Sirte University Scientific Journal (Applied Sciences) Vol.7(2),111–126,December2017

Geological Characterization as integral part of Petroleum reservoir management (Fajer pool of Nafoora oil field)

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Abstract

The understanding of reservoir management has improved greatly over the last few years and a methodology is slowly emerging to facilitate its routine implementation. Reservoir management used to be identified with production engineering, then became synonymous with numerical reservoir simulation. This paper discusses some issues belongs to reservoir characterization which considered as one of the most important players in understanding and verifying the under studied reservoir. Our example is Fajer pool, small reservoir located in the northwestern part of the Nafoora field that is located in in the eastern part of Libya in the Concession 51 West, owned by Arabian Gulf Oil Company.

Keywords: *Reservoir management, Production engineering, Fajer pool,.*

1. Introduction

Reservoir management is the application of available technology and knowledge to a reservoir system in order to control operations and maximise economic recovery within a given management environment.[1]

The most common objectives of reservoir management are:

1. to decrease risk
2. to increase oil and gas production
3. to increase oil and gas reserves
4. to maximise recovery

5. to minimise capital expenditures
6. to minimise operating costs

2. Basic definitions

2.1 Data Management. This process represents the organizing of raw and interpreted data into a readily accessible form. It is not intended to imply what type or quantity of data is needed. Those issues are addressed in other processes.

2.2 Data Captured. This information includes raw data such as seismic records, well logs, conventional and special core analyses, fluid analyses, static pressures, pressure-transient tests, flowing pressures, periodic well production tests, and monthly produced volumes of oil, gas, and water. Interpreted data could include seismic time maps, seismic conversion of time-todepth maps, seismic attribute maps, log analyses, formation tops, structure and isopach maps, cross sections, geologic models, and simulation models.[2]

How much information and how to capture this information varies with the size of the database, size of the resource, and the remaining life of the resource. Hand-kept records and hard copies of information may be adequate for small resources. However, digital databases should be considered for all resources for the systematic acquisition of data, the growing usability of software for data interpretation, and the value of having data available to individuals in a distributed network.

2.3 Quality Assurance. Processes for the timely capture and quality maintenance of data also should be established. Personnel may be required for this specific purpose. While this assignment may be a drain on limited manpower, the benefits of readily available, high-quality data will save time spent in reorganizing, checking, and reinterpreting data each time a study is conducted. The time savings more than returns the cost of quality data capture. Studies of work output indicate that as much as 50% of the time spent on a project can be consumed by finding and organizing data that is not maintained in a readily accessible, high-quality format. .[3]

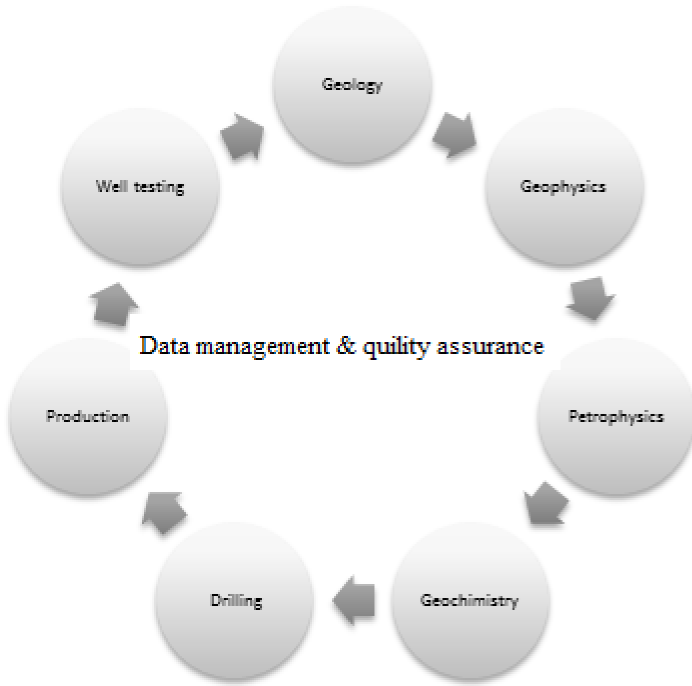

Figure.1. Data management and quality assurance

2.4 Reservoir Description. This process is the development of an up-to-date, detailed description of the reservoir that incorporates available data and technology into a field wide interpretation consistent with observed historical reservoir performance. Variations and risks in the description should be included. Again, the effort that goes into this description depends on the size of the remaining resource.

