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FULL LENGTH ARTICLE

Application of integrated petroleum reservoir study for intervention and field development program in western onshore field, India

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Abstract In this research, an integrated reservoir study is performed in the J#Field (J-Oil Field) of western onshore, India to evaluate its additional reserves expectations and implement field developments plan using waterflood pilot program. The target strata includes two formations of Paleogene, which is about 3600 ft, namely G#Fm (G-Formation) of the Eocene and T#Fm (T-Formation) of Oligocene, subdivided into 11 zones. Based on these results, an attempt was made to construct of an optimization plan to exploit it, taking into account that the field is producing since 1947, with a cumulative production of 183.5 MMbbl and an overall recovery factor of 28% until January 2016. On the basis of the potential evaluation and geological modeling, blocks J48 and J45 were simulated, and the remaining oil distribution characteristics in two blocks were studied after history match. The work includes the stratigraphic studies, seismic study, logging interpretation, sedimentary facies modeling, three dimensional geological modeling, simulations for waterflooding, and future field development plans.

1. Introduction

The low crude oil prices reported in the last three quarters caused the oil companies to perform huge disinvestments for optimizing the production of their reserves in a short period, under an economically attractive scenario. In accordance to the foregoing statements, an integrated reservoir study of J#Field (J-Field) in western onshore, India was performed. J#Field (oil field) located in western onshore, India was discovered in the year 1946. It is located in the Ahmedabad-Mehsana tectonic block of Cambay basin in India (Fig. 1). The sediment fill is mostly of Tertiary age [4]. In the middle-west basin, there are high angle faults of east dip direction, which belongs to Cretaceous, Paleogene, Neogene-Quaternary ages. Meanwhile,

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Nomenclature

J#Field	J-field, western onshore, India	OWC	oil-water contact
G#Fm	G-Formation	BOFD	barrels of fluid per day
T#Fm	T-Formation	BOPD	barrels of oil per day
Φ	Porosity	bbl/d	barrels/day
K	intrinsic permeability	API	American Petroleum Institute
S_w	water saturation	GOR	gas-oil ratio
V_{sh}	volume of shale	SEM	scanning electron microscopy
Mbbl	one thousand barrels	RF	recovery factor
MMbbl	one million barrels	OOIP	original oil in place
BHP	bottom hole pressure		
THP	tubing head pressure		

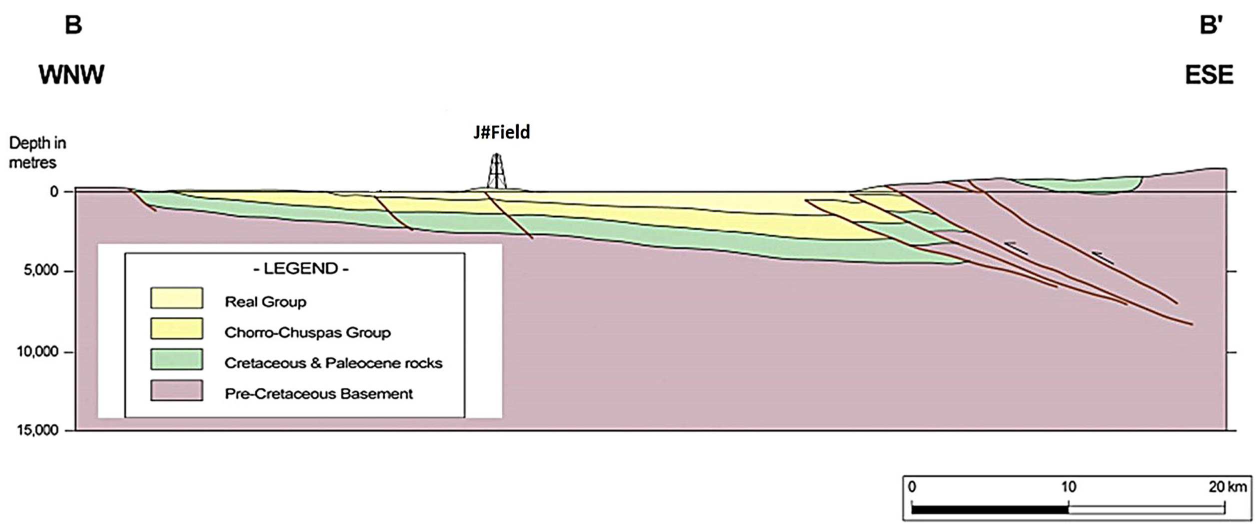

Figure 1 Structural section map of J#Field basin.

Eocene, Oligocene and Miocene of Paleogene are fluviatile facies and mud inter-bed sediment with the thickness 2000–4000 ft, which are main oil-bearing formations in these areas. Oil is mainly formed in Cretaceous and migration and accumulation is mainly occurred in Neogene [2].

J#Field was put into production in January of 1947, which progressed through four stages including improvement stage (1947–1956), stable production stage (1957–1961), decline stage (1962–2004), regulations stage (2005–present) (Fig. 2), and it reached the highest output of 29,760 bbl/d and the highest quantity of 157 production wells in July of 1959. At present, the oilfield has 274 drilled oil wells in total. The target strata includes 2 formations of Paleogene, which is about 3600 ft, they are G#Fm (G-Formation) of the Eocene and T#Fm (T-Formation) of Oligocene, subdivided into 12 zones. The stratigraphic division is given in Table 1. General characteristics of the formations T#Fm and G#Fm is given in Table 2.

