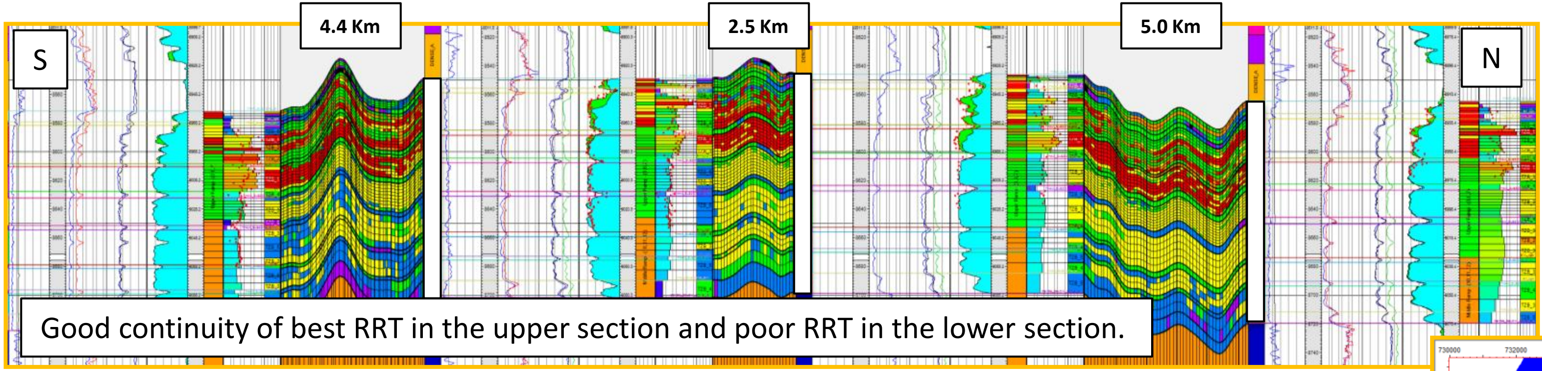




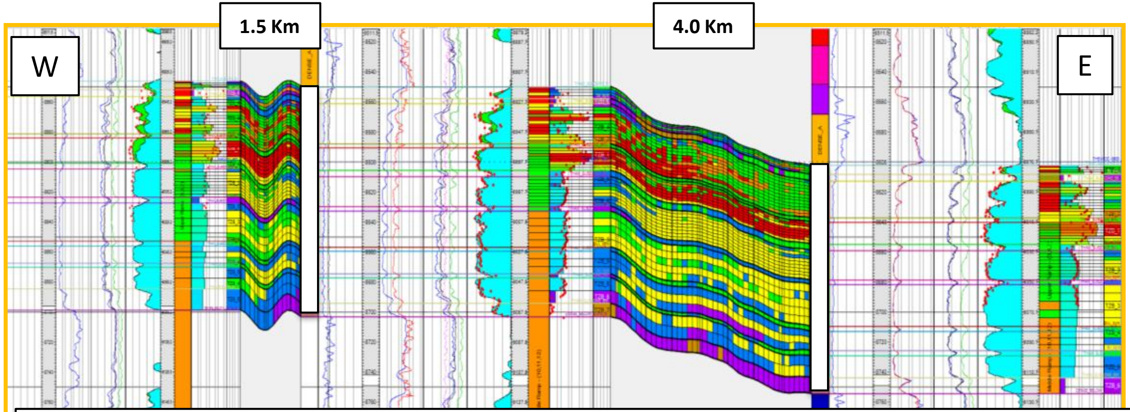


3.f. Petrophysical Modeling

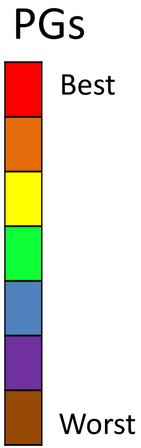
RRT - Intersection

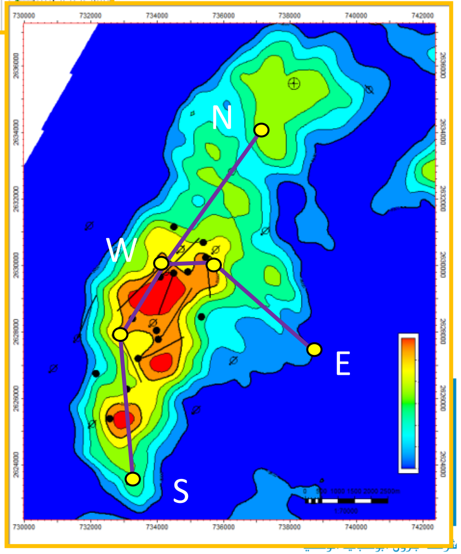


Good continuity of best RRT in the upper section and poor RRT in the lower section.