Geophysical, geological, and engineering interpretations are expected to produce information on the distribution of hydrocarbons in place and reserves. These interpretations include field and regional structure maps, including fluid-contact locations and the size of aquifers; isopach and porosity maps; the number of flow units or individual producing zones; the depositional environment including information on diagenetic changes and vertical and areal barriers to flow (or lack thereof); and variations in fluid saturations and permeabilities. The expected variability in these values should be included in these assessments. Descriptions from hand-drawn maps and correlations may suffice for small resources; however, in most cases, a geologic model is developed to capture these interpretations, with more complex models being needed for larger resources. .[4]

3. Fajer Pool

3.1 Background Summary

Fajr pool is a small reservoir located in the northwestern part of the Nafoora field that is located in Concession 51 West, owned by Arabian Gulf Oil Company. It is in the eastern part of Libya. The location of Fajr pool in Nafoora field is presented in (Figure 2).

The fajr Pool was discovered by well G052 in August 1967. It was put on production in April 1979 by producing wells: G052, G118, G161. Consequently, additional wells were drilled and produced for variable intervals. Some wells with poor productivity have not been produced and classified as observation wells. Twenty wells have been drilled in this pool. Currently, 12 wells are classified as producers and 8 wells as observation. Presently, Only four wells are producing, three of them by natural flow – G118, G195, and G234 and one well G224 by gas lift. The reason for the high number of shut-in wells is the shortage of lift gas. The well status is presented in (Table 1).

The reservoir pressure has been remained fairly constant, supported by the underlying aquifer. The original reservoir pressure is 4710 psia. The present reservoir pressure is estimated at 4218 psia with a decline of 492 psia from the original reservoir pressure. The pool is producing significantly above the bubble point pressure (measured at 1690 psia). Reported gas production has been negligible and the reservoir assumed to have no gas cap. The main source of energy driving the production from the reservoir comes from the strong natural water drive (from edge and bottom).

The cumulative oil and water production in December, 2001 were 38.23 MMSTBO and 6.77 MMSTBW. The average oil rate in the year 2001 is 3711 STBO/d at a water cut of 22% and a GOR of 487 SCF/STB. In this pool, production rates vary significantly amongst wells.

3.2 Basic data

3.2.1 PVT Data

A PVT analysis are carried out on bottom hole oil samples taken from the well G-212, the oil at reservoir conditions (4710 psia and 240 ^{o}F) is undersaturated. The observed bubble point pressure is 1690 psia . The hydrocarbon compositions of the reservoir fluids through Hexane's for the sample of well G-212 are presented in (Table 2). The results of pressure-volume relations are presented in (Table 3). At several pressure levels below the observed saturation pressure, the reservoir fluid parameters subjected to differential vaporization at 240 ^{o}F are summarized in (Table 4) and are graphically represented in (Figures: 3 and 4). The viscosity of the liquid phase was measured at the reservoir temperature of 240 ^{o}F, and over a wide range of pressures, from above saturation pressure to atmospheric pressure. This data is presented in (Table 5) and graphically represented in (Figure: 5). At conditions based on saturation pressure at reservoir temperature, a series of four single stage flash separation tests at 400 ^{o}F, 300 ^{o}F, 200 ^{o}F and 100 ^{o}F were performed in the laboratory. The factors and data derived from these tests are found in (Table 6).

3.2.2 Seismic Data

A 3D seismic survey, which covered the entire Fajr Pool was conducted in 1998. This program was intended to better define the complex structural blocks. The review of seismic profiles has shown that the throw of Nafoora fault is approximately 200 ft. The half anticline of Fajr Pool has its top about 9870 ft ssl just south of the Nafoora fault. The dip of the horizontal north and south of the Nafoora fault in close vicinity to the fault is the same. Amal north and Granite south of the Nafoora fault shows the same response in seismic profiles. The minor fault what seems to be the northern boundary of the Fajr Pool has a throw of approximately 125 ft. The dip on both sides is the same. In the Fajr south it seems that the horizon between the Bahi-top (or Amal-top) and the basement (Granite) has a thickness of 0 at the top area of G-67 and up to approximately 450 ft near the Nafoora fault. .[5]

3.3 Geology

3.3.1 Stratigraphy and Tectonics

The Fajr Pool is a deep reservoir consists of two producing horizons of different geological age, namely the Cretaceous Bahi and Cambro-Ordovician Amal. See the geological column of Nafoora Field in (Figure 6).