At present, there are 78 producing oil wells. The average daily oil production is 2,967 bbl/d, and the daily fluid production is 11,626 bbl/d with 73% water cut. Meanwhile, 51 wells of G#Fm is producing, and the daily oil production is 2,137 bbl/d, and the daily fluid production is 6,065 bbl/d with composite water cut of 61%. 27 wells of T#Fm are producing, and the daily oil production is 829 bbl/d, and the daily fluid production rate is 5 491 bbl/d with the water cut of 87%.

2. J#Field fluid properties

The API density of oil from G#Fm in J#Field is 21–28 °API, and that from T#Fm is 17–25 °API, and the API density is higher in south than that in north. Thus the oil quality in the south and upper T#Fm is better. According to the oil property classification standards, the crude belongs to heavy-medium oil. (Fig. 3, Table 3)

According to the production data (the initial gas-oil ratio (GOR) is 260 scf/bbl, which is 46 sm^3/m^3 in T#Fm and 300 scf/bbl, which is 53 sm^3/m^3 in G#Fm), the reservoir belongs to low gas-oil ratio type. The saturation pressure is 1950 psia in G#Fm, and 1800 psia in T#Fm. From PVT data, the volume factor is 1.2 in G#Fm, and 1.15 in T#Fm.

3. Main characteristics and existing problems in J#Field development

The J#Field has a long oil-bearing interval, with many oil-bearing series of strata, complex structure and complex

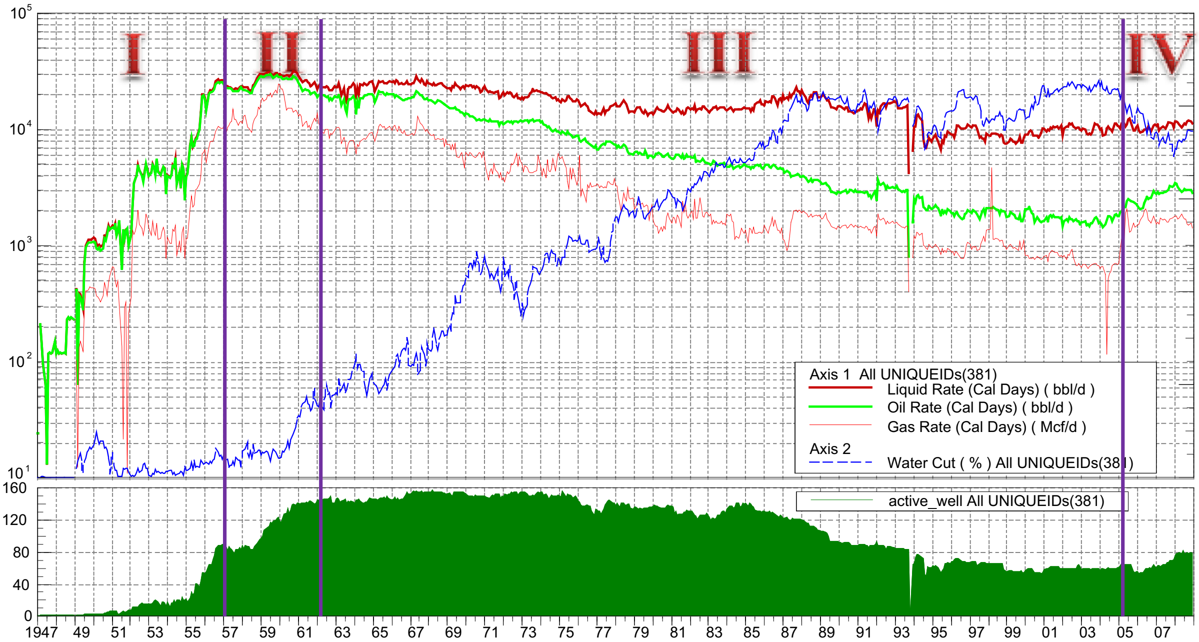

Figure 2 J#Field production history, flow rate (bbl/d) vs. time (years).

Table 1 The stratigraphic division of T#Fm and G#Fm formations.

Formation	Group	Zone	Thickness (ft)
T#Fm		T-I	604–715
		T-II	179–209
		T-III	159–185
		T-IV	170–225
		T-IV	153–238
		T-VI	183–248
G#Fm	G-I		450–591
	G-II		381–431
	G-III		219–291
	G-IV		247–223
	G-V		402–532

Table 2 The reservoir characteristics of the formations T#Fm and G#Fm.

Parameter	T#Fm	G#Fm
Porosity, %	24.5	21
Permeability, mD	1565	720
Initial water saturation, %	44	38
Fracture gradient, psi/ft	0.7	0.75
Initial pressure, psi	2100	3000
Saturation pressure, psi	1800	1950
Current pressure, psi	1900	2200
Volumetric factor, RB/STB	1.15	1.2
Area, acres	1890	3820
OOIP, MMbls	194.7	438.9
GOR, SCF/STB	500	100
Datum (ss), ft	4300	6500
Viscosity, cP at Datum	50	25
Temperature, °F at Datum	140	150
Net thickness, ft	109	136
Salinity, ppm Cl	37,000	36,000

water-oil relations. The oilfield has a long production history, resulting in the wide range decline of production. It has about 69 year's development history and the production was decreased from the highest of 29,760 bbl/d to 3000 bbl/d. Recovery ratio of recoverable reserves is high but its potentiality and direction is uncertain. According to the pre-existing reserves, the reserve recovery ratio of G#Fm is up to 97%, while that of T#Fm is 93%. A detailed flow model for the J#Field development is given below (Fig. 4).

