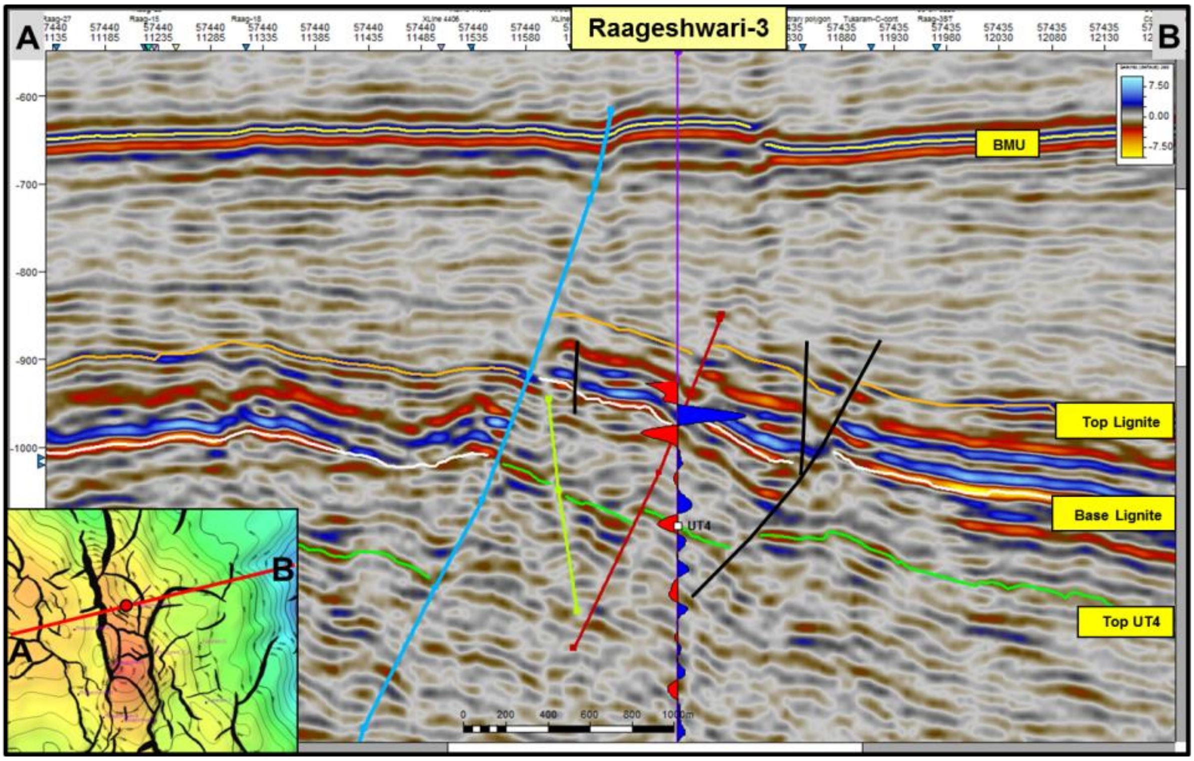

Figure 2.3.3. 1: Seismic Section along Raageshwari-3 Well

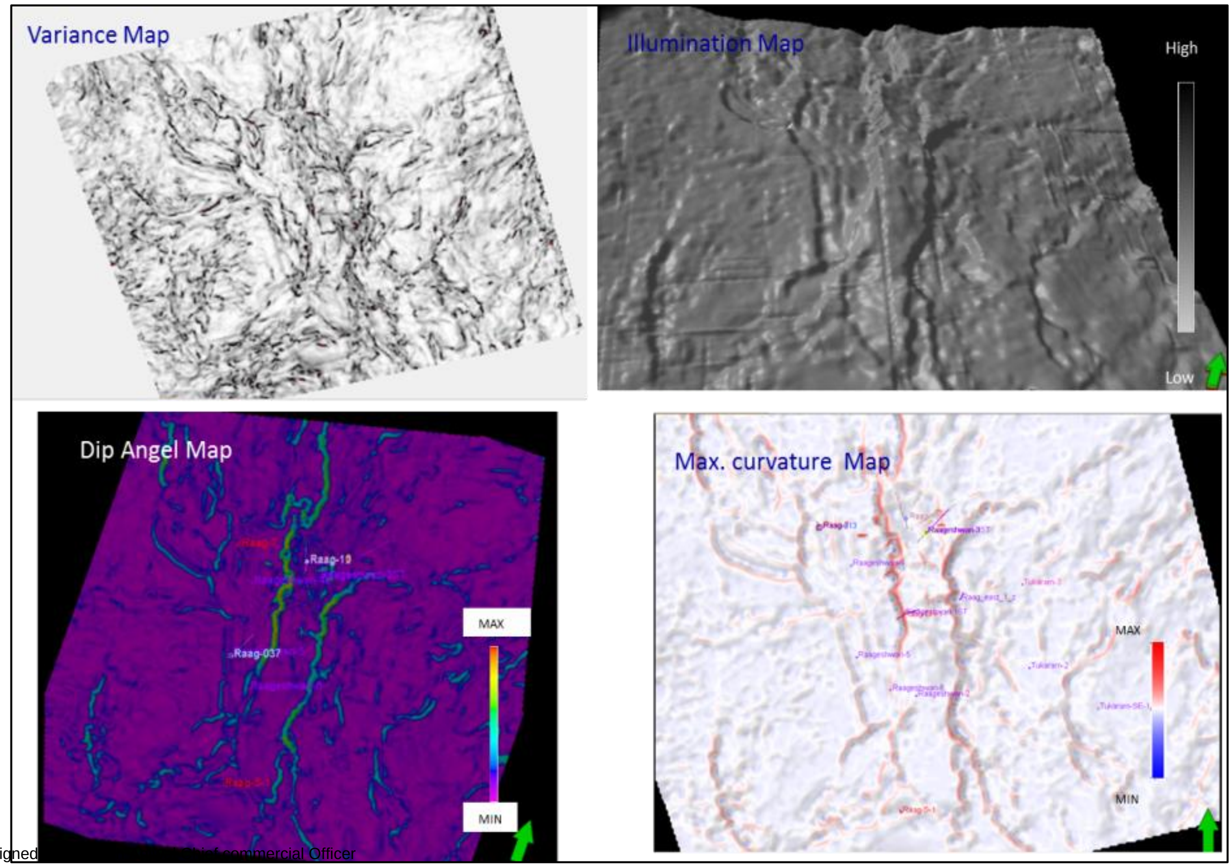

Figure 2.3.3. 2: Attributes used for Fault Interpretation

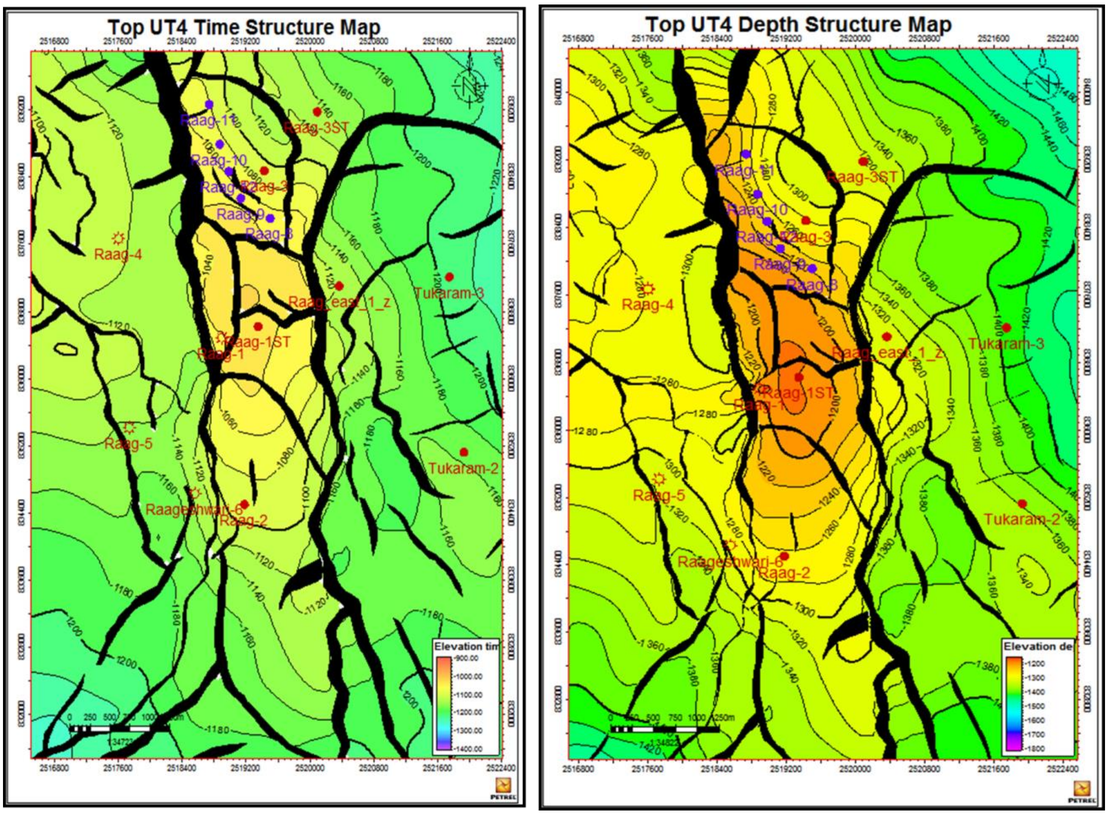

Figure 2.3.3. 3: Top UT4 TWT and Depth Structure Map

2.3.4. Time-Depth Conversion

Time to depth conversion has been carried out using polynomial function due to very little lateral velocity variations at the Upper Thumbli interval. Time and depth values for the Top UT4 stratigraphic marker are plotted and T-D polynomial function used for the depth conversion is shown in the Figure 2.3.4.1. The Top UT4 structure map after final correction to the formation tops is shown in Figure 2.3.3.4.