The Bahi formation consists of fine-grained shaly sandstone with granite chips. Test results show movable oil in most wells. High productivity is associated

with coarser, less shaly intervals, for example in G118.

The Amal formation consists of fine-grained sandstone. The Amal sequences can be subdivided into three zones by shaly intervals. These intervals are thin on paleo-highs and thick on lows.

This is particularly observable towards the west. In wells G198 and G238 all zones (including Bahi) consist of shale. Towards the east the shale-out is indicated by an almost 90^{o} change of the strike, due to differential compaction. The Nafoora Fault to the South and another major fault to the North in 3-5 km, bound the Fajr reservoir. The West-East extent of the pool is approximately 7 km Structure top map of Amal formation is presented in (Figure 6). Reservoir tops and properties are presented in (Table 7).

Silica cement occurs in all Amal zones but it is extensive in the lower part of the Amal 3 Zone that forms the bottom of the reservoir. The top seal is 400 ft. shale at the bottom of the Tagrift Formation. The downward displacement on all faults is toward NE. Most of the faults are nearly parallel with the boundary faults. Most of the production appears to be more related to a major mid-field fault, than to the sand thickness, indicating fracture enhancement of porosity and permeability. Non-producers occur along another major fault in the southern part of the field. The original oil/water contact at 10,355 ft. s.s. occurs as seen in most edge wells.

Table.1. Well Status

Well No.	TD Ft. KB	GOR SCF/STB	WC %	DAILY PRODUCTION		MONTHLY PRODUCTION				
				OIL Bbl/d	WATER Bbl/d	OIL BBL	WATER BBL	OIL BBL	WATER BBL	
	10645							1403254	783080	SIPRO
G-67	9600									OBS
G-69	9820									OBS
G-106	10500							98599	40184	OBS
G-118	10553	404	4.1	1861	79	57681	2435	11925603	261534	PRO
G-158	10460									SIPRO
G-161	10450							2476969	11835	SIPRO
G-195	10540	521	60	729	1112	20418	31133	7965991	3662848	PRO
G-196	10520							85049	810	OBS
G-197	10505							107994	13404	OBS
G-198	10433									OBS
G-199	10500									OBS
G-200	10500									SIPRO
G-212	10500							1800194	229110	OBS
G-213	10500									SIPRO
G-214	10500							405421	30162	SIPRO

G-222	10650							894596	378826	SIPRO
G-223	10660							31670	966	SIPRO
G-224	10660	523	47.5	158	143	4909	4444	5523798	993547	PRO
G-234	10668	531	19.3	1343	321	41648	9961	5917551	488167	PRO
G-235	10571							114543	1249	OBS
G-238	10600							114543	1249	OBS
						124656	47973	38751232	6895722	

NOTE:
SIPRO:Shut-in Producer Well, PRO: Producer Well
OBS: Observation Well

Table2.Hydrocarbon analysis of reservoir fluid sample (Well-212)

	MOL	**WEIGHT**	**DENSITY**	**API**	**MOLECULAR**
COMPONENT	**PERCENT**	**PERCENT**	**Gm/cc**	**@ 60 ^{oF}**	**WEIGHT**
Hydrogen Sulfide	0.00	0.00			
Carbon Dioxide	0.96	0.28			
Nitrogen	1.41	0.26			
Methane	25.94	2.75			
Ethane	5.82	1.16			
Propane	5.20	1.52			
Iso-Butane	1.44	0.55			
n-Butane	3.96	1.52			
iso-Pentane	1.66	0.79			
n-Pentane	2.22	1.06			
Hexanes	2.49	1.41			
Heptanes Plus	48.90	88.70	0.8453	35.7	274
	100.00	**100.00**			

3.3.2 Log interpretation and petrophysics

The petrophysical parameters of the Fajr pool have been defined from both the cores and the well logs in wells G-52, G-158, G-161, G-198. The emphasis was on quantitative interpretation of well logs, while the core-derived data have served as a control of the processed values. The control cores, with some exceptions, give less favorable values than the logs. This may simply be due to the fact that the more compact, less porous reservoir parts give the best core recovery. .[5]