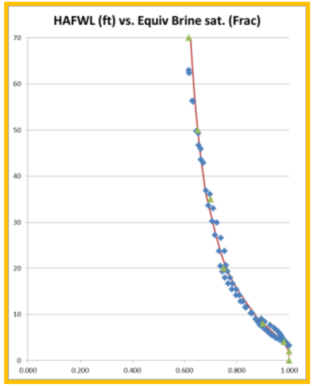
Transverse section shows how the best RRT is being degraded from RRT1 to RRT2 or 4 (consistent with sedimentological interpretation and petrophysical evaluations).

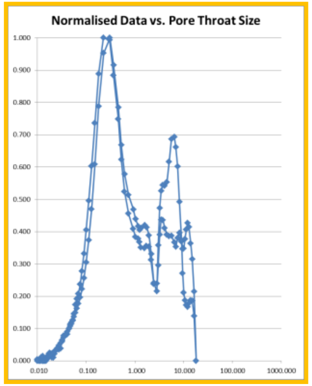


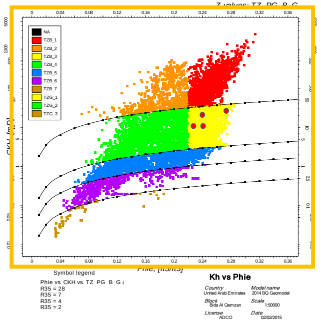


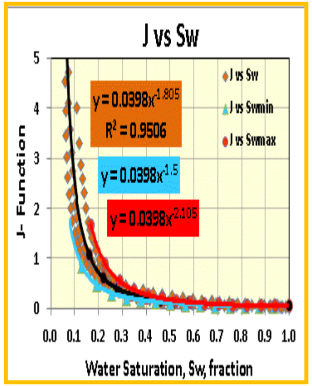
3.g. Petrophysical Modeling

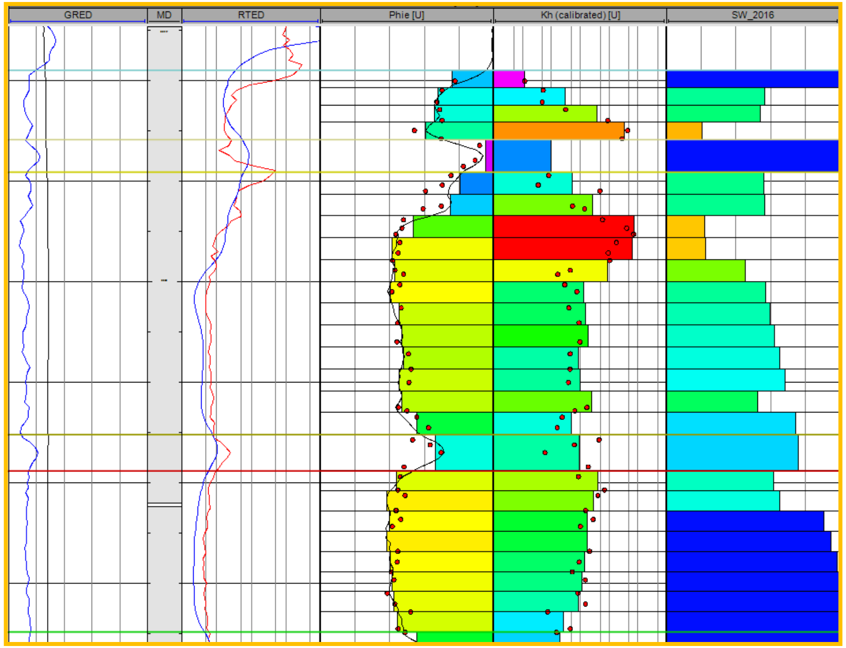
SW Model











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

	Type	Pr	Int	Name	Base value	Distribution	Arguments							
1	Uncertain			$OWC_B	-8600	Uniform	Min	-8605	Max	-8595				
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							
5	Uncertain			$BI_Ver_Facies	3	Truncated nor	Mean	3	Std	0.5	Min	2	Max	4
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
9	Uncertain			$BIIIL_Maj_Facie	4000	Truncated nor	Mean	4000	Std	250	Min	3500	Max	4500
10	Expression			$BIIIL_Min_Facie	3000		$BIIIL_Maj_Facies-1000							
11	Uncertain			$BIIIL_Ver_Facies	4.8	Truncated nor	Mean	4.8	Std	0.5	Min	3.8	Max	5.5
12	Uncertain			$BIIIU_Maj_Facie	2500	Truncated nor	Mean	2500	Std	250	Min	2000	Max	3000
13	Expression			$BIIIU_Min_Facie	1500		$BIIIU_Maj_Facies-1000							
14	Uncertain			$BIIIU_Ver_Facie	5.5	Truncated nor	Mean	5.5	Std	0.5	Min	4.5	Max	6
15	Uncertain			$G_Maj_Facies	4000	Truncated nor	Mean	4000	Std	250	Min	3500	Max	4500
16	Expression			$G_Min_Facies	3000		$G_Maj_Facies-1000							
17	Uncertain			$G_Ver_Facies	3.8	Truncated nor	Mean	3.8	Std	0.5	Min	2.8	Max	4.8
18	Uncertain			$BI_INR_Maj_Por	3000	Truncated nor	Mean	3000	Std	250	Min	2500	Max	3500
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
21	Uncertain			$BI_SHR_Maj_Po	2500	Truncated nor	Mean	2500	Std	250	Min	2000	Max	3000