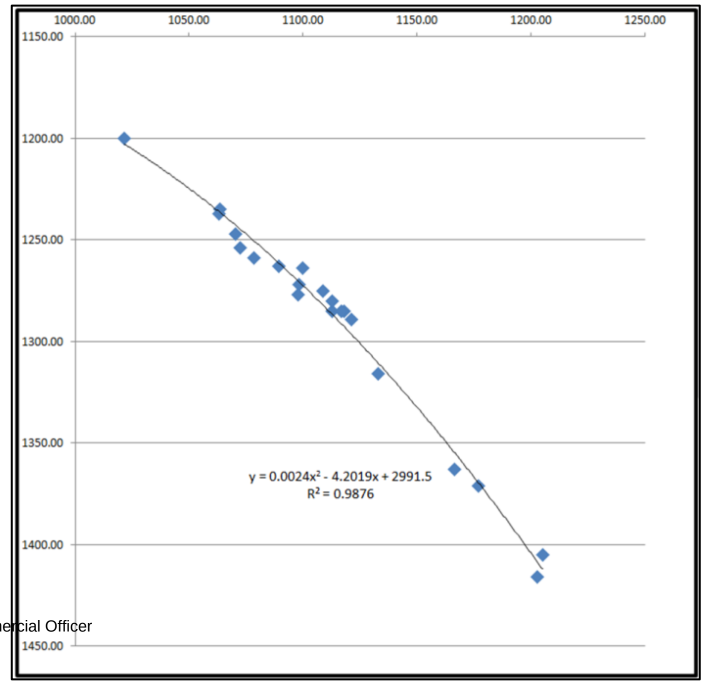

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Figure 2.3.4. 1: Time Depth Relation

2.3.5. Geophysical Uncertainty

The main source of geophysical uncertainty in the Raageshwari field relates to structural interpretation of top Thumbli (UT4). Compaction trend is uniform in the area at Thumbli level and hence velocity error within individual fault blocks is negligible. The TWT pick error based on the seismic data quality and velocity error contribute around 1% to the depth envelope uncertainty. Fault definitions at Thumbli level is based on the reflector discontinuity at the base of lignite interval reflections and therefore have lateral positioning uncertainty of ±50m.

