



### **3D Petrophysical Model for Mansouriya Gas Field/Jeribe Formation by using Petrel**

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#### **Abstract:**

Mansuriya Gas field is an elongated anticlinal structure aligned from NW to SE about 25 km long and 5-6 km wide. The Jeribe formation considered the main reservoir, contains gas condensate fluid, has a uniform thickness about 60 m. The reservoir is significantly over-pressured.

In this study, the 3D geological model for Jeribe Formation in Mansuriya Gas Field is set-up by using Petrel. Jeribe Formation represents the most important reservoir in Mansuriya Gas Field. Four vertical wells (Mn-1, Mn-2, Mn-3 and Mn-4) were drilled in Mansuriya Gas Field and used to set-up water saturation and porosity models represented by a 3D static geological model in three dimensions. The main reservoir, Jeribe Formation carbonate, is subdivided into 8 zones namely J1 to J8, according mainly to porosity log (RHOB and NPHI) trend, DT trend and saturation trend. Petrophysical model (porosity and water saturation) for Jeribe Formation was set-up from values of porosity and water saturation using Sequential Gaussian Simulation algorithm. According to data analyses and the results from modeling the units (J1, J3, J4, J5, J6 and J8) are considered as high-quality reservoir units due to the high PHIE, low water saturation and no shale content. Units (J2 and J7) are considered as non-pay units because of very high-water saturation. Cross sections of petrophysical model were conducted to show the vertical and horizontal distribution of porosity and water saturation between wells in the field.

**Keywords:** Gas field, 3D Petrophysical model, Petrel software.

## موديل بتروفيزيائي ثلاثي الابعاد لتركيب الجريبي في حقل المنصورية الغازي بأستخدام احد برامج النمذجة المكنية (بترل)

### الخلاصة:

حقل المنصورية الغازي عبارة عن طية ممتدة من الشمال الغربي إلى الشمال الشرقي، ويبلغ طولها حوالي 25 كم وعرضها 5-6 كم. يعتبر تكوين الجريبي المكن الرئيسي حيث يحتوي على غاز متكثف ويبلغ سمكه حوالي 60 متر. يعد بناء الموديل الجيولوجي ثلاثي الابعاد من المعلومات تحت السطحية والحقلية مهمة اساسية في الدراسات الجيولوجية المتضمنة تقييم الموارد الطبيعية وتحديد الخطورة. يتضمن هذا البحث بناء موديل جيولوجي ثلاثي الابعاد لتكوين الجريبي في حقل المنصورية الغازي باستخدام برنامج البتريل . يمثل تكوين الجريبي المكن الأكثر أهمية في حقل المنصورية الغازي. أربعة آبار عمودية حفرت في الحقل واستخدمت لغرض بناء الموديل البتروفيزيائي (المسامية والتشبع المائي) متمثلاً بموديل جيولوجي بالإبعاد الثلاثة. تم تقسيم تكوين الجريبي الرئيسي إلى 8 وحدات هي J1 إلى J8 وأعتد التقسيم بشكل أساسي على سلوك تسجيلات المسامية وبالإضافة الى كميات التشبع المائي والهيدروكاربوني ثم تم بناء موديل بتروفيزيائي لتكوين الجريبي من قيم المسامية والتشبع المائي. لقد اعتبرت الوحدات (J1,J3,J4,J5,J6 and J8) ذات مواصفات مكنية عالية نظراً الى المسامية الفعالة العالية التي تمتلكها والتشبع المائي الواطئ. اما الوحدات (J2 and J7) فقد اعتبرت غير منتجة وغير حاملة للهيدروكاربونات نتيجة للمسامية الفعالة الواطنة والتشبع المائي العالي جدا. اعدت المقاطع العرضية للموديل البتروفيزيائي لتوضيح التوزيع العمودي والأفقي للمسامية والتشبع المائي بين الآبار في الحقل.

### Introduction:

Geological modeling and the static model are very important in the reservoir study. In two dimensions, a geological formation or unit is represented by a polygon which can be bounded by faults, unconformities or by its lateral extent, or outcrop. In geological models, a geological unit is bounded by 3-dimensional triangulated or gridded surfaces. The equivalent to the mapped polygon is the fully enclosed geological unit, using a triangulated mesh. For the purpose of property or fluid modeling these volumes can be separated further into an array of cells, often referred to as volumetric elements. These 3D grids are the equivalent to 2D grids used to express properties of single surfaces.

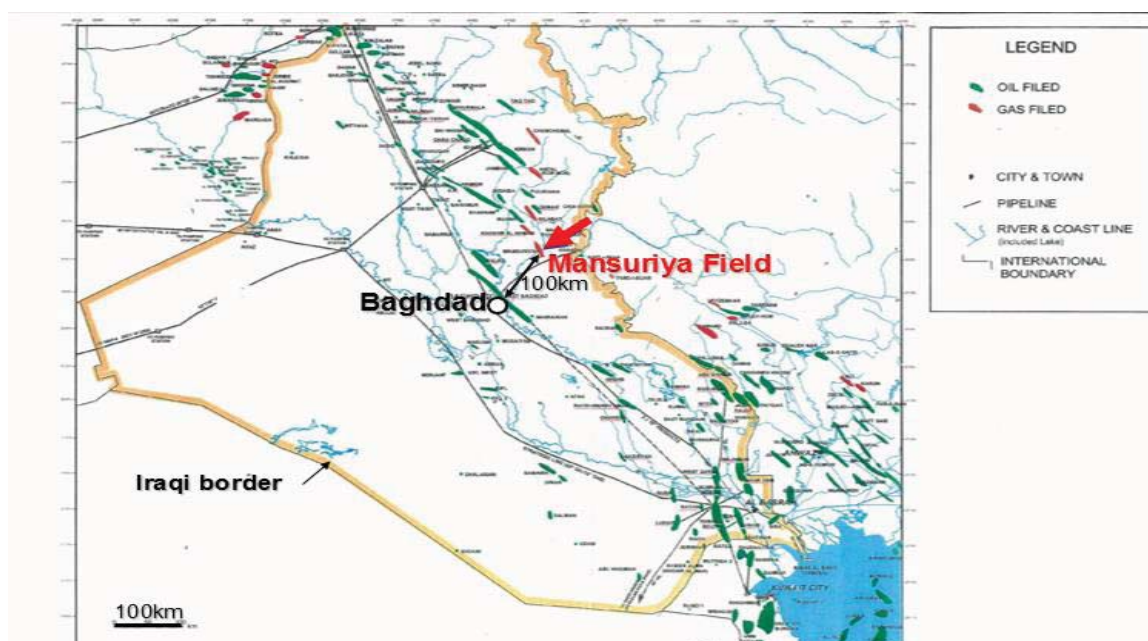
Identifying and recovering hydrocarbons require accurate, high-resolution geological modeling of the reservoir structure and stratigraphy [1].