22	Expression			$BI_SHR_Min_Po	1500		$BI_SHR_Maj_Por-1000							
23	Uncertain			$BI_SHR_Ver_Po	3.5	Truncated nor	Mean	3.5	Std	0.5	Min	2.5	Max	4.5
24	Uncertain			$BII_INR_Maj_Po	2600	Truncated nor	Mean	2600	Std	250	Min	2100	Max	3100
25	Expression			$BII_INR_Min_Po	1600		$BII_INR_Maj_Por-1000							
26	Uncertain			$BII_INR_Ver_Po	5.7	Truncated nor	Mean	5.7	Std	0.5	Min	4.5	Max	6.5
27	Uncertain			$BII_SH_Maj_Por	2600	Truncated nor	Mean	2600	Std	250	Min	2100	Max	3100
28	Expression			$BII_SH_Min_Por	1500		$BII_SH_Maj_Por-1000							
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
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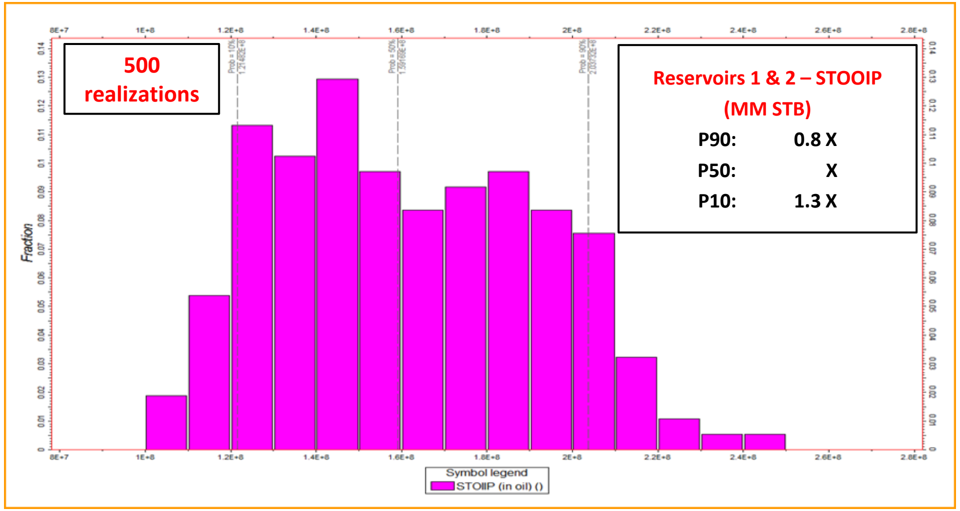
36	Uncertain			$BIIIU_SHR_Maj_	3000	Truncated nor	Mean	3000	Std	250	Min	2500	Max	3500
37	Expression			$BIIIU_SHR_Min_	2000		$BIIIU_SHR_Maj_Por-1000							
38	Uncertain			$BIIIU_SHR_Ver_	4.8	Truncated nor	Mean	4.8	Std	0.5	Min	4	Max	5.5
39	Uncertain			$BIIIU_UR_Maj_P	3000	Truncated nor	Mean	3000	Std	250	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_SWI	3000	Truncated nor	Mean	3000	Std	250	Min	2500	Max	3500
52	Expression			$G_MR_Min_SWI	2000		$G_MR_Maj_SWlog-1000							
53	Uncertain			$G_MR_Ver_SWI	3.8	Truncated nor	Mean	3.8	Std	0.5	Min	3	Max	4.5
54	Uncertain			$G_SH_Maj_SWI	3000	Truncated nor	Mean	3000	Std	250	Min	2500	Max	3500
55	Expression			$G_SH_Min_SWI	2000		$G_SH_Maj_SWlog-1000							
56	Uncertain			$G_SH_Ver_SWI	3.8	Truncated nor	Mean	3.8	Std	0.5	Min	3	Max	4.5
57	Uncertain			$G_UR_Maj_SWI	3000	Truncated nor	Mean	3000	Std	250	Min	2500	Max	3500
58	Expression			$G_UR_Min_SWI	2000		$G_UR_Maj_SWlog-1000							
59	Uncertain			$G_UR_Ver_SWI	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