Table3. Pressure –voleume relation at 240 °F (Well G-212)

PRESSURE		**RELATIVE VOLUME (1)**	**Y FUNCTION (2)**
PSIG		**V/Vsat**	
5000		0.9661	
4000		0.9751	
3000		0.9848	
2500		0.9903	
2400		0.9916	
2300		0.9927	
2200		0.9938	
2100		0.9950	
2000		0.9961	
1900		0.9975	
1800		0.9987	
1700		0.9999	
1690	**Saturation Pressure**	1.0000	
1676		1.0045	3.007
1612		1.0180	2.966
1529		1.0379	2.902
1422		1.0680	2.836
1305		1.1084	2.754
1171		1.1677	2.655

1035		1.2467	2.563
909		1.6461	2.470
763		1.5091	2.363
624		1.7507	2.241
511		2.0534	2.144
435		2.3548	2.073
369		2.7292	2.003
304		3.2644	1.931
262		3.7661	1.875

(1) Relative Volume: V/Vsat is barrels at indicated pressure per barrel at saturation pressure.

(2) Y Function = (Psat-P) / (Pabs)(V/Vsat-1)

Table 4. Differential vaporization at 240 ^{o}F (Well G-212)

Pressure PSIG	Solution Gas/Oil Ratio (1)	Relative Oil Volume (2)	Relative Total Volume (3)	Oil Gm/cm	Deviation Factor Z	Gas Formation Volume Factor (4)
1690	430	1.354	1.354	0.7138		
1600	411	1.346	1.384	0.7153	0.919	0.01128
1300	356	1.321	1.506	0.7216	0.930	0.01402
1000	302	1.069	1.715	0.7285	0.943	0.01842
700	245	1.295	2.144	0.7355	0.958	0.02657
400	185	1.238	3.271	0.7436	0.975	0.04659
200	135	1.209	5.997	0.7523	0.988	0.09112
100	102	1.185	11.197	0.7590	0.994	0.17139
0	0	1.086		0.7776		
	At 60 ^{o}F =	1.000				

Gravity of Residual Oil = 35.9 ^{o}API at 60 ^{o}F

(1) Cubic feet of gas at 14.7 psia and 60 ^{o}F. per barrel of residua oil at 60 ^{o}F.

(2) Barrels of oil at indicated pressure and temperature per barrel of residual oil at 60 ^{o}F.

(3) Barrels of oil plus liberated gas at indicated pressure and temperature per barrel of residual oil at 60 ^{o}F.

(4) Cubic feet of gas at indicated pressure and temperature per cubic foot at 14.7 psia and 60 ^{o}F.

Table 5. Viscosity data at 240 ^{o}F

Pressure PSIG		Oil Viscosity cp	Calculated Gas Viscosity cp	Oil/Gas Viscosity Ratio
5000		1.249		
4000		1.173		
3000		1.097		
2000		1.021		
1800		1.005		
1690	**Saturation Pressure**	**1.000**		
1600		1.010	0.0164	61.59
1300		1.049	0.0155	67.68
1000		1.098	0.0148	74.19
700		1.162	0.0141	82.41
400		1.263	0.0133	94.96
200		1.379	0.0123	112.11
100		1.548	0.0113	136.99
0		2.234		

Table6. Separation tess of reservoir fluid sample (Well G-212)

Separator Pressure PSI Gauge	Separator Temperature ^oF	Gas/Oil Ratio (1)	Gas/Oil Ratio (2)	Stock Tank Gravity ^oAPI @ 60 ^oF	Formation Volume Factor (3)	Separator Volume Factor (3)	Specific Gravity of Flashed Gas
400 to 0	126 60	165 116	180 116	 39.7	 1.238	1.089 1.000	0.727 0.898
300 to 0	126 60	184 90	197 90	 39.8	 1.240	1.073 1.000	0.743 0.922
200 to 0	126 60	221 63	233 63	 39.7	 1.238	1.056 1.000	0.774 0.985
100 to 0	126 60	267 31	277 31	 39.4	 1.230	1.038 1.000	0.835 1.016

(1) Gas/Oil Ratio in cubic feet of gas at 14.73 psia and 60 ^oF. per barrel of oil at indicated pressure and temperature.
(2) Gas/Oil Ratio in cubic feet of gas at 14.73 psia and 60 ^oF. per barrel of stock tank oil at 60 ^oF.
(3) Formation Volume Factor is barrel of saturated oil at 1699 psig and 240 ^oF. per barrel of stock tank oil at 60 ^oF.
(4) Separator Volume Factor is barrels of oil at indicated pressure and temperature per barrel of stock tank oil at 60 ^oF.