4. Formation classification and layer division and correlation

4.1. Regional stratigraphy developmental characteristics

J#Field is located in western onshore basin, India. Oil and gas is produced from the tertiary strata of terrestrial facies sand and shale. Western onshore basin is a Meso-Cenozoic faulted basin and its basement is mainly Precambrian eruptive rock or metamorphic rock. Generalized stratigraphy of the study area is shown in Fig. 5. The oil-bearing series of J#Field is T#Fm of Oligocene and G#Fm of Eocene, which are fluvial/deltaic deposits. Sandstone is inter-bedded with mudstone continually with the sedimentary thickness of 3000–3600 ft, which develops gray fine-grained and coarse sandstones and gray, gray green, red mudstone.

4.2. Seismic data acquisition and interpretation

J#Field's 3-D seismic data processed in the year 2015 was applied for the structure interpretation works. The 3-D seismic data is about 63 km^2 with inlines 1001–1492, cross lines 5047–

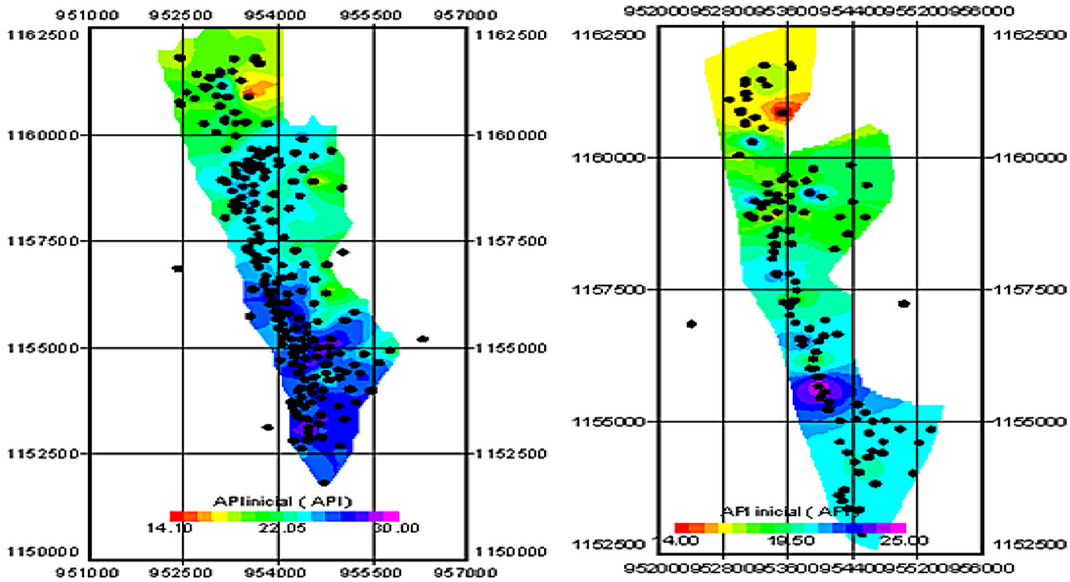

Figure 3 API density distribution map in G#Fm (left) and T#Fm (right).

Table 3 Classification of crude oil density.

Type	Relative density	API density
Light oil pool	< 0.855	> 34
Medium oil pool	0.855–0.934	34–20
Heavy oil pool	> 0.934	< 20

5279 and bin 25 × 25 m. The Two-Way Time (TWT) interval of the target zone of G and T groups is 760 ms–2200 ms and the signal/noise ratio of J#Field 3-D seismic data is relatively low especially in the target interval.

The dominant frequency of the 3-D data is 35 Hz with a frequency range of 10–50 Hz. The data was processed based on 3-D survey of the north area acquired and that of the south area. Comparing to the data of south area, the frequency range of the north area is relatively wider and the dominant frequency of the north area is relatively higher (Fig. 6). A connection trace could be observed clearly on the inline 134 seismic sections (Fig. 7).

4.3. Structure interpretation

According to the geological understanding and research requirement, totally 13 horizons, the top and bottom interfaces

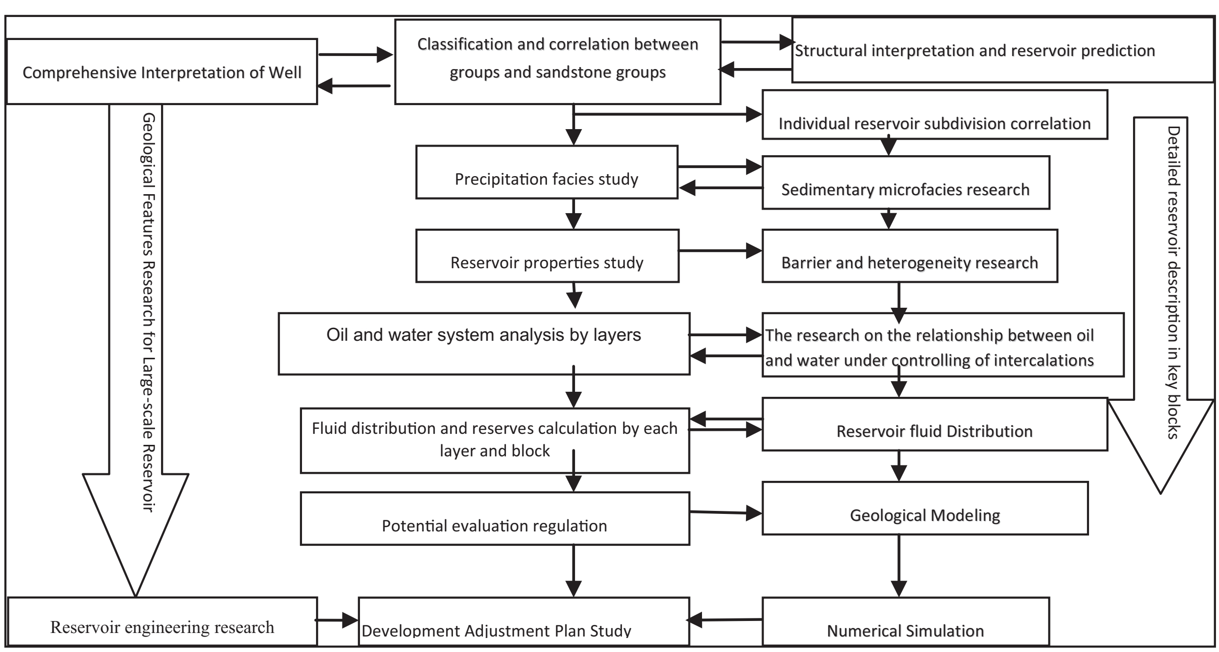

Figure 4 Integrated reservoir study flow model for J#Field.

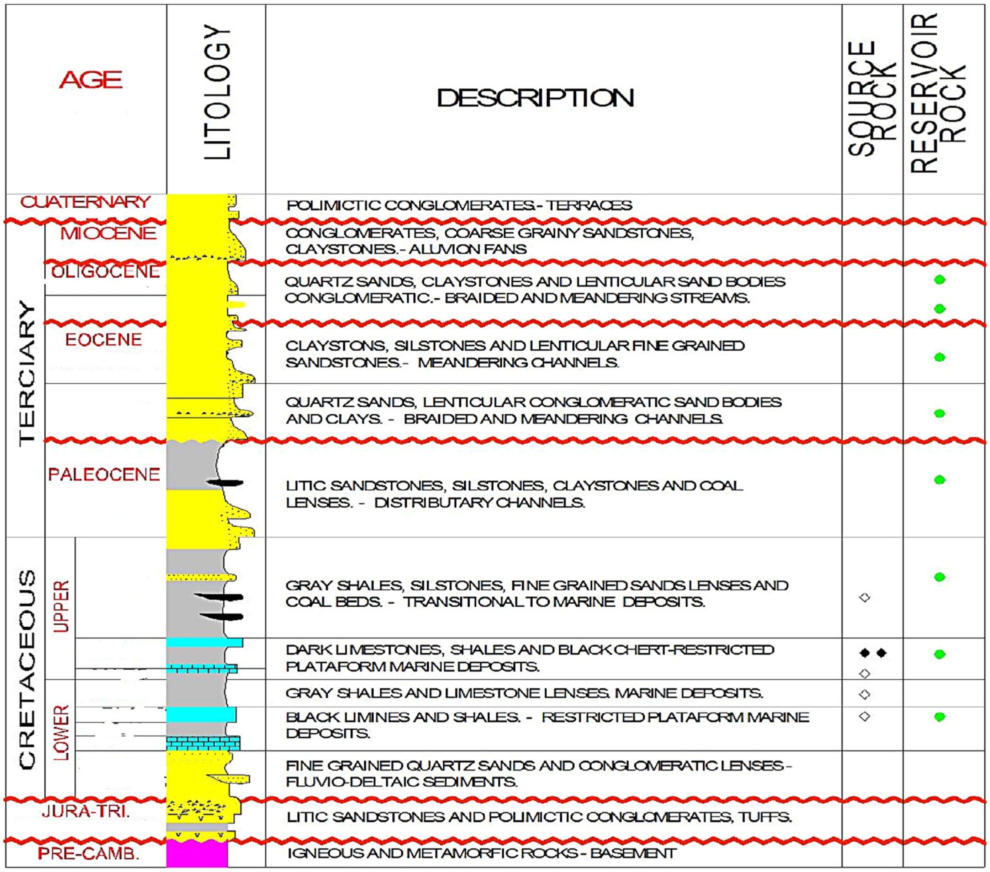

Figure 5 Generalized stratigraphy of the study area (Western Onshore Basin Geological Column).

of the sand zones in G group and T group, were interpreted by using traditional 3-D as well as 2-D method. 3-D seismic interpretation result of G bottom is shown in Fig. 8.

Based on the structural interpretation as well as reservoir logging prediction results, the oil accumulation properties of J#Field were summarized combining with the well drilling and field production information, then the integral evaluation works emphasizing reservoir performance were conducted and new well locations were proposed.

G-V zone is a typical stratified trap and its OWC of the sand layers 1, 2 and 3 in J45 block is −6722 ft, −6935 ft, and −7310 ft respectively, each of them is different to each other. The reservoir of G-V top and G-V middle in well WELL-0028, which is located around the OWC of J45 block, are water layers and only 32 ft per one oil bearing layer was interpreted at the depth of 7652–7684 ft (Fig. 9). Analysis G-II's stacked map of well cumulated oil production, the average porosity, and the top structure (Fig. 10), which come to a conclusion of that the wells which cumulated oil production more than 600 Mbbl are mainly located at the areas with good reservoir petro-physical properties.

4.4. Sedimentary facies and reservoir characteristics

Through core observation, in well WELL-0297, 6092.5 ft–6098.8 ft interval develops reddish brown mudstone (Fig. 11), 6147.9 ft–6152 ft interval develops mauve mudstone that indicates over-water oxidation environment; in well WELL-0129, 6011.6 ft–6020.2 ft, 6095.6 ft–6101.7 ft, 6116.3 ft–6121.7 ft and 6130.25 ft–6141.8 ft intervals develop dark grey mudstone, and 6067 ft–6076.7 ft interval develops grey green mudstone (Fig. 12) that indicates underwater reduction environment.

The mudstone in the coring wells has both the color of over-water oxidation and the color of underwater reduction, which reflects the sedimentary environment of water-land transition. Through the data of core observation and laboratory analysis, T#Fm and G#Fm in the J#Field oilfield mainly develop conglomerate and pebbled sandstone, medium-coarse sandstone while the siltstone and mudstone are less common (Fig. 13). The textural maturity in the research area is low, which reflects the proximal sedimentary environment.

4.5. Digenetic features

The burial depth of T#Fm and G#Fm in the research area is mostly 3000–9000 ft (by drilling). During deep burial, the sediments underwent complicated digenetic change under different environments and conditions, and the digenesis affecting reservoir mainly includes compaction, cementation and dissolution.

4.6. Compaction

The common types of grain contact are point and long grain contacts in the T#Fm sandstone (Fig. 14). Moderate to

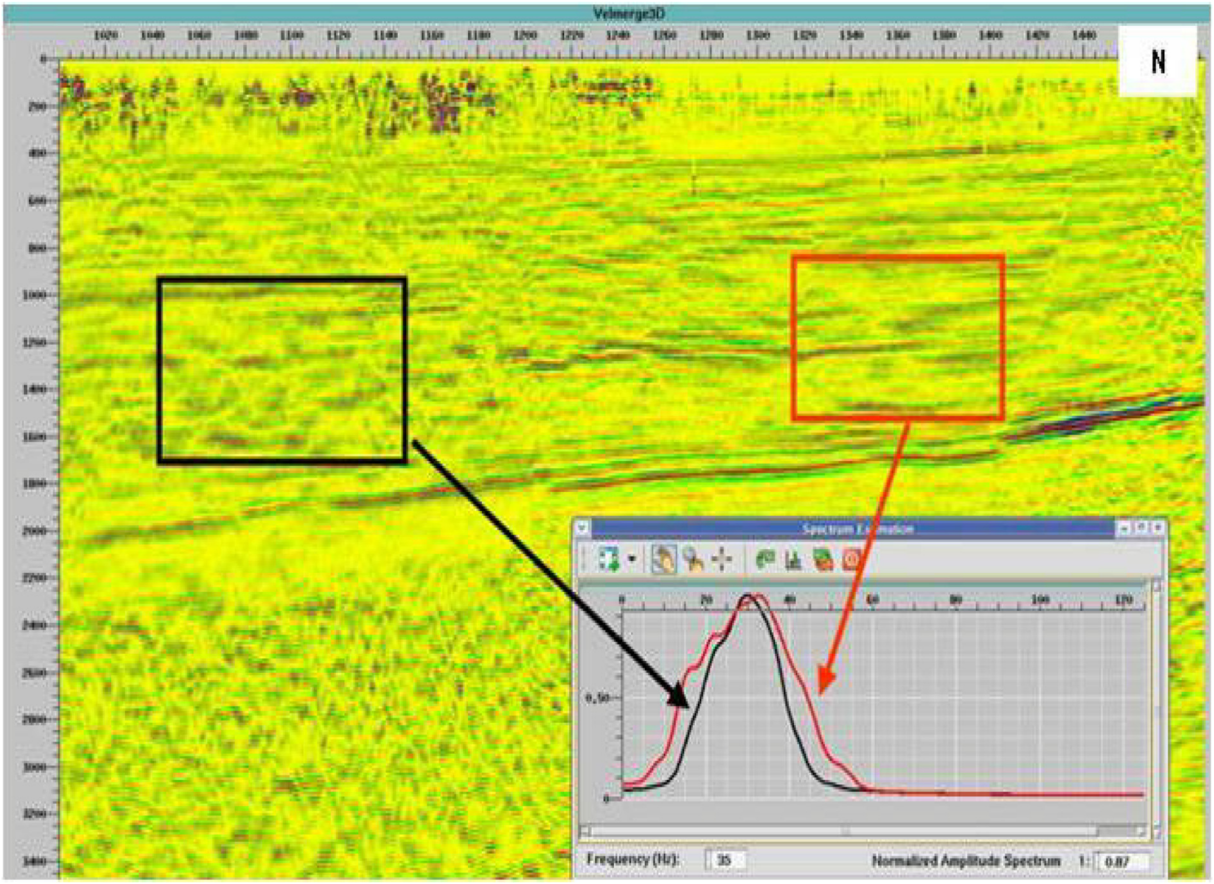

Figure 6 J#Field 3-D seismic section of xline5200.

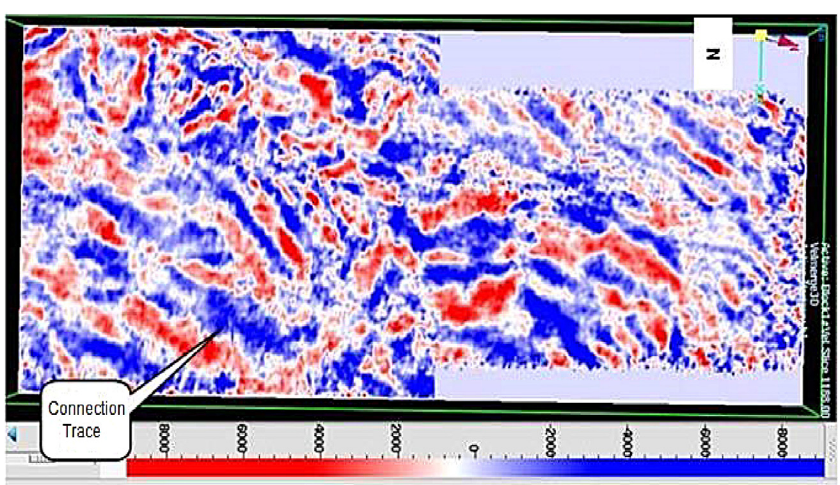

Figure 7 J#Field 3-D seismic data time slice at1188 ms.

locally moderately tight packing shows medium intensity of compaction. Compared to T#Fm, G#Fm is buried deeper, but the common types of grain contact are still point and long contacts, which may be due to have undergone more significant disaggregation (high quartz content), many samples are loose, and the sandstone generally shows weak compaction intensity.

4.7. Cementation

Because most of samples are loose, T#Fm and G#Fm sandstone cementation is poorly developed. SEM data shows clay mineral authigenesis and less carbonate cementation in a few samples. There are no silica cements and the other authigenic minerals are rare.

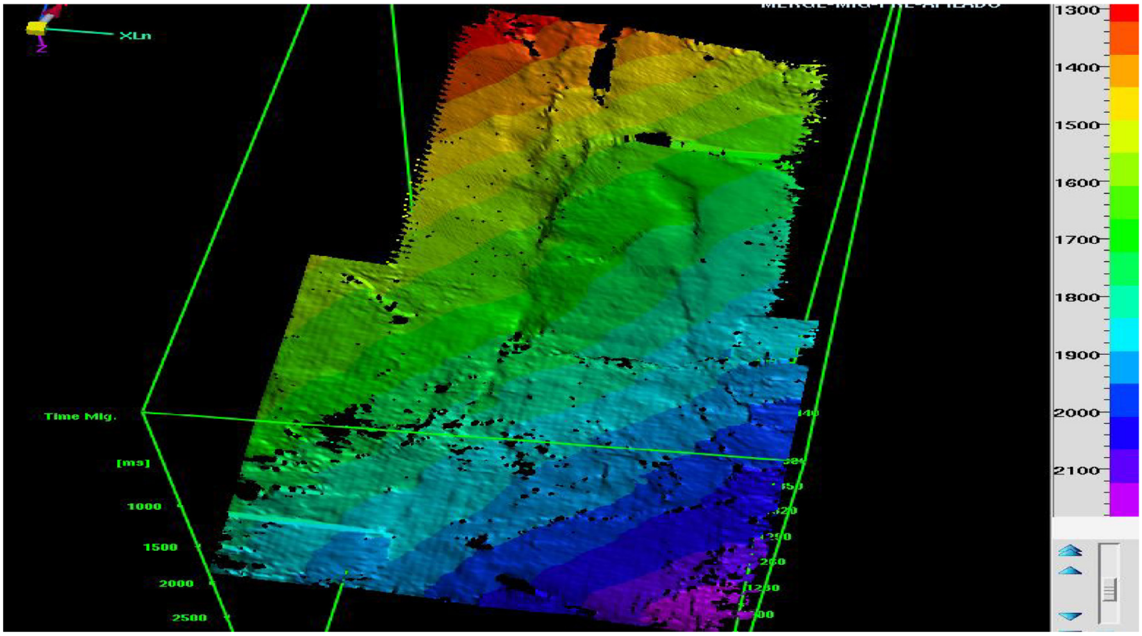

Figure 8 3-D seismic interpretation result of G bottom. Logging and comprehensive interpretation (Integral evaluation of oil accumulation).

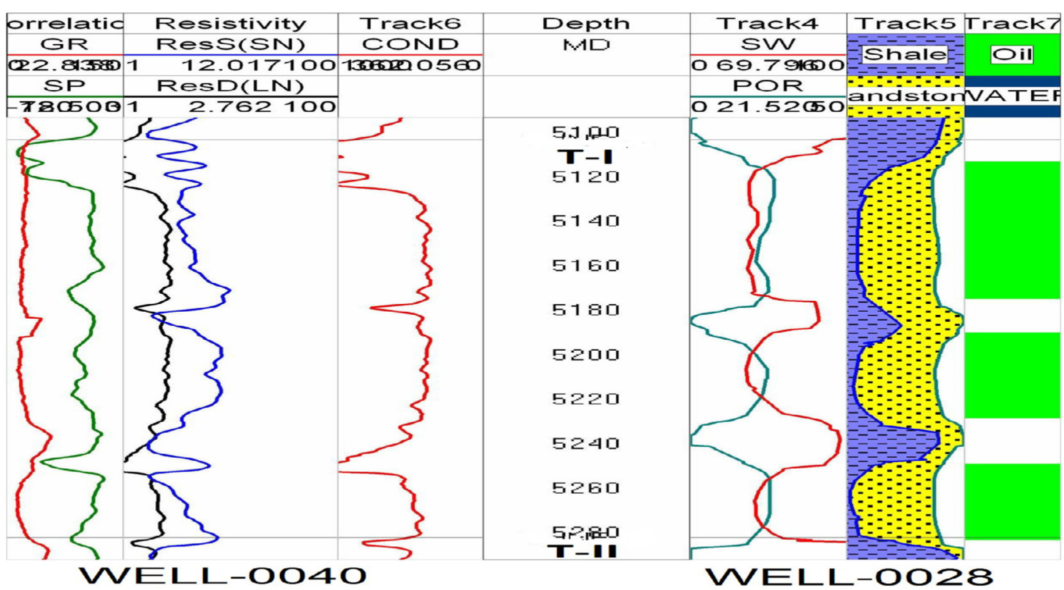

Figure 9 Logging interpretation diagram of well WELL-0040 and WELL-0028.

Common to abundant smectitic clays are observed as webbed/crenulated grain-coating/pore-ling clays and a few illite, chlorite and kaolinite are present, there is no mixed layer minerals [1]. Common zeolites are present as finely-crystalline pore-lining, locally partially pore-occluding sub-/euhedra (Fig. 15).

4.8. Three-dimensional geological modeling

According to the results of reserve calculations, G#Fm is the major oil-bearing layer series of J#Field, its geological reserves is 522.29 MMbbl, accounting for 80.7% of the total reserves. The J48-J45 fault-block area is the most important oil-bearing block of J#Field oilfield. The geological reserves of G#Fm in J48-J45 fault-block area is 266.05 MMbbl, accounting for 49.9% of the total reserves. Therefore, in this research, G#Fm of the J48-J45 fault-block area is selected to establish reservoir geological model to lay foundation for the reservoir numerical simulation and development indicator forecasting and adjustment program selection.

4.9. Establishment of structure and stratigraphic framework model

The fault development of G#Fm and fault model is the basis for the establishment of accurate structural model. In this research, firstly, the fault surface data of new three-

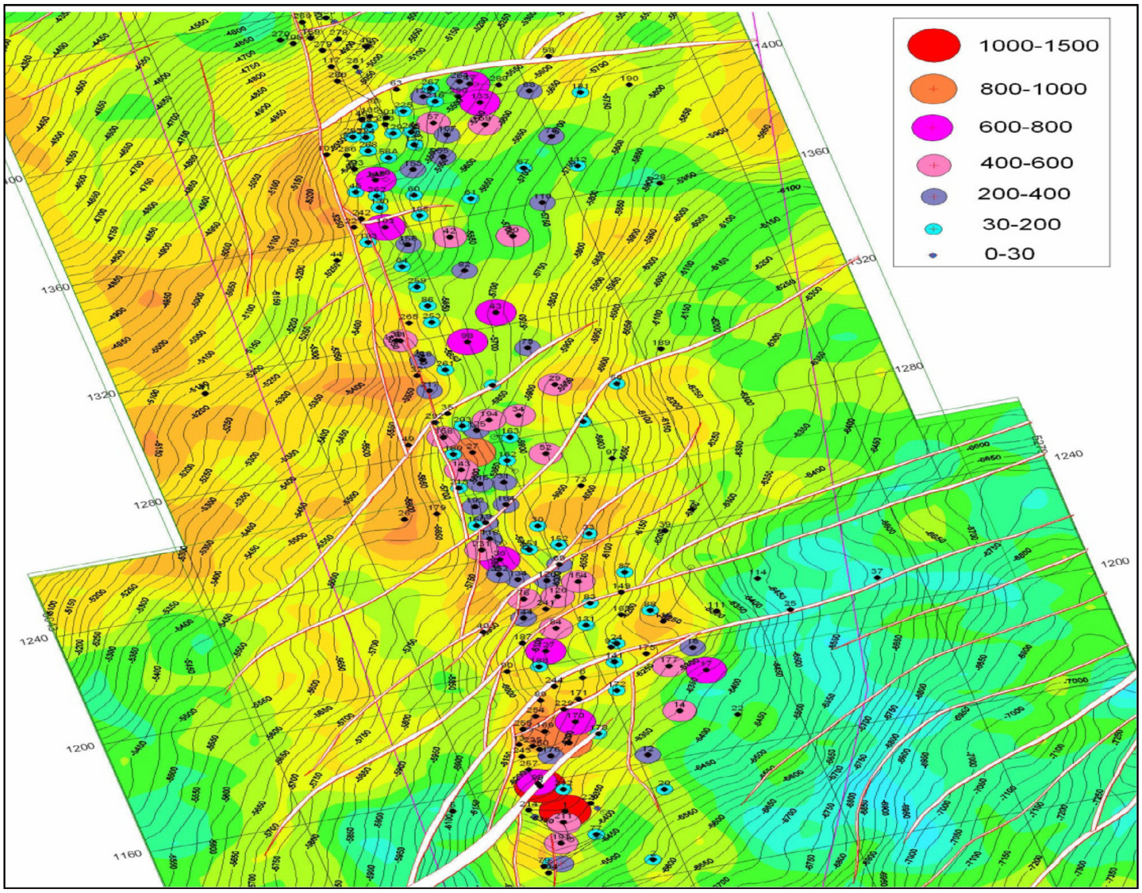

Figure 10 The stacked map of well cumulated oil production, average porosity and the top structure of G-II.

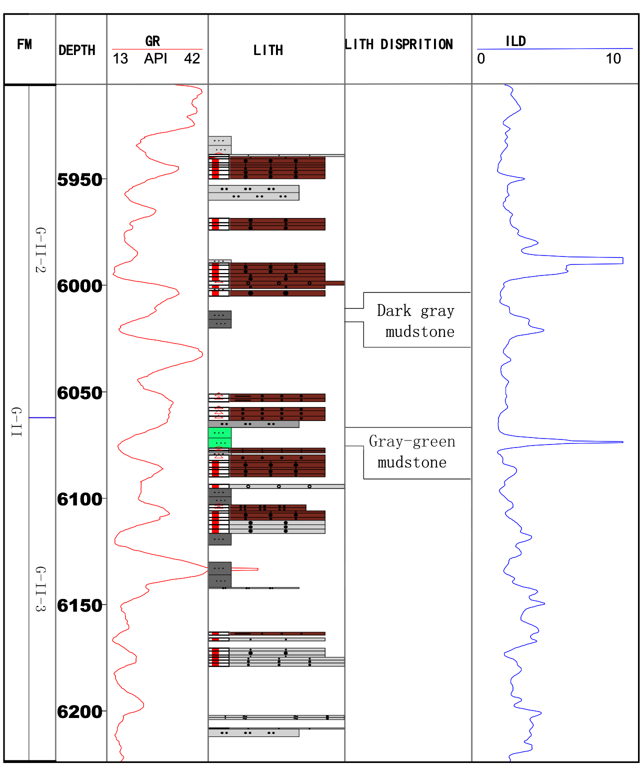

Figure 11 Lithologic column of well WELL-0297.

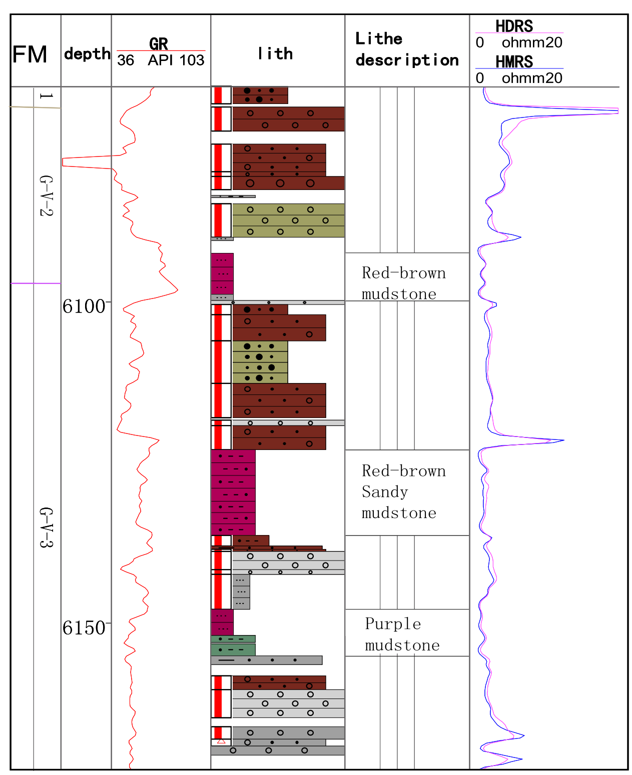

Figure 12 Lithologic column of well WELL-0129.

Figure 13 Core pictures of well WELL-0297.

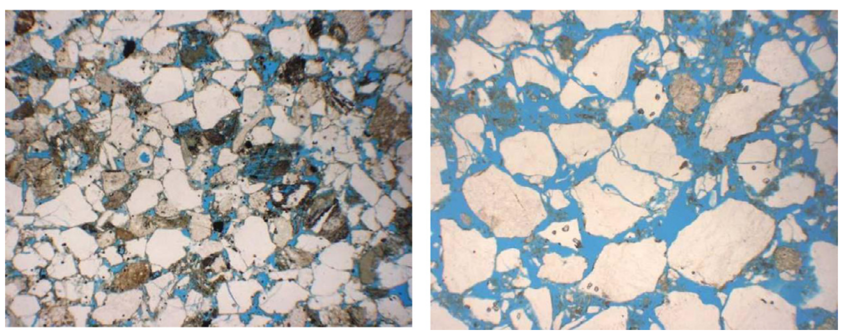

Figure 14 Thin section in well WELL-0297.

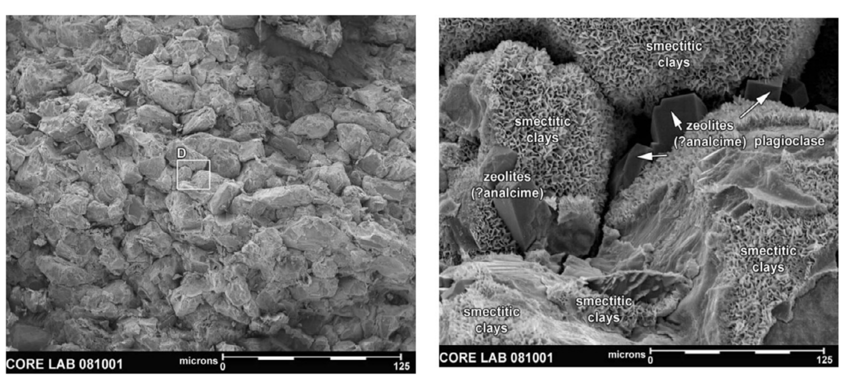

Figure 15 SEM in well WELL-0297 (3956ft).

dimensional seismic interpretation is transferred into the depth domain, and then by reasonable fault combination, to make the three-dimensional shape conform to tectonic stress characteristics. Then revise the fault section in moderate pursuant to well-point layer data, so that breakpoints in stratigraphic contrast of previous stages are locked to the fault section, thus the fault model in depth domain is acquired, and a total of 14 three-dimensional faults (Fig. 16) are established. The G#Fm of J48-J45 fault-block area is divided into 10 sub-blocks (Fig. 17), and 65 breakpoints are implemented.

4.10. Three-dimensional structure model

In order to ensure the precision of structure model and make it accord with the understanding of isochronous stratigraphic contrast and structural analysis, the establishment of this sur-

Figure 16 G#Fm three-dimensional fault model.

Figure 17 G#Fm three-dimensional stratigraphic structure mode.

face model takes well-point hierarchical data as hard data, and the trend surface of top structure is used as soft data for constraints, using the deterministic inter-well interpolation method [3] to establish structure model for the tops and bottoms of 15 layers in G#Fm, so as to finally establish the three-dimensional structure of G#Fm (Fig. 18).