Mansuriya Gas field is an elongated anticlinal structure aligned from NW to SE about 25 km long and 5-6 km wide. The Jeribe formation considered the main reservoir where it contains gas condensate fluid and has a uniform thickness about 60 m. In this study a 3D geological model for Jeribe Formation in Mansuriya Gas Field will be set-up by using Pertel and used to set-up water saturation and porosity models in three dimensions then calculate the gas initially in place for the Jeribe formation.

### The Study Area:

The location of Mansuriya Gas field in block 45 in Diyala governorate about 45 km north east of Ba'quba. It is also located about 100 km north east of Baghdad as shown in Figure (1). The 2D seismic data was acquired between 1977 and 1982. 2D Seismic lines were re-processed in 2002 and again in 2006.

The Mansuriya field is an elongated anticlinal structure aligned from NW to SE about 25 km long and 5-6 km wide. The hydrocarbon accumulation (gas condensate) is located in the Jeribe formation which is considered the main reservoir, has a uniform thickness about 60 m. The reservoir is significantly over-pressured [2].



**Fig. (1) Mansuriya Gas Field Location Map [4]**

**Methodology:****Model Design**

Petrel, the modeling program, allows the user to interpret seismic data, perform well correlation, build reservoir models suitable for simulation, submit and visualize simulation results, calculate volumes, produce maps and design development strategies to maximize reservoir exploitation. [1].

**Import Data**

Data Prepared in files, one file for each data object, are imported by Petrel program. This data includes:

**Well heads:** the position of the well in X, Y and Z directions.

**Well tops:** markers representing significant points.

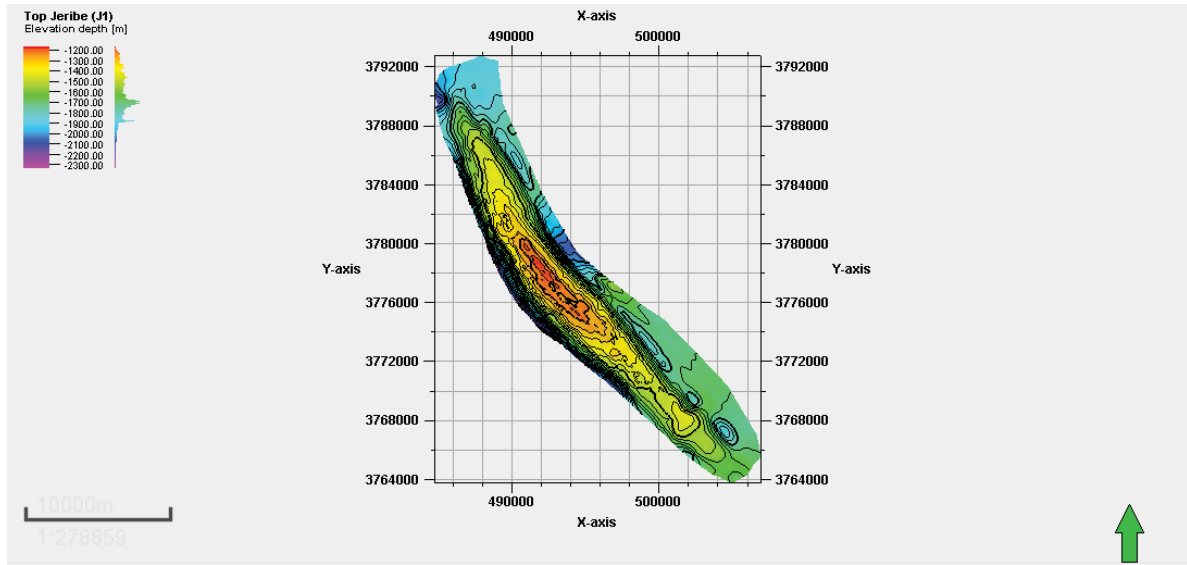
**Well logs and core data.**

**Structural Modelling:**

It consists of three operations: fault modelling, pillar gridding, and vertical layering.

Eight contour maps have been built for the eight units of Jeribe formation as divided in the log interpretation shown in the CPI of the wells .These contour maps have been built depending on the contour map from the last study on the reservoir where it is corrected for seismic lines. Contour maps have been built from the tops of the Jeribe formation. In constructing these maps, old contour map direction is considered as a general direction in building the new contour maps [2].

Figure (2) shows a contour map for the J1 unit.

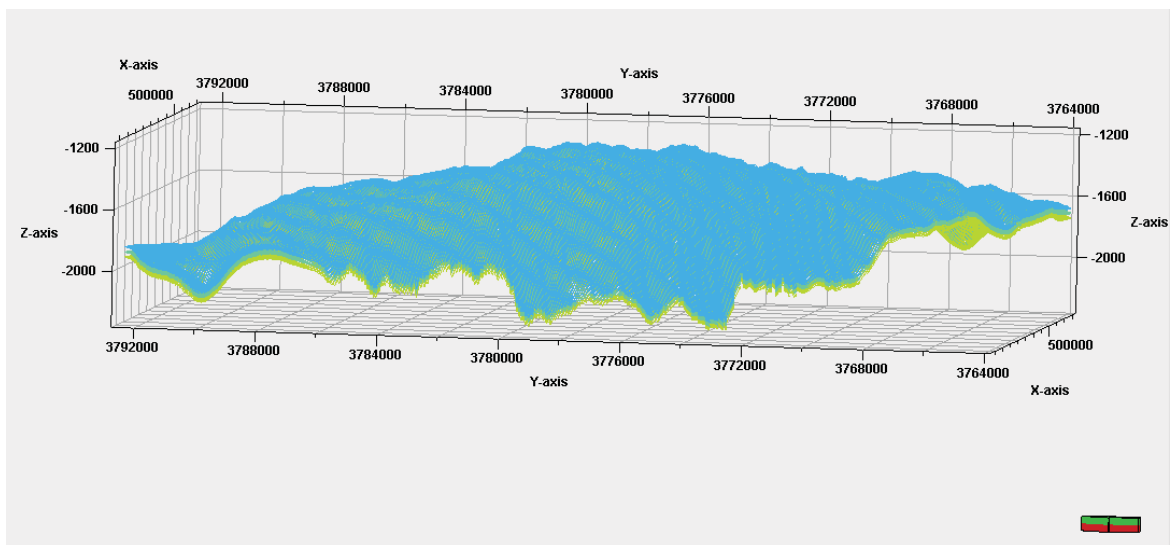


**Fig. (2) Structural contour map for J1 unit.**

**Pillar Gridding**

Pillar Gridding is the process of making the ‘Skeleton Framework’ which is consisting of a Top, a Mid and a Base skeleton grid, each attached to the Top, the Mid and the Base points of the Key Pillars. [2]