B.

Table 7. Reservoir tops and properties

Well No.	BAHI FORMATION						AMAL FORMATION					
	Top ft. KB.	**Gross ft**	**Net ft**	**ϕ %**	**S_w %**	**k.h mD.ft.**	**Top ft. KB**	**Gross ft**	**Net ft**	**ϕ %**	**S_w %**	**k.h mD.ft.**
G-52	10225	93	89	11.1	49	560	10318	152	134	10.9	19.8	15240
G-67	9384											
G-69	9494											
G-106	10319	86	79	11	55.6	525	10405	64	61	11	21.3	378
G-118	10102	106	76	10.5	44.5	6794	10208	233	183	8.4	29.1	178
G-158	10088	97	88	12.7	42.6	-	10185	142	133	10.3	22.9	2450
G-161	10160	46	30	10.9	45.5	275	10206	234	192	9.3	24.5	2811
G-195	10204	91	35	10.5	48	3950	10295	214	206	12.8	12.9	24823
G-196	10270	80	42	10.9	15.7	340	10350	109	0	0	0	0
G-197	10269	87	74	9.6	57.6	200	10356	114	70	10.5	22.4	4640

G-198	10107	98	12	7.9	0	776	10205	214	60	7.3	43.3	118
G-199	10101	81	48	10.5	43	324	10182	303	97	8	35.9	160
G-200	10141	71	62	12.8	40.7	1350	10212	199	143	9.8	24	554
G-212	10191	90	66	9.9	50.3	4700	10281	185	164	9.6	22.5	5554
G-213	10130	76	38	13.5	40	1760	10206	187	120	10	25.6	420
G-214	10033	115	104	12	39.8	1210	10148	266	218	10.1	23.3	530
G-222	10291	66	58	11.9	48.4	650	10357	118	111	10.2	22.4	3736
G-223	10293	81	36	9	60.6	375	10374	121	85	8.4	38.9	150
G-224	10234	78	70	10.2	50.4	4453	10312	179	154	10.2	20.6	10040
G-234	10290	67	43	10.6	56	6525	10357	130	128	11.2	22.9	25259
G-235	10290	145	133	11.6	54.1	1160	10435	32	61	12.2	17.9	1460
G-238	10310	76	67	0	0	360	10386	0	0	0	0	1170

As mentioned before several reservoir parameters will be investigated. The table below illustrates the reservoir properties with their investigated values. Each scenario includes different value start with smallest value in first scenario until reach highest value in fourth scenario. The parameters will be change individually while others keep constant. This process will be done when the coal is deep thick, and also when the coal is shallow thin respectively.