4. Modeling Uncertainties in Realizations

Uncertainty Variables, Distribution and Monte Carlo Simulation

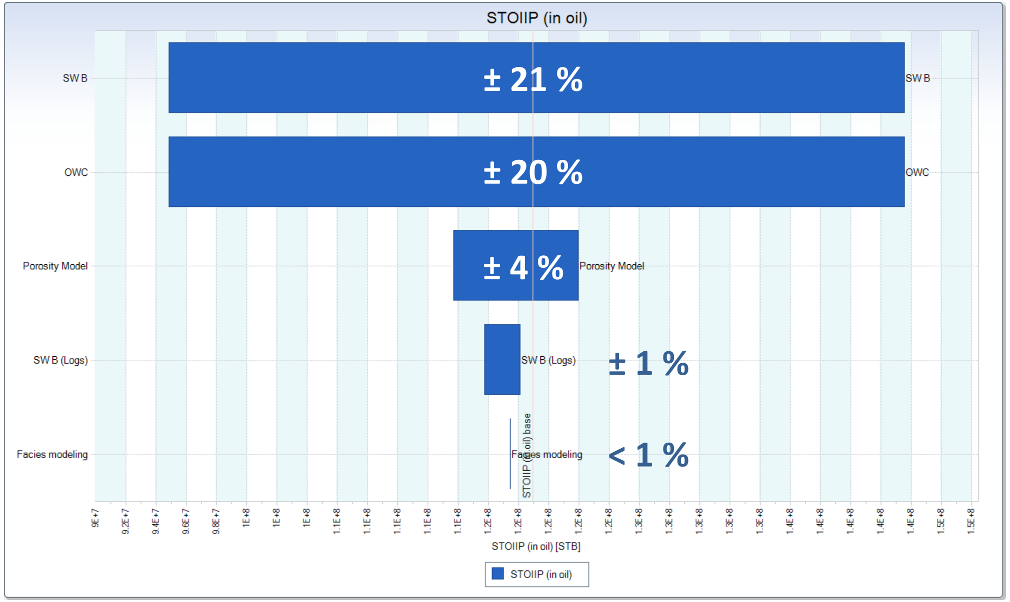
95 variables were defined to run uncertainty model in:

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



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

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.

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