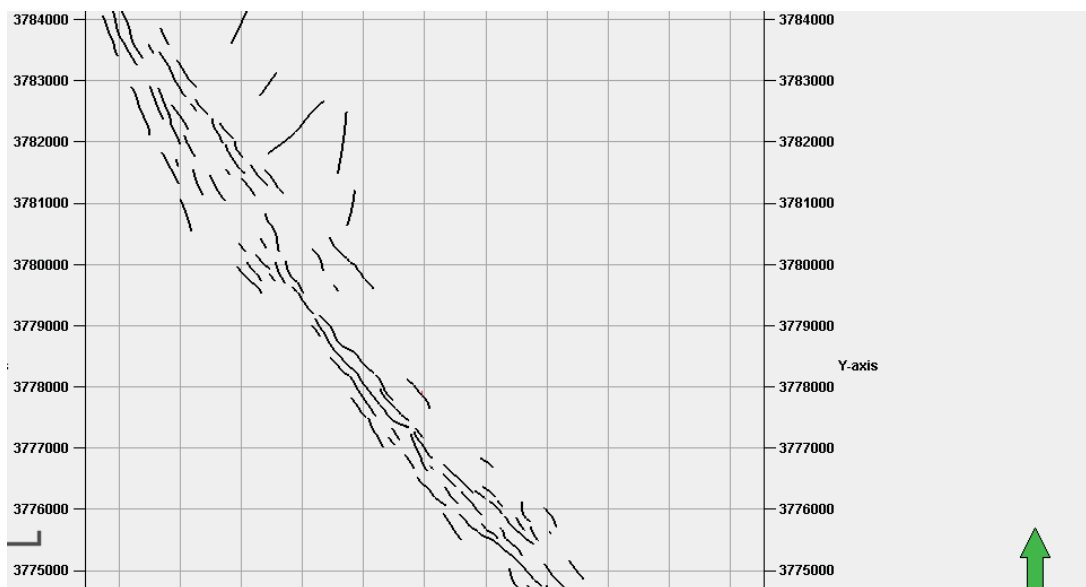
Jeribe formation is represented by three-dimensional grid systems of 50\*50 grid elements along the x and y axis as shown in the Figure (3).



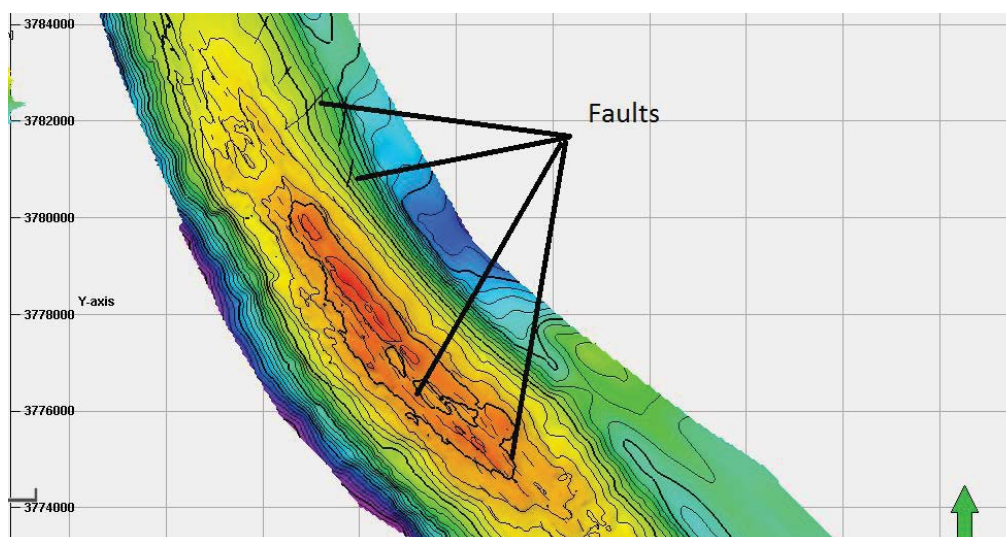
**Fig. (3) The Skeletons of the Jeribe formation.**

### Fault Modelling:

The current interpretation of the Mansuriya structure contains in excess of 120 small faults with a predominantly NW SE orientation where depends on the last 3D seismic study for Mansoriya Gas field 2013 conducted by the Oil Exploration company and interpreted by Schlumberger [2]. Figure (4) shows the faults of the Jeribe formation. These faults have been explicitly modeled in Petrel as vertical faults and the overall trend has been used to define the orientation of the cells within the model, Figure (5).



**Fig. (4) The faults in the Jeribe formation [1]**



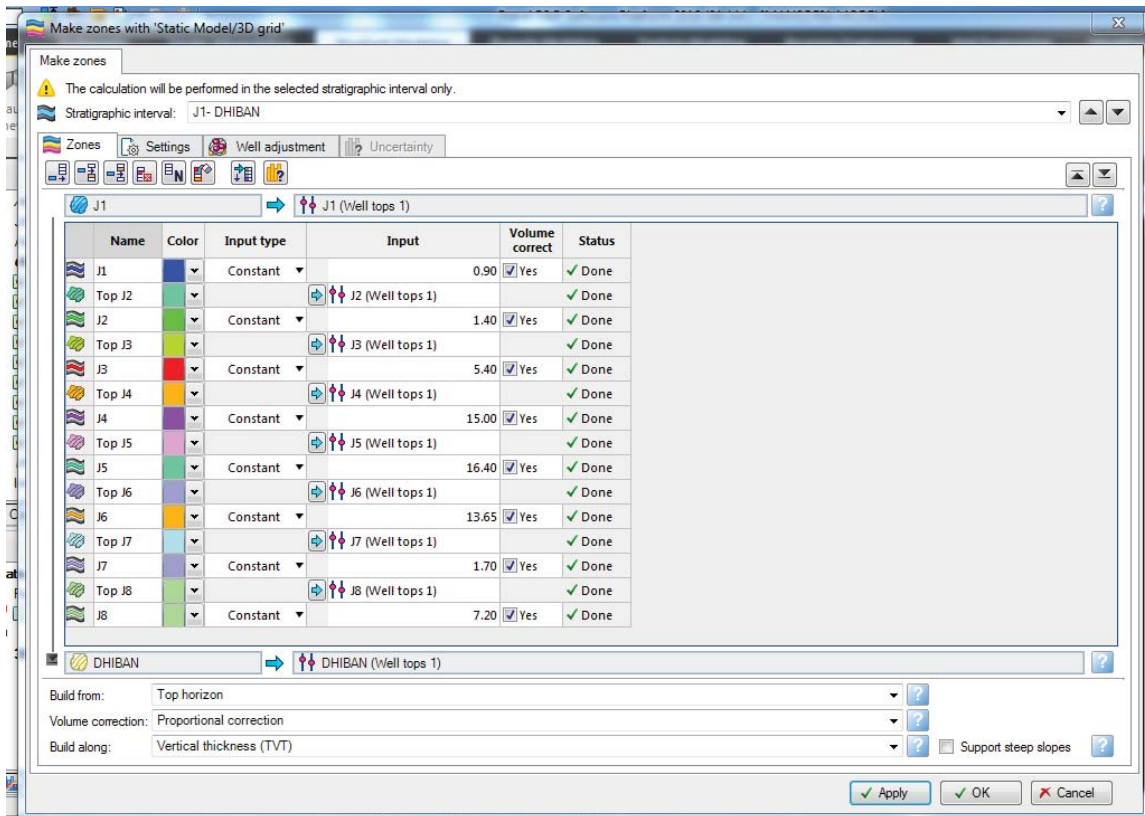
**Fig. (5) Faults of the Jeribe formation and their effect.**