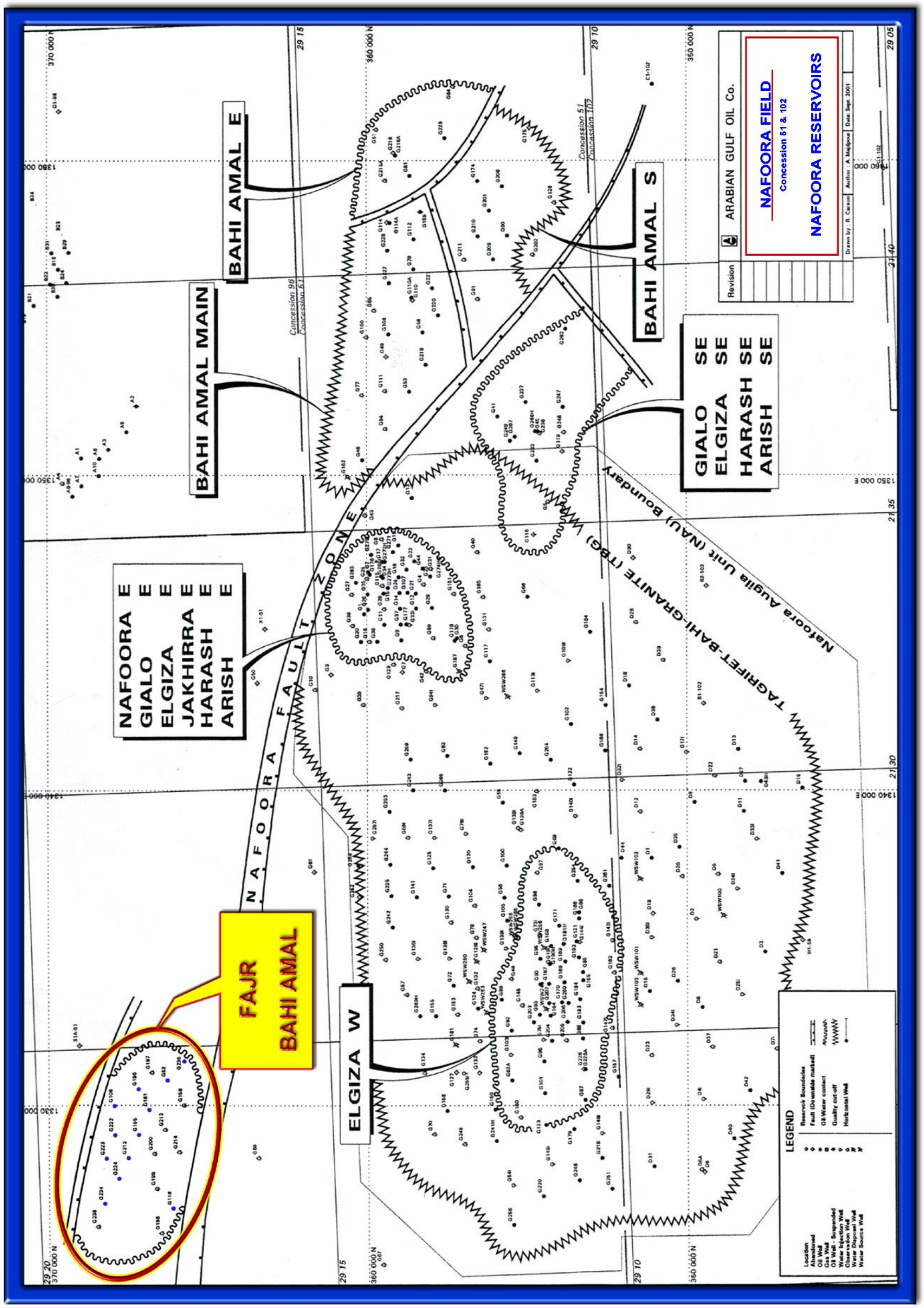

Figure2. Location of Fajr Pool in Nafoora Field

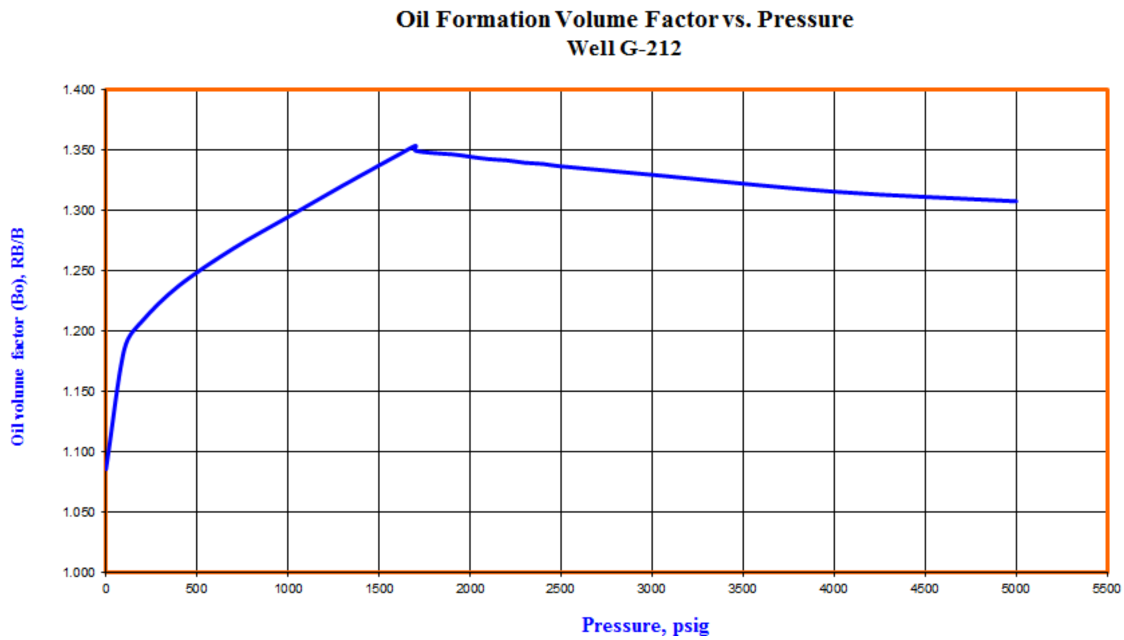

Figure3. Formation volume factor

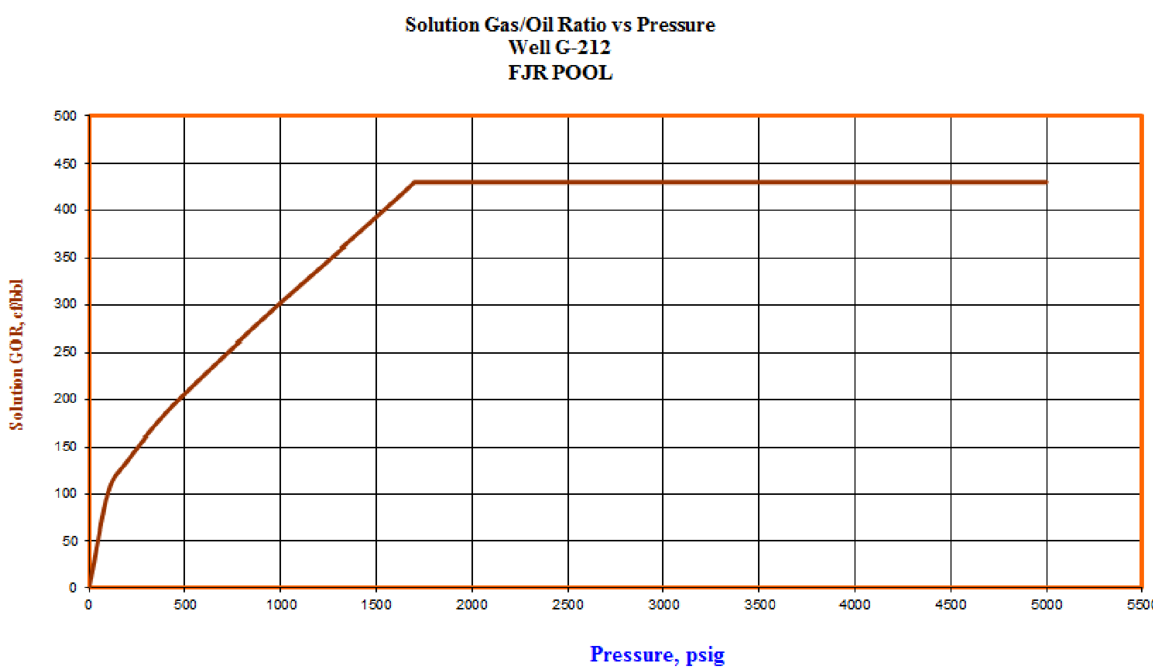

Figure 4. Solution gas oil ratio

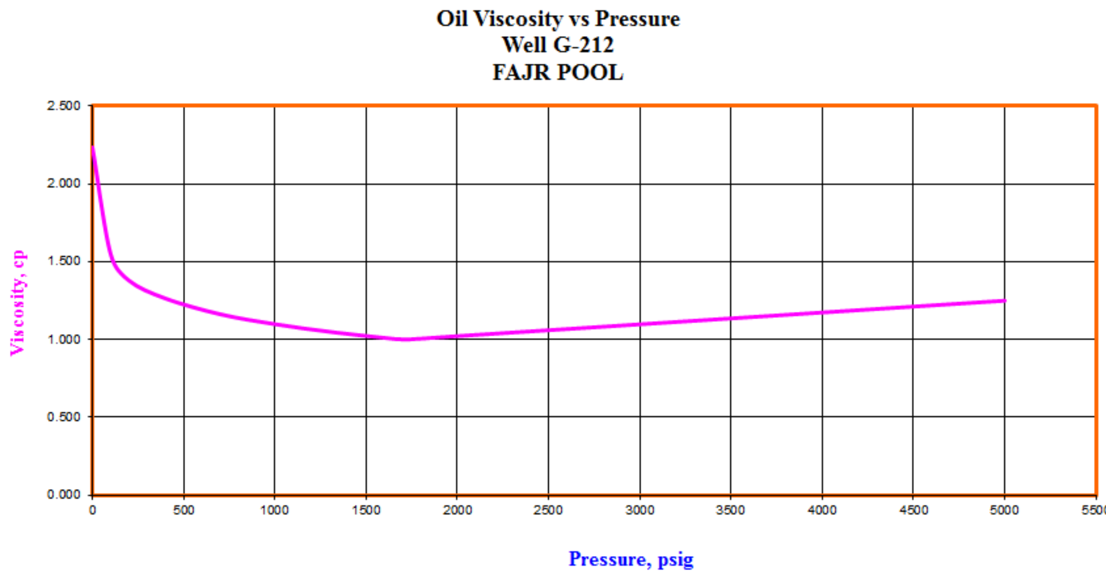

Figure 5*.* Oil viscosity