2.4. Petrophysics

A deterministic petrophysical evaluation has been conducted on all the wells of Raageshwari shallow Oil field and output curves of clay volume, effective and total porosity, effective water saturation and permeability have been generated. These results were provided as input to the geo-cellular model.

Most of the new development wells such as Raag-9 and Raag-12 have modern logging suites such as NMR (CMR+) and Image data. The petrophysical model has been built by integrating all available data such as NMR and other modern logging suites.

2.4.1. Evaluation Methodology

A deterministic methodology was used for Raageshwari-Oil field petrophysical evaluation. There is no conventional core acquired in this field.

2.4.2. Available Data

All the available log data are summarized in Table 2.4.2.1.

Table 2.4.2. 1: Available Well-log Data of the Raag-Oil Field

Wells	GR	Resistivity	Neutron	Density	Sonic	Image	NMR	MDT	DST	Core	Mud log
Raag-1	√	√	√	√	√				√		√
Raag-3	√	√	√		√			√	√		√
Raag-8	√	√	√	√	√			√			√
Raag-9	√	√	√	√		√	√				√
Raag-10	√	√	√	√							√
Raag-11	√	√	√	√	√						√
Raag-12	√	√	√	√		√	√				√
Raag-32	√	√	√	√	√			√			√
Raag-39	√	√	√	√	√			√			√
Raag-1ST	√	√	√	√	√	√	√				√
Raag-3ST	√	√	√	√	√				√		√
Raag-6	√	√	√	√							√
Raag Oil-14	√	√	√	√							√
Raag Oil-16	√	√	√	√				√		√	√

2.4.3. Log Evaluation

All the raw data were QC'd and processed prior to interpretation. Depth shifts were performed prior to the petrophysical evaluation using Gamma ray as reference.

Clay Volume (Vcl)

Shale in the study area has a very large volume of clay minerals (up to 50 – 70%). Estimates of clay volume are made using the gamma ray and neutron-density separation. It was assumed that clay volume varies linearly to non-linearly in response to various logs. To arrive at a final shale volume, different factors of individual Vclay estimates were combined.

Silt Volume (V_{silt})

The silt volume formula from Interactive Petrophysics used was:

$V_{silt} = 1 - V_{wetClay} - PhiE / PhiMax$

Pore Volumes and Fluid Saturations

The neutron-density log was used for porosity estimation. Sandstone, shaly-sand and shale are the predominant lithologies in this field, and hence a grain density of 2.65 gm/cc was used for total porosity estimation (PhiT).

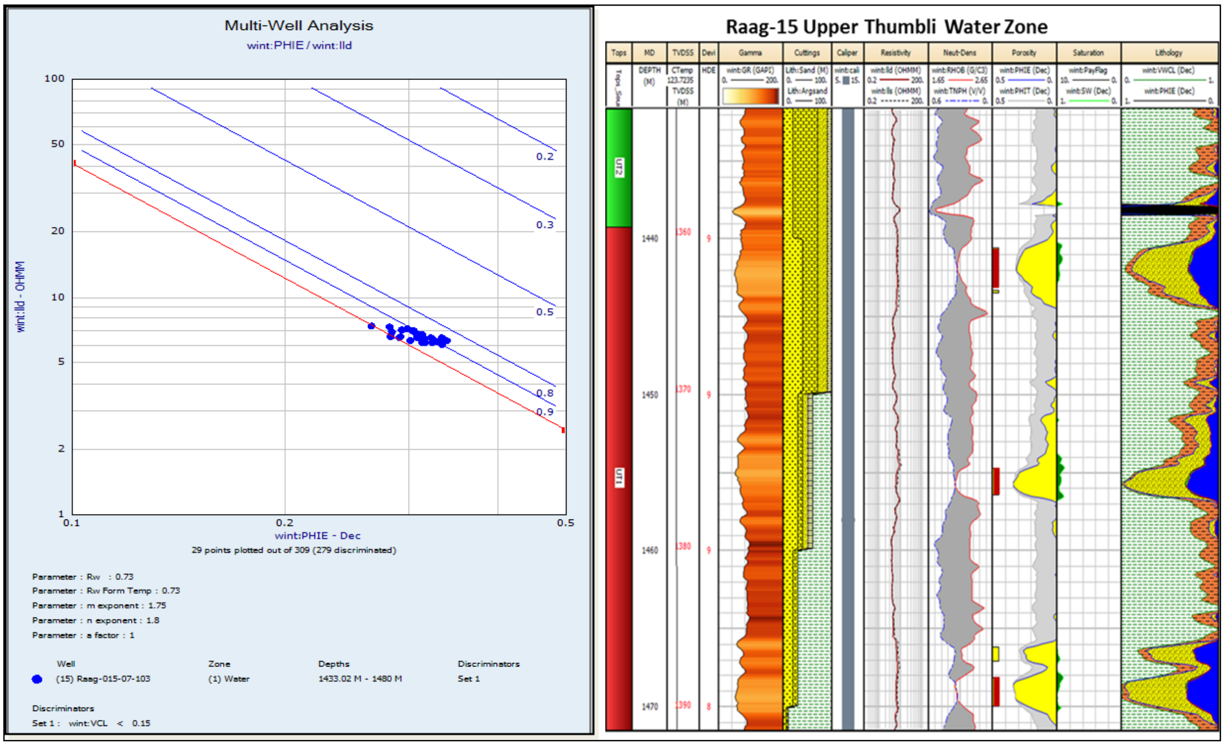

Figure 2.4.3. 1: The Pickett plot of water bearing zones in Raageshwari field

A fluid density of 0.85 gm/cc was used for the wells drilled with SOBM and 1 gm/cc for the wells drilled with WBM (older wells such as Raag-1, Raag-2, Raag-3, Raag-4 and Raag-5). As a calibration of porosity, NMR porosity (TCMR) was used to validate the total porosity (PhiT). Effective porosity (PhiE) was derived by subtracting the volume of clay-bound water from PhiT. Water saturation was calculated using Indonesian equations.

Raag-15 Upper Thumbli is good candidate for estimating “m” as these water bearing zones (Figure 2.4.3.1) are clean sand reservoirs and no Hydrocarbon shows were observed during drilling against these sands. By using Archie equation Sw^n = (a.Rw)/(Rt.phi^m), in water zone with Sw =1, Archie parameter “m” is estimated from (LogRw-LogRo)/LogPhi. It is not possible to estimate parameter “n” in absence of core data. The parameter “n” has been assumed to be closer to parameter “m” by rule of thumb. “n” parameter is about 1.8 in conventional reservoir in Barmer Basin (Fatehgarh core data from Mangala).

The parameters used in saturation equations are as follows:

‘a’ = 1; ‘m’ = 1.75; ‘n’ = 1.8

Rw = 1.34 ohmm at 30°C (equivalent salinity ≈ 3500mg/l which is in line with water sample analysis data) (Figure 2.4.3.1)

There are no capillary pressure curves available to generate saturation height functions. Hence, log-based saturation height model was established by using Harrison-Skelt saturation height function model. The well test data was used for estimating permeability.

2.4.4. Fluid Contacts

The reservoir pressure data is analysed to get the fluid contacts and found that the field has various pressure compartments. The gas-oil-contact (GOC) is found in Raageshwari Deep-Gas development well Raag-39 at 1195 mSS. The Fluid contacts based on pressure data and log based ODT are presented in Table 2.4.4.1.

Raageshwari-39: In UT4 zone where Raag-39 well falls under Raag-1 block, pressure data show gas-oil-contact at around 1195 mSS (Figure 2.4.4.1). The well goes into the Raag central block at UT3 level.
Raageshwari-3: In the Raag-3 well in Raag-3 block, pressure data shows free water level (FWL) at around 1310 mSS (Figure 2.4.4.1).

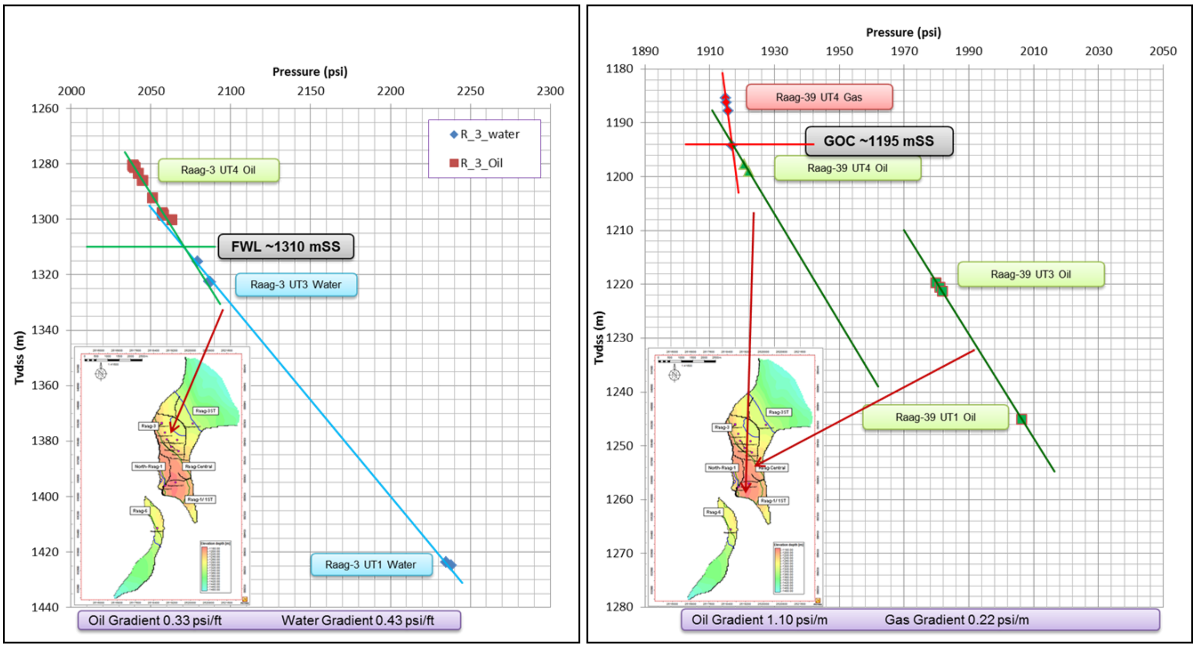

Figure 2.4.4. 1: The pressure vs depth plots for Raag-3, Raag-1&1ST and Raag Central

Table 2.4.4. 1: Fluid Contacts Considered in Different Fault Blocks

<table>
<tr><th rowspan="2">Block</th><th colspan="3">Fluid Contacts based on pressure data (m TVDSS)</th><th colspan="2">Fluid Contacts used for Subsurface modeling (m TVDSS)</th></tr>
<tr><th>GOC/GDT</th><th>ODT</th><th>OWC</th><th>GOC</th><th>ODT</th></tr>
<tr><td>Raag 3</td><td>-</td><td>-</td><td>1310 (R-3)</td><td rowspan="5">1211</td><td>1303</td></tr>
<tr><td>Raag 1 & 1ST</td><td rowspan="2">GOC~1195 (R-39)</td><td rowspan="2">1313 (R-1ST)</td><td rowspan="2">-</td><td rowspan="2">1313</td></tr>
<tr><td>Raag Central</td></tr>
<tr><td>N Raag 1</td><td>-</td><td>1220 (R-32)</td><td>-</td><td>1220</td></tr>
<tr><td>Raag 3ST</td><td>-</td><td>1326 (R-3ST)</td><td>-</td><td>1326</td></tr>
<tr><td>Raag 6</td><td>GDT~1296</td><td>1331 (R-6)</td><td>-</td><td>1296</td><td>1331</td></tr>
</table>

2.4.5. Cut-offs: Net Reservoir and Net Pay Determination

Using the Interactive Petrophysics program built-in module, reservoir and pay sensitivity analysis was carried out for volume of clay, porosity and water saturation for the upper Thumbli Formation (Figure 2.4.5.1). Reservoir and pay cut-offs were decided based on sensitivity analysis and summarized below in Table 2.4.5.1.

Table 2.4.5. 1: Reservoir and Pay Cut-offs

Cutoffs used			
Zone Name	Vcl	PhiE	Sw
Reservoir Summary			
Upper Thumbli	<= 0.5	>=0.11	
Pay Summary			
Upper Thumbli	<= 0.5	>=0.11	<= 0.6

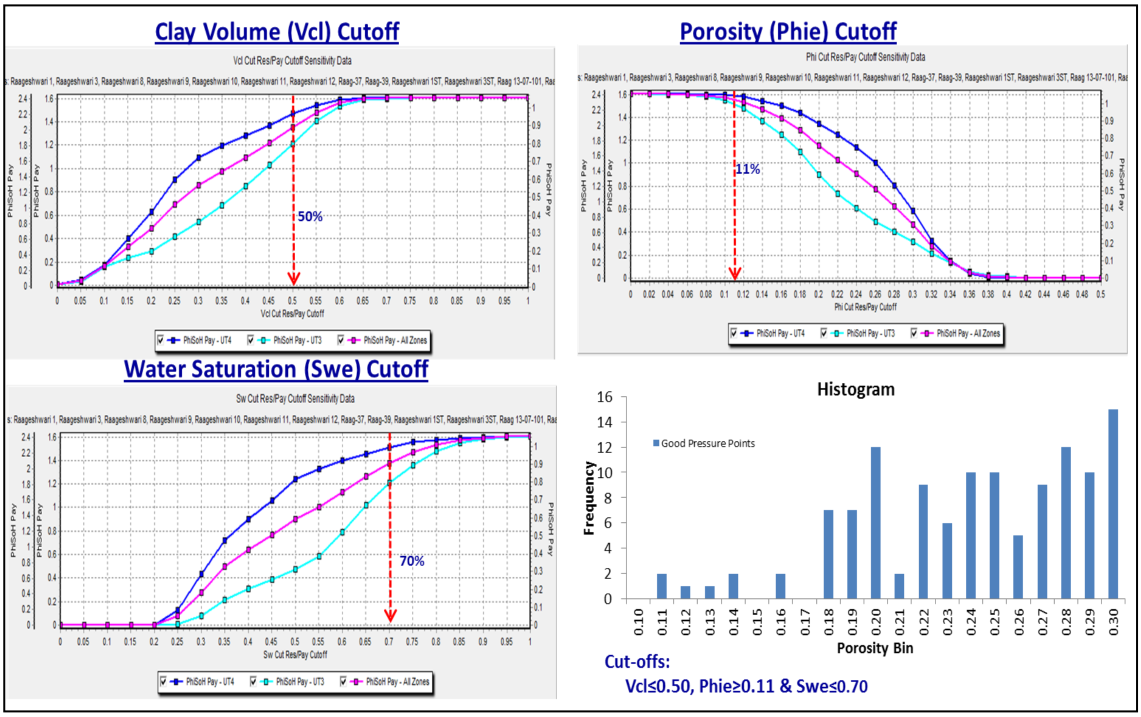

Figure 2.4.5. 1: Cut-offs: Net Reservoir and Net Pay Determination Plots

Reservoir and pay summaries for each well are shown below in Table 2.4.5.2.

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Table 2.4.5. 2: Reservoir and Pay Summaries for individual wells

Reservoir Summary											
Well	Zone	Top	Bottom	Top	Bottom	Gross	Net	N/G	Av Phi	Av Sw	Av Vcl
		mMD	mMD	mTVDSS	mTVDSS	mTVDSS	mVDSS	TVDSS	v/v	v/v	v/v
Raag 3	UT4	1341.73	1370.76	1278.97	1307.93	29.03	17.14	0.59	0.25	0.45	0.27
Raag 3	UT3	1370.76	1405.03	1307.93	1342.22	34.27	6.55	0.19	0.2	0.69	0.41
Raag 8	UT4	1402.5	1428.18	1237.64	1260.89	23.24	11.26	0.49	0.29	0.41	0.26
Raag 8	UT3	1428.18	1463.98	1260.89	1293.31	32.42	10.23	0.32	0.26	0.48	0.28
Raag 9	UT4	1361.77	1388.21	1235.47	1260.17	24.73	7.95	0.32	0.28	0.34	0.28
Raag 9	UT3	1388.21	1417.26	1260.17	1287.38	27.16	5.89	0.22	0.25	0.54	0.32
Raag 10	UT4	1326.66	1353.52	1260.97	1287.02	26.11	11.66	0.45	0.26	0.44	0.28
Raag 10	UT3	1353.52	1382.68	1287.02	1315.38	28.32	8.84	0.31	0.26	0.49	0.26
Raag 11	UT4	1403.86	1430.52	1253.96	1277.91	24.01	7.83	0.33	0.24	0.46	0.33
Raag 11	UT3	1430.52	1455.3	1277.91	1300.24	22.31	5.94	0.27	0.27	0.48	0.28
Raag 12	UT4	1352.29	1382.96	1247.85	1277.41	29.52	14.3	0.48	0.27	0.39	0.29
Raag 12	UT3	1382.96	1406.77	1277.41	1300.34	22.94	12.43	0.54	0.18	0.66	0.39
Raag 3ST	UT4	1728.08	1757.5	1317.14	1338.93	21.8	8.05	0.37	0.25	0.46	0.33
Raag 3ST	UT3	1757.5	1790.36	1338.93	1363.39	24.43	10.48	0.43	0.19	0.71	0.4
Raag-32	UT4	1319.08	1342.68	1193.91	1215.83	21.92	5.73	0.26	0.26	0.59	0.3
Raag-32	UT3	1342.68	1370.34	1215.83	1241.48	25.71	1.39	0.05	0.19	0.79	0.43
Raag 1	UT4	1241.73	1250.88	1181.81	1191.01	9.15	4.1	0.45	0.29	0.59	0.27
Raag 1	UT3	1250.88	1272.39	1191.01	1212.51	21.51	6	0.28	0.23	0.49	0.39
Raag 1	UT1	1301.9	1385.46	1242	1325.6	83.56	11.8	0.14	0.22	0.55	0.43
Raag 1ST	UT4	1348.03	1369.33	1180.88	1199.75	18.86	11.27	0.6	0.21	0.52	0.27
Raag 1ST	UT3	1369.33	1399	1199.75	1226.02	26.25	13.27	0.51	0.21	0.62	0.43
Raag 1ST	UT1	1438.04	1619.8	1260.71	1427.72	166.98	11.22	0.07	0.2	0.61	0.39
Raag 39	UT4	1286.02	1302.04	1184.62	1199.98	15.24	7.83	0.51	0.25	0.36	0.29
Raag 39	UT3	1302.04	1325.84	1199.98	1222.59	22.64	5.94	0.26	0.23	0.48	0.37
Raag 39	UT1	1348.26	1480.37	1243.91	1369.48	125.55	1.89	0.02	0.15	0.66	0.48
Raag 6	UT4	1350.3	1367.91	1292.62	1310.09	17.48	6.75	0.39	0.22	0.48	0.31
Raag 6	UT3	1367.91	1390.45	1310.09	1332.39	22.33	8.82	0.4	0.2	0.66	0.38
Raag Oil-14	UT4	1513.18	1549.01	1220.20	1236.15	15.95	6.03	0.38	0.24	0.56	0.30
Raag Oil-14	UT3	1549.01	1596.25	1236.15	1257.65	21.50	4.43	0.21	0.18	0.58	0.45
Raag Oil-14	UT1	1642.20	1754.81	1278.79	1330.29	51.50	6.27	0.12	0.21	0.57	0.39
Raag Oil-16	UT4	1405.38	1442.38	1257.89	1290.60	32.82	14.08	0.43	0.27	0.41	0.25
Raag Oil-16	UT3	1442.38	1471.99	1290.60	1316.63	25.93	12.72	0.49	0.21	0.71	0.33

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Pay Summary											
Well	Zone	Top	Bottom	Top	Bottom	Gross	Net	N/G	Av Phi	Av Sw	Av Vcl
		mMD	mMD	mTVDSS	mTVDSS	mTVDSS	mVDSS	TVDSS	v/v	v/v	v/v
Raag 3	UT4	1341.73	1370.76	1278.97	1307.93	29.03	15.93	0.55	0.26	0.44	0.26
Raag 3	UT3	1370.76	1405.03	1307.93	1342.22	34.27	3.2	0.09	0.23	0.62	0.39
Raag 8	UT4	1402.5	1428.18	1237.64	1260.89	23.24	10.72	0.46	0.3	0.4	0.25
Raag 8	UT3	1428.18	1463.98	1260.89	1293.31	32.42	9.42	0.29	0.26	0.47	0.27
Raag 9	UT4	1361.77	1388.21	1235.47	1260.17	24.73	7.67	0.31	0.29	0.33	0.27
Raag 9	UT3	1388.21	1417.26	1260.17	1287.38	27.16	5.8	0.21	0.25	0.54	0.32
Raag 10	UT4	1326.66	1353.52	1260.97	1287.02	26.11	10.5	0.4	0.27	0.41	0.26
Raag 10	UT3	1353.52	1382.68	1287.02	1315.38	28.32	8.16	0.29	0.26	0.48	0.25
Raag 11	UT4	1403.86	1430.52	1253.96	1277.91	24.01	6.21	0.26	0.26	0.41	0.3
Raag 11	UT3	1430.52	1455.3	1277.91	1300.24	22.31	5.94	0.27	0.27	0.48	0.28
Raag 12	UT4	1352.29	1382.96	1247.85	1277.41	29.52	12.8	0.43	0.28	0.36	0.26
Raag 12	UT3	1382.96	1406.77	1277.41	1300.34	22.94	6.65	0.29	0.21	0.59	0.34
Raag 3ST	UT4	1728.08	1757.5	1317.14	1338.93	21.8	7.82	0.36	0.25	0.46	0.32
Raag 3ST	UT3	1757.5	1790.36	1338.93	1363.39	24.43	3.94	0.16	0.22	0.65	0.38
Raag-32	UT4	1319.08	1342.68	1193.91	1215.83	21.92	3.34	0.15	0.29	0.45	0.25
Raag-32	UT3	1342.68	1370.34	1215.83	1241.48	25.71	0.19	0.01	0.21	0.62	0.31
Raag 1	UT4	1241.73	1250.88	1181.81	1191.01	9.15	3.9	0.43	0.3	0.58	0.26
Raag 1	UT3	1250.88	1272.39	1191.01	1212.51	21.51	5.3	0.25	0.24	0.47	0.39
Raag 1	UT1	1301.9	1385.46	1242	1325.6	83.56	10.7	0.13	0.22	0.54	0.42
Raag 1ST	UT4	1348.03	1369.33	1180.88	1199.75	18.86	10.03	0.53	0.22	0.5	0.25
Raag 1ST	UT3	1369.33	1399	1199.75	1226.02	26.25	12.65	0.48	0.21	0.61	0.43
Raag 1ST	UT1	1438.04	1619.8	1260.71	1427.72	166.98	9.61	0.06	0.21	0.59	0.38
Raag 39	UT4	1286.02	1302.04	1184.62	1199.98	15.24	7.83	0.51	0.25	0.36	0.29
Raag 39	UT3	1302.04	1325.84	1199.98	1222.59	22.64	5.22	0.23	0.23	0.45	0.35
Raag 39	UT1	1348.26	1480.37	1243.91	1369.48	125.55	1.6	0.01	0.15	0.65	0.47
Raag 6	UT4	1350.3	1367.91	1292.62	1310.09	17.48	6.75	0.39	0.22	0.48	0.31
Raag 6	UT3	1367.91	1390.45	1310.09	1332.39	22.33	4.95	0.22	0.24	0.61	0.33
Raag Oil-14	UT4	1513.18	1549.01	1220.20	1236.15	15.95	4.87	0.31	0.25	0.55	0.28
Raag Oil-14	UT3	1549.01	1596.25	1236.15	1257.65	21.50	3.18	0.15	0.20	0.56	0.44
Raag Oil-14	UT1	1642.2	1754.81	1278.79	1330.29	51.50	3.77	0.07	0.23	0.54	0.37
Raag Oil-16	UT4	1405.38	1442.38	1257.89	1290.60	32.82	13.00	0.40	0.27	0.39	0.24
Raag Oil-16	UT3	1442.38	1471.99	1290.60	1316.63	25.93	1.07	0.04	0.29	0.56	0.27

2.4.6. Facies Definition

Due to absence of core data, the simplified binary facies scheme was applied based on the reservoir and non-reservoir definition from petrophysical cut-offs. The production data suggest consistent permeability distribution across the reservoir and this simplified binary facies definition also supports the same. The binary facies scheme has been tabulated in Table 2.4.6.1:

Table 2.4.6. 1: Facies Definition

Facies	PhiE Cut-off Applied
Mudstone	PhiE ≤11% and V-shale ≥ 50%
Sandstone	PhiT ≥ 11% and V-shale ≤ 50%

2.4.7. Permeability

Permeability was computed using the modified Coates & Dumanoir equation and calibrated with well test permeability.

Signed By: Rakesh Agrawal, Chief commercial Officer

2.4.8. Saturation Height Function

A log-based Harrison-Skelt saturation height function model was used to distribute water saturation in geo-cellular model. The Free Water Level (FWL) was established from Formation Pressure Tester data at wells (Figure 2.4.8.1). Log-derived water saturations were then used to calibrate the function and shown in Figure 2.4.8.1.

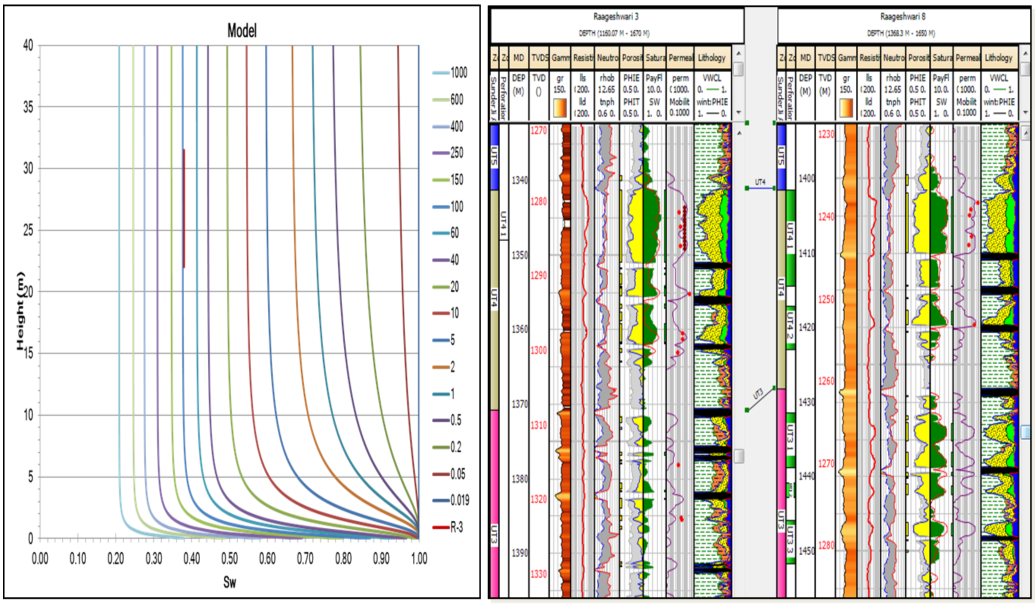

Figure 2.4.8. 1: Saturation Height function and its output comparison to calibrate the function

2.5. Fault Block consideration in 2P

Raag-3, N-Raag-1, Raag-1/1ST, Raag-Central, Raag-3ST fault blocks have been considered in 2P. Without any firm development plan of Raag-6 fault block, it has not been considered in 2P (Figure 2.5.1).

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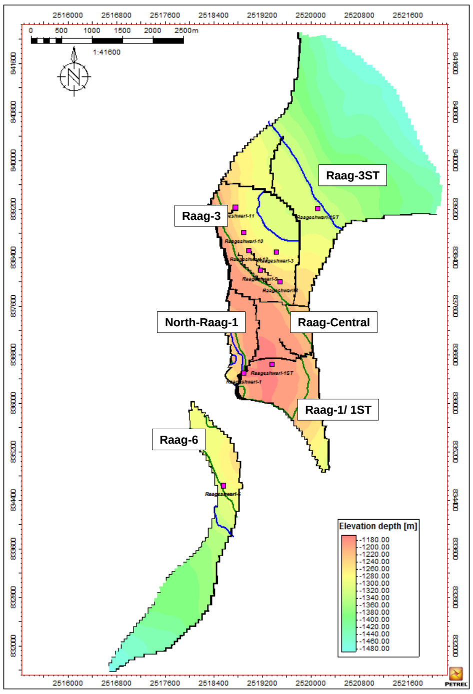

Figure 2.5. 1: 2P Fault Block Consideration

2.6. Geocellular Modelling

Full-field reservoir studies have been carried out with the objective of preparing static and dynamic models for hydrocarbon bearing intervals of the Upper Thumbli formation and to identify development opportunities for the current stage of field development. The static model for Raageshwari-Oil has been prepared by integrating revised subsurface data and interpretations presented in the preceding sections. PETREL (Version 2014) suite has been used for building the static model with standard modelling work-flow as used in the existing FDP. The 2 wells drilled as part of execution of RFDP-1 has come more or less as per predicted in the static model. The updation of static model would be carried out after drilling of all the proposed wells of RFDP.

2.6.1. Structural Model

Structural framework has been created using best case structural interpretation of horizons and faults as discussed in **Section 2.3**. The input data considered for modelling are Top UT4 (reservoir top) depth surface and interpreted fault sticks. An array of structure bounding N-S trending normal faults and E-W trending internal faults have been modelled to define the individual fault blocks in the structural model (Figure 2.6.1.1). A 3D grid with 50 sq. m areal dimension has been prepared using conventional pillar gridding approach. Horizon modelling has been carried out incorporating well-tied Top UT4 surface and well based isochored surfaces for UT3, UT2 and UT1 (Figure 2.6.1.2). Layering sensitivity has been carried out considering the reservoir heterogeneity and in the four zones, 236 layers have been created proportionately. Separate fluid contacts for individual fault blocks have been considered as mentioned in Table 2.4.4.1.

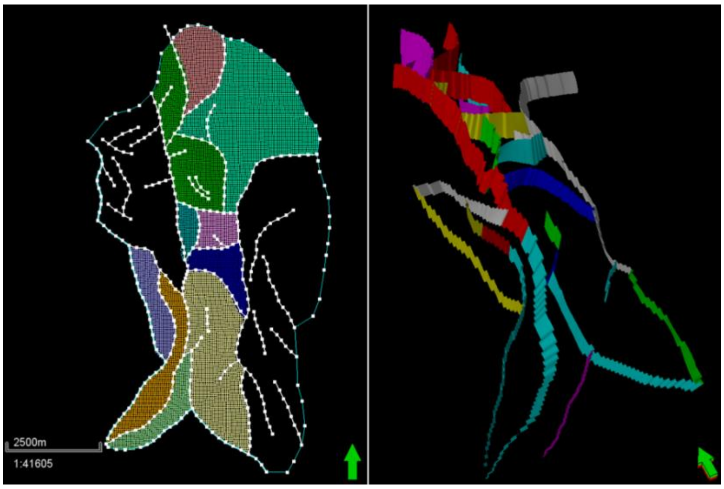

Figure 2.6.1. 1: Fault Model based on Revised Seismic Interpretation

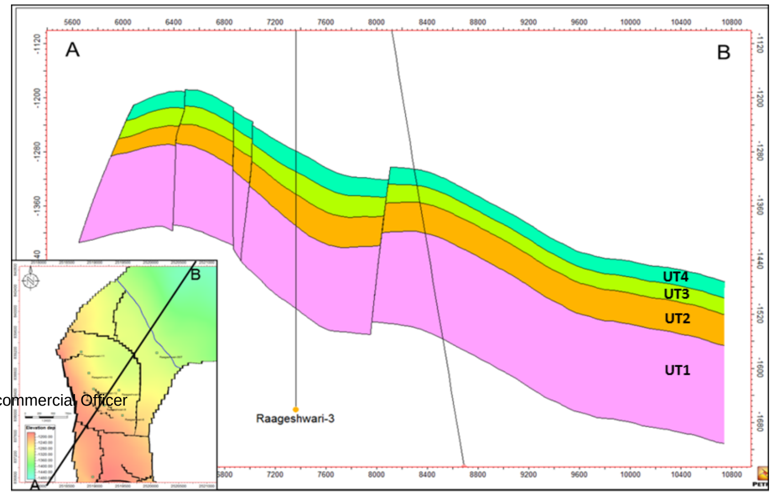

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Figure 2.6.1. 2: Zone in Raag-Oil Model