As it can be seen above in figure (5) the faults within the Jeribe formation have no effect on the contour lines of the Jeribe formation and this was approved by the last 3D seismic survey in 2013.

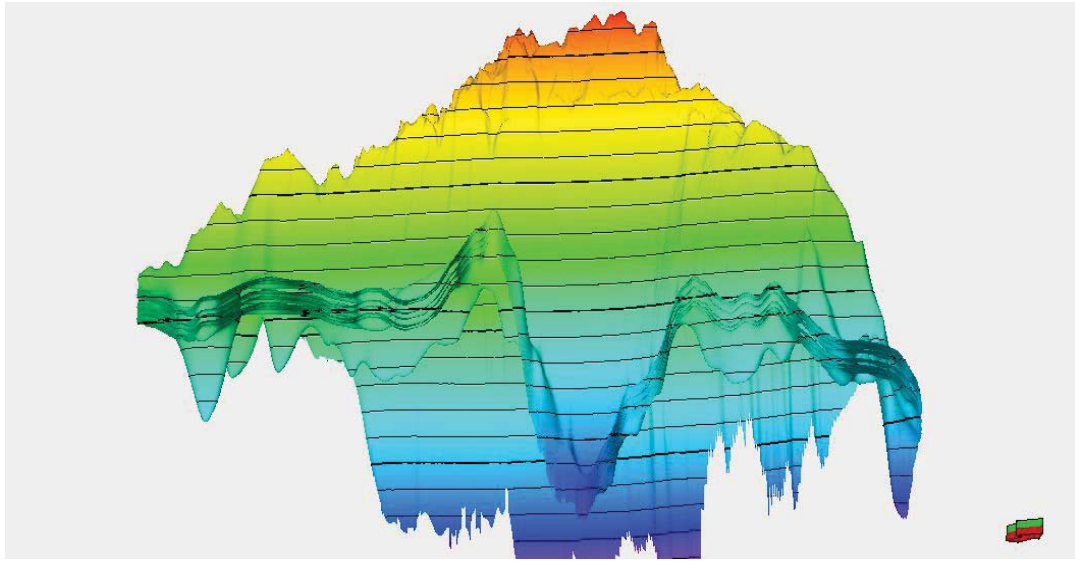
**Make horizons [2]**

It is the first step used in defining the vertical layering of the 3D grid in Petrel.

The eight horizons that have been built up for the formation were built by entering main structural maps that had been built in (Structural modeling). Figures (6-A, 6-B) show the main zones of Jeribe formation.[2]



**Fig. (6-A) Main zones of Jeribe formation (table).**



**Fig. (6-B) Main zones of Jeribe formation (map).**

### **Layering**

The layering allowed the definition of the final vertical resolution of the grid by setting the cell thickness or the number of desired cell layers [2]. The formation has been divided into many layers depending on petrophysical properties and these layers have been build depending along the vertical thickness of each layer which has been determined based on porosity log (RHOB and NPHI) trends, DT trend and saturation trend. Figures (7-A), (7-B) show the layering of Jeribe formation.



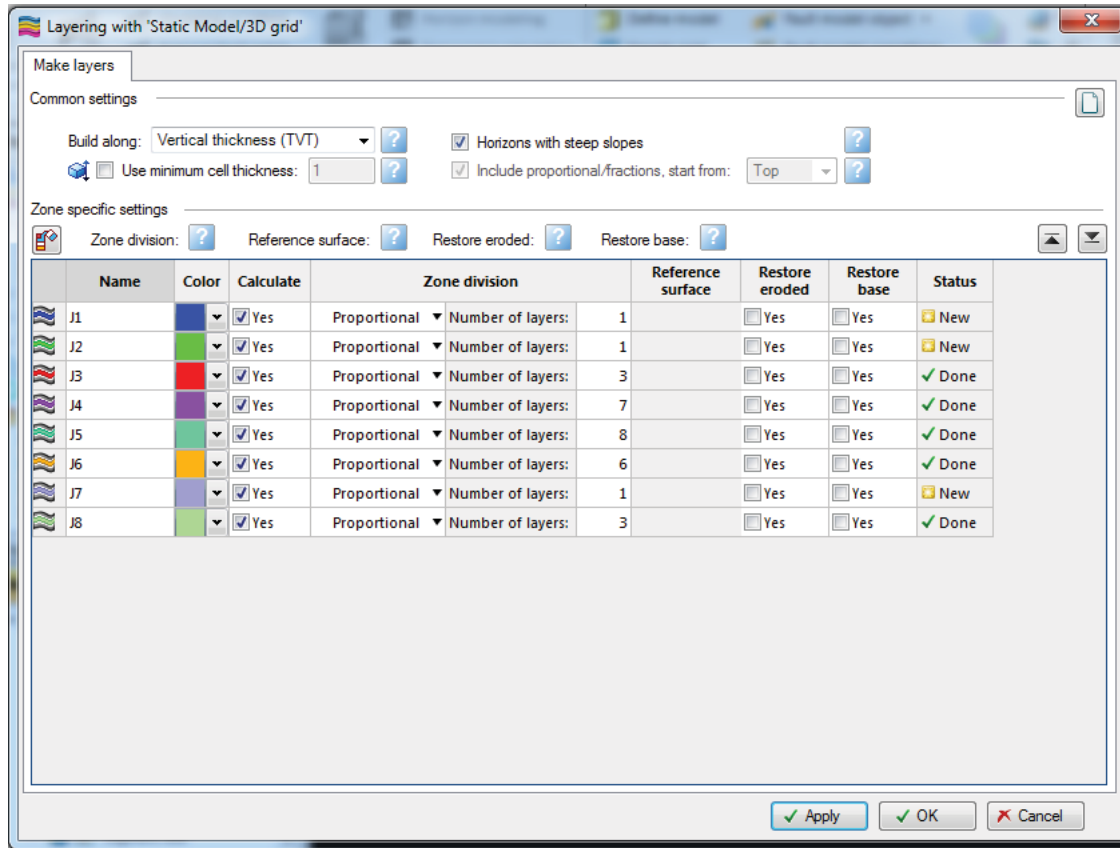


Fig. (7-A) The layering in the Jeribe formations (table).

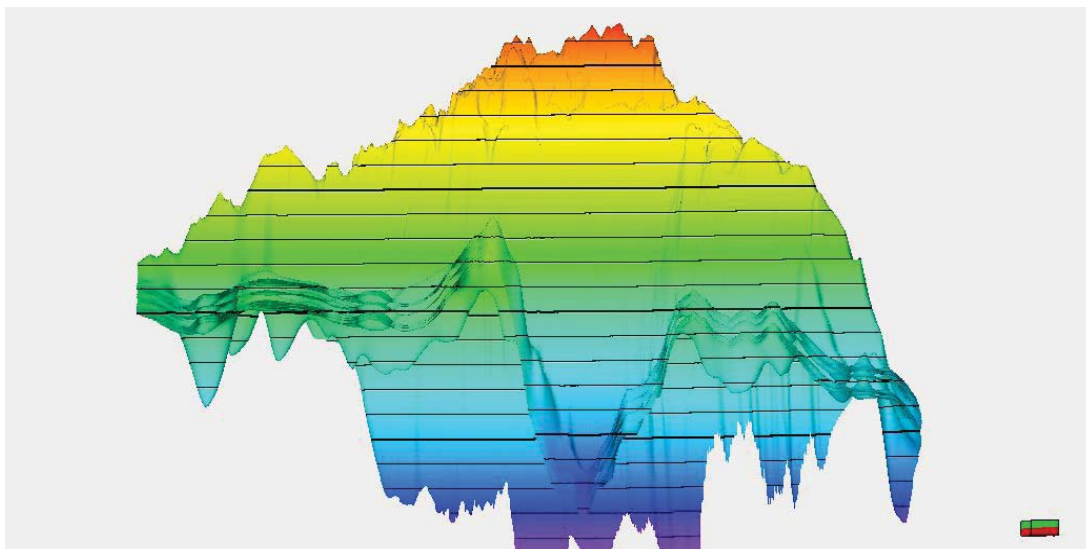


Fig. (7-B) The layering in the Jeribe formations (map).

### Scale up of Well Logs

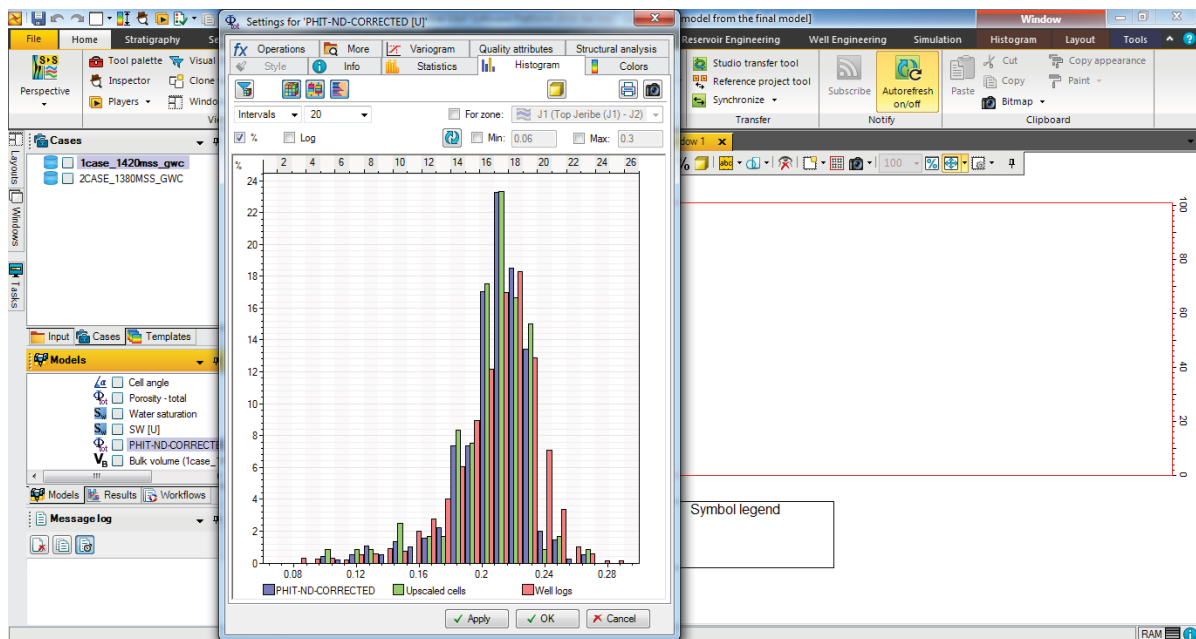
For each grid cell, all log values that fall within the cell will be averaged according to the selected algorithm to produce one log value for that cell [2]. The porosity and water saturation values have been scaled up using the (arithmetic average).[10]

### Petrophysical Modeling process

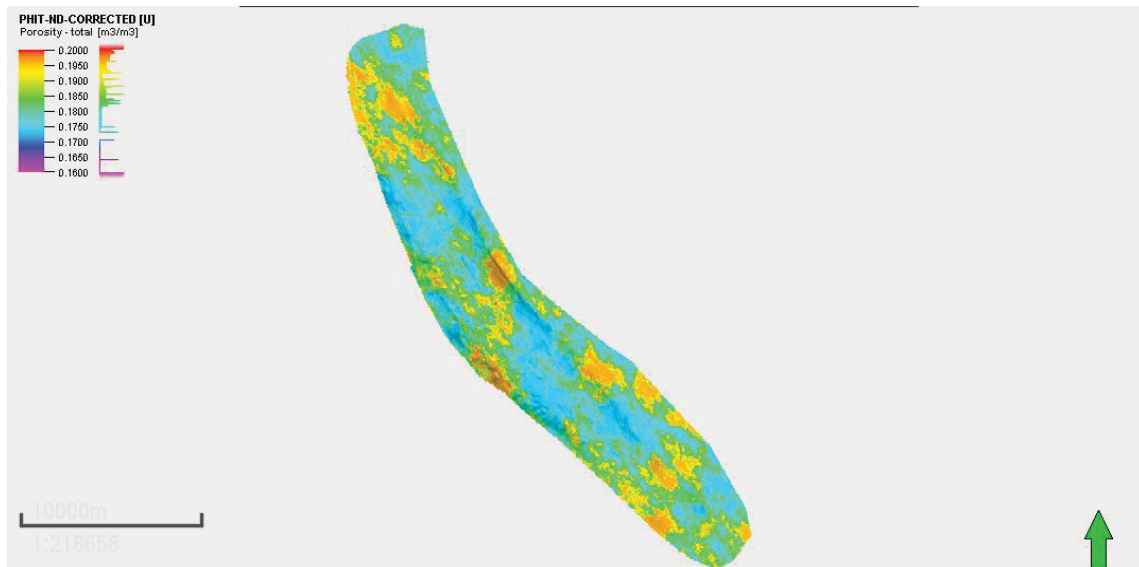
It is a process of assigning petrophysical property values to each cell of the 3D grid [2]. The petrophysics models include:

#### Porosity model

It was built depending on the final results of the porosity logs (density, neutron, and sonic logs) from CPI. Statistical sequential Gaussian simulation algorithm has been used. Some erroneous values appeared in the upscaled porosity model but the results in general are similar. Figure (8) shows the comparison between the porosity from log up scaled porosity. Figure (9) shows the porosity model for Jeribe formation.



**Fig. (8) Porosity comparison**



**Figure (9) Porosity distribution.**

Generally, it has been noticed that porosity values in Jeribe formation increases in the flanks better than on the crust and in the North West direction.

### **Water saturation model**

It was built after the scale up of water saturation from CPI for each reservoir unit of the Jeribe formation in the Mansoriya field [1]. The same Geostatistical method was used as in the porosity, according to the available data. Figure (10) shows the comparison between the Sw from log and the upscaled Sw. Figure (11) shows the water saturation model for Jeribe formation.

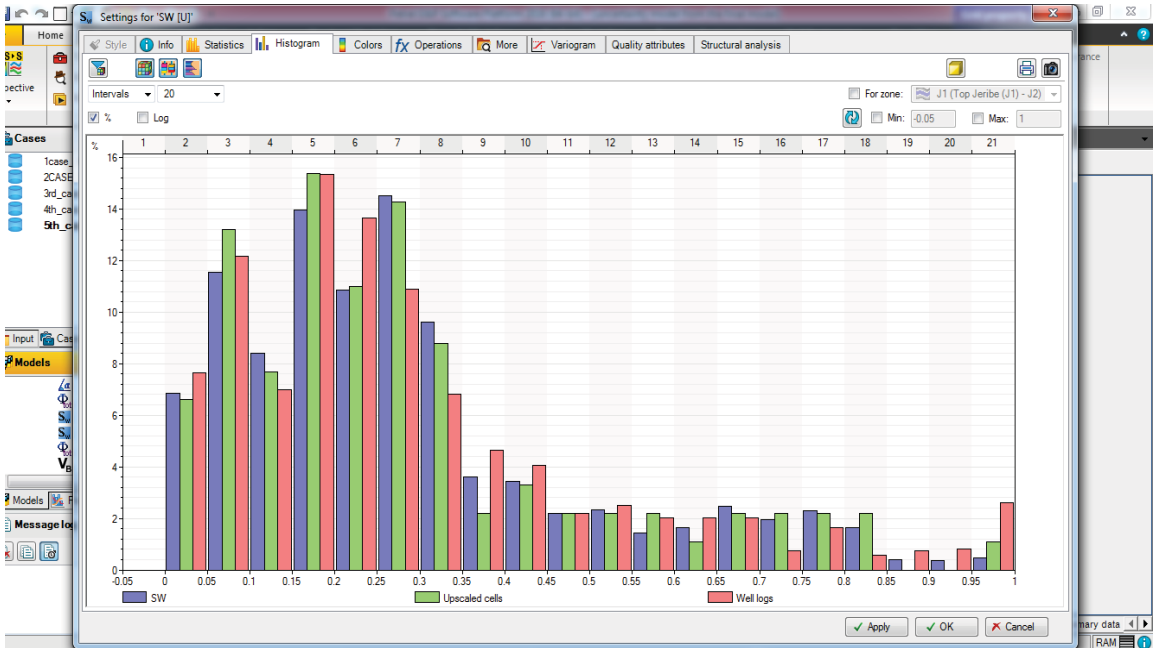


Fig. (10) Water saturation comparison

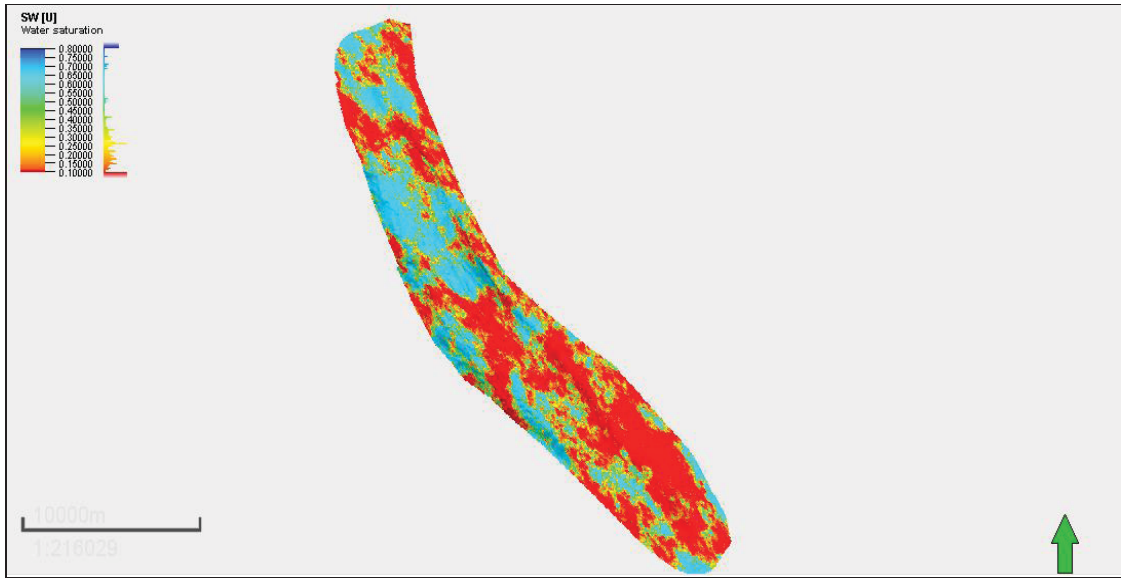


Fig. (11) Water saturation distribution

Water saturation model shows increasing in (SW) values in the northern part more than the southern part of Jeribe formation.

### Net to Gross reservoir estimation

Net to gross refers to the sum of productive intervals of a reservoir and is determined by the application of cutoffs of porosity, shale volume and water saturation which is a specified limit below which a formation would be unable to achieve or sustain commercial production [10].

No Vsh cutoff is applied for the Jeribe formation, as the petrophysical analysis found the Jeribe to be a clean formation. In order to designate the anhydrite as non-reservoir layers (layer 2 and 7), it is assumed to be (net to gross = 0).

The porosity cutoff has affects only zones 6 and 8 only and the average N/G for the other layers (2, 7 not included) is 0.95 as shown in in Table (1).

**Table (1) Net to gross values with summary calculations for well MN-1.**

Zone Name	Top	Bottom	Gross	Net	N/G	Av Phi	Av Sw
J1	1349.5	1350.7	1.2	1.2	1	0.152	0.085
J2	1350.7	1352.1	1.4	0	0	---	---
J3	1352.1	1357.4	5.3	5.3	1	0.192	0.148
J4	1357.4	1375.2	17.8	17.8	1	0.211	0.169
J5	1375.2	1390.3	15.1	15.1	1	0.197	0.236
J6	1390.3	1405.9	15.6	15.6	1	0.195	0.354
J7	1405.9	1407.6	1.7	0	0	---	---
J8	1407.6	1415	7.4	7.22	0.976	0.221	0.31
TOTAL	1349.5	1415	65.5	62.27	0.951	0.202	0.245
All Zones	1349.5	1415	65.5	62.22	0.95	0.202	0.245

### Gas Water Contact

Fluid contact of the Jeribe Formation has estimated by using the bottom hole build-up pressure data measured from the well tests and the actual well results such as Lowest Known Gas (LKG) in the well MN-2, Highest Known Water (HKW) in the well MN-4.

The plot of pressure versus depth shows that there is a considerable scatter in the gas pressure data, due largely to the poor accuracy of the Amerada gauges. However, the

pressure data could be divided into two groups according to their behaviour with gas gradient.

The gas gradient was calculated from the specific gravity of the fluid which was calculated from the pvt model  $\approx 0.11$  psi/ft. This gas gradient line was passed through a weighted average of all the gas pressure points in both groups. Similarly, the water gradient was determined from the salinity of the water sample from test Well MN-4 to be 0.456 psi/ft [3]. The water gradient line has passed through the well test average reservoir pressure. The gas and water gradient lines intercept at depths of 1420 and 1380 mss. We have therefore taken two gas water contacts at 1420 and 1380 mss. Table (2) shows the raw test data that used to calculate GWC. Figure (12) shows gas gradient used to calculate GWC.

**Table (2) The raw test data that used to calculate GWC**

well	half of the tested interval		SHUT IN BHP	Gauge depth
	RTKB	mss	psig	mss
MN-1	1371	1288	4033	1234.5
	1413	1330	3987	1323
MN-2	1411	1323	4048	1280.5
	1465	1377	4012	1379.5
	1423	1335	3938	1314
MN-4	1654	1518	4200	1532
	1662	1526	4146.7	1534
MN-3	1436	1346	4089	1322.5

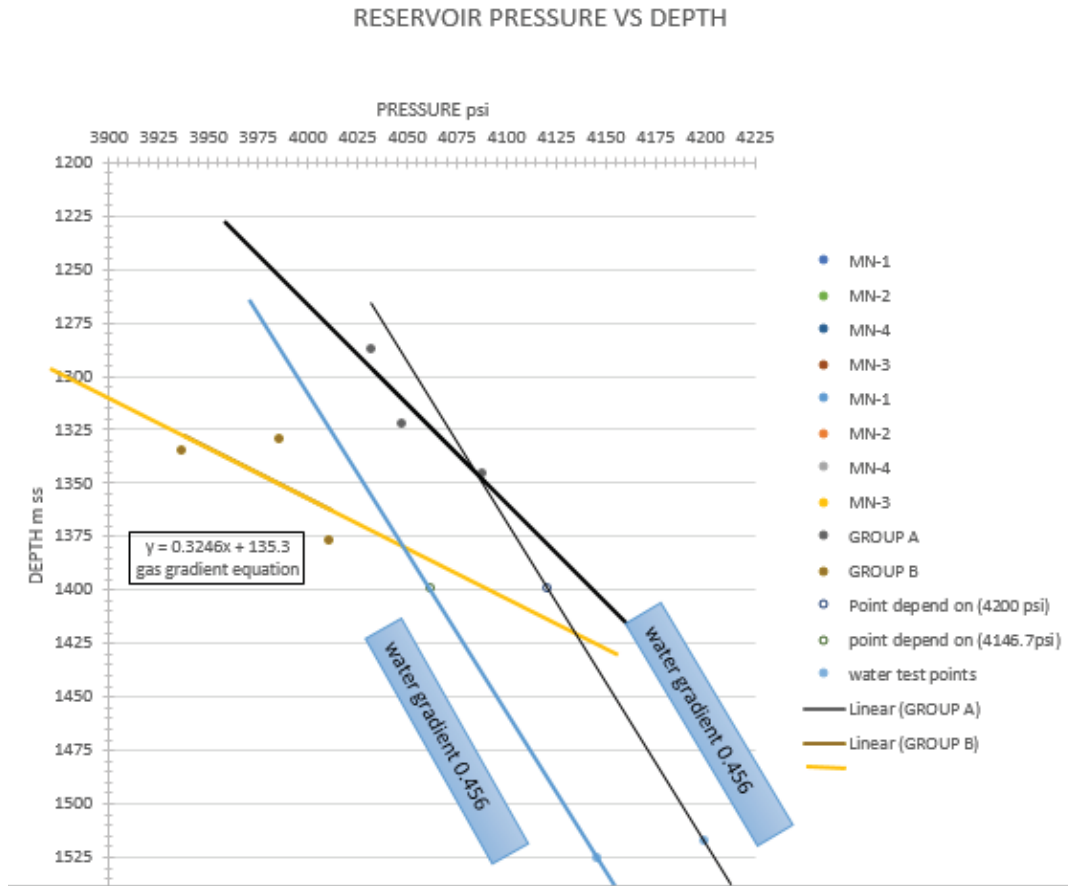


Fig. (12) Gas gradient used to calculate GWC.

**Gas Expansion Factor**

The gas expansion factor at initial reservoir conditions is 270 scf/rcf, as derived from the pvt reservoir fluid composition model [1].

**Volumetric Calculation**

The volume of Initial gas in place of Jeribe formation which was calculated by Petrel at a GWC at 1420 mss is 2,330 bcf and at 1380 mss is equal 1,723 bcf. Figure (13) shows the equations which has been used for volume calculations in Petrel. Tables (3) and (4) show the volumetric calculations summary for Contacts at 1380 mss and at 1420 mss respectively.[2]

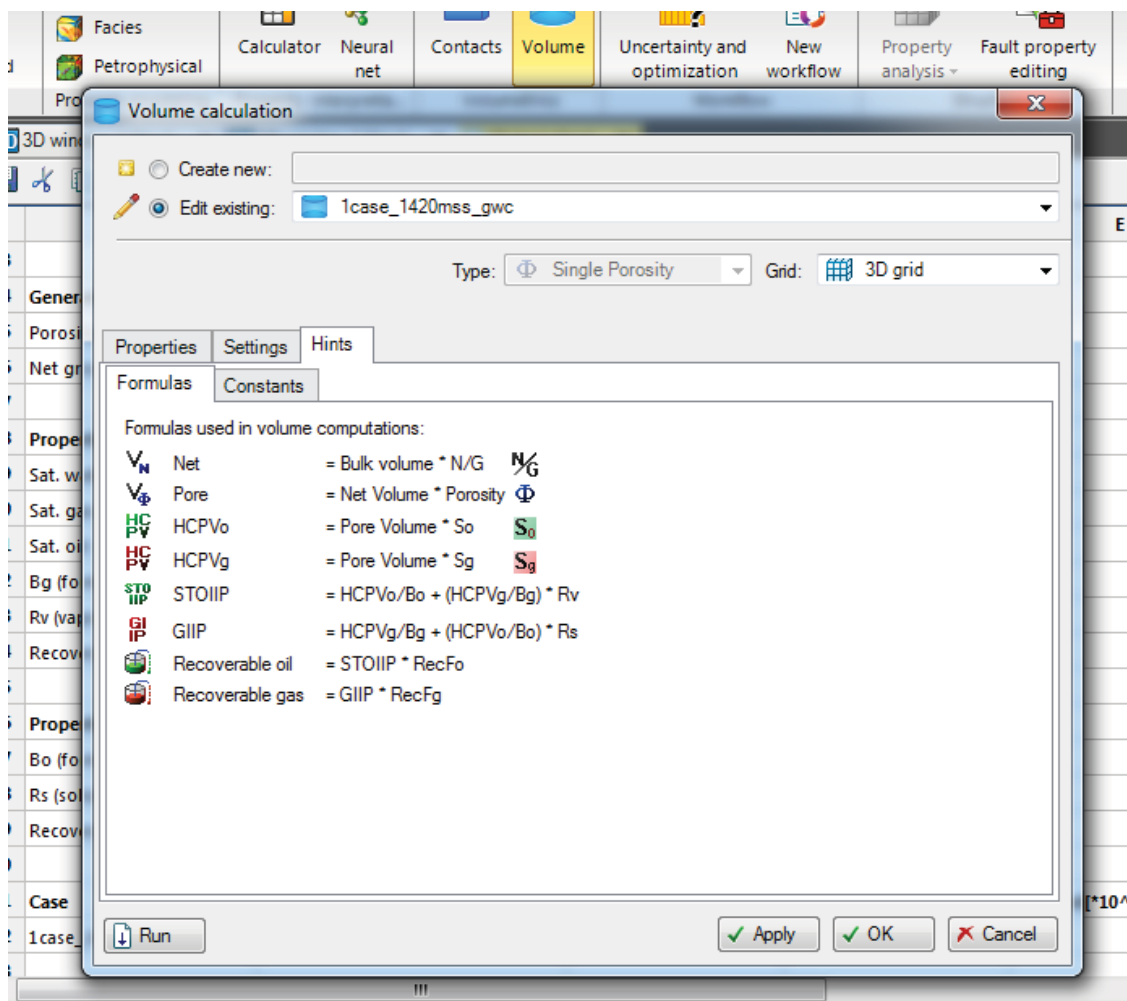


Fig. (13) The equations that used for volume calculations in petrol.

Table (3) Volumetric calculations summary for Contact at 1380 mss

Case	Bulk volume[*10 <sup>6</sup> m3]	Net volume[*10 <sup>6</sup> m3]	Pore volume[*10 <sup>6</sup> rm3]	HCPV gas[*10 <sup>6</sup> rm3]	GIIP[*10 <sup>6</sup> sm3]
1case_1420mss_gwc	1735	1543	329	249	66037
Zones					
J1	29	27	5	3	882
J2	50	0	0	0	0
J3	171	161	34	31	8127
J4	485	456	100	86	22808
J5	438	412	87	68	18179
J6	358	336	70	41	10826
J7	42	0	0	0	0
J8	161	151	33	20	5215



**Table (4) Volumetric calculations Summary for Contact at 1420 mss**

Case	Bulk volume[*10 <sup>6</sup> m <sup>3</sup> ]	Net volume[*10 <sup>6</sup> m <sup>3</sup> ]	Pore volume[*10 <sup>6</sup> m <sup>3</sup> ]	HCPV gas[*10 <sup>6</sup> m <sup>3</sup> ]	GIIP[*10 <sup>6</sup> m <sup>3</sup> ]
2CASE_1380MSS_GWC	1264	1124	240	184	48853
Zones					
J1	24	22	4	3	735
J2	40	0	0	0	0
J3	134	126	27	24	6352
J4	375	352	77	66	17545
J5	316	297	63	49	13147
J6	240	226	47	28	7454
J7	28	0	0	0	0
J8	108	101	22	14	3620

### **Conclusions:**

1. Structural model shows that Mansuriya Gas Field represents an elongated anticlinal structure aligned between NW and SE, about 25 km long and 5-6 km wide.
2. No Vsh cut-off is applied for the Jeribe formation, as the petrophysical analysis found the Jeribe to be a clean formation. In order to designate the anhydrite as non-reservoir layers (layer 2 and 7), it is assumed to be (net to gross = 0) .The porosity cutoff has affected zones 6 and 8 only and the average N/G for the other layers (2, 7 not included) is 0.95.
3. Fluid contact for the Jeribe Formation was estimated by using the bottom hole build-up pressure data measured from the well tests and the actual well results such as Lowest Known Gas (LKG) in the well MN-2, Highest Known Water (HKW) in the well MN-4.
4. Generally, it has been noticed that porosity values in Jeribe formation increases in the flanks better than on the crest and in the North West direction while water saturation model shows increasing in (SW) values in the northern part more than the southern part of Jeribe formation.
5. The volume of Initial gas in place of Jeribe formation at a GWC at 1420 mss is 2,330 bcf and at 1380 mss is equal 1,723 bcf while the GIIP from the TPOC study in 2014 is 2.378 bcf at 1460 mss and the GIIP for Mitsubishi study in 2006 is 2.058 bcf at GWC = 1428 mss.

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**Nomenclature**

$S_o, S_w, S_g$	Oil, water and gas saturation [fraction]
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**Greek Symbols**

$\emptyset$	Porosity [fraction]
$\emptyset_e$	effective porosity, fraction

**Abbreviations**

CPI	Computer Processed Interpretation
PHI	Porosity [dimensionless]
STO	stock-tank oil