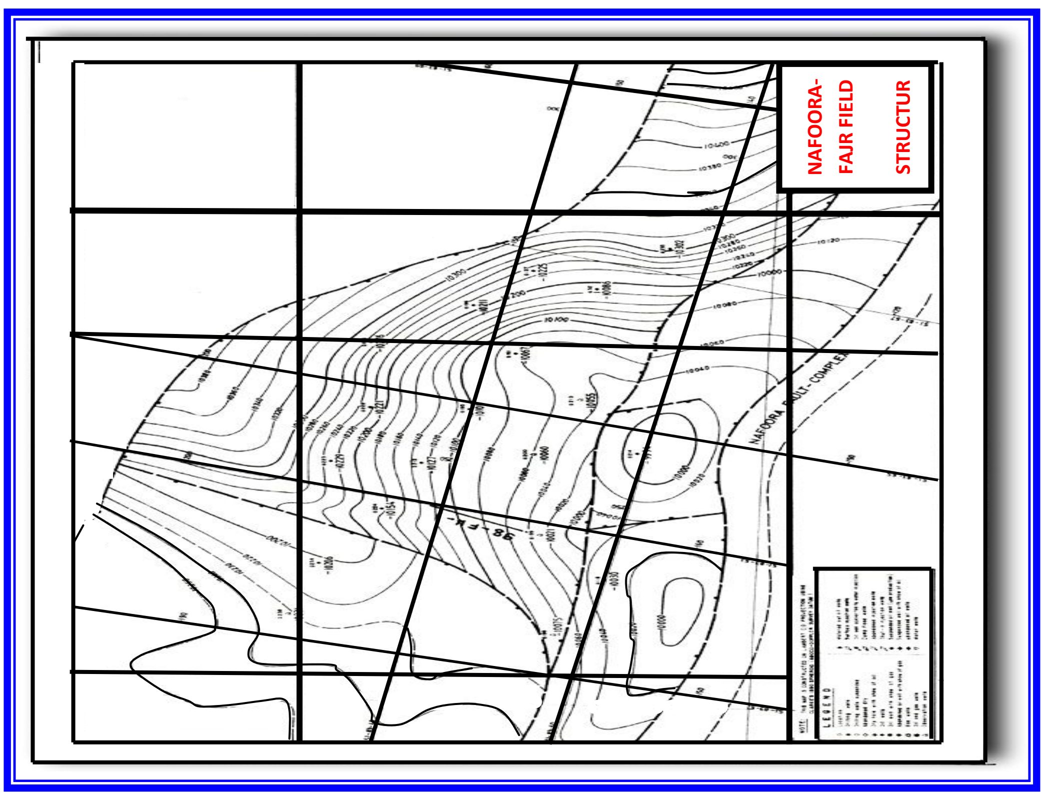

Figure 6.Structur map for Fajer pool

4. Conclusion

- The paper discusses the reservoir management fundamentals as well as data processing and applications.
- Understanding the application of performance analysis and incremental reservoir characterization are very essential , greatly influences the future reservoir studies for predicting the reserves and recoveries.
- Reservoir characterization is the key parameter in determining flow behavior and flow quantity leads to reservoir simulation accuracy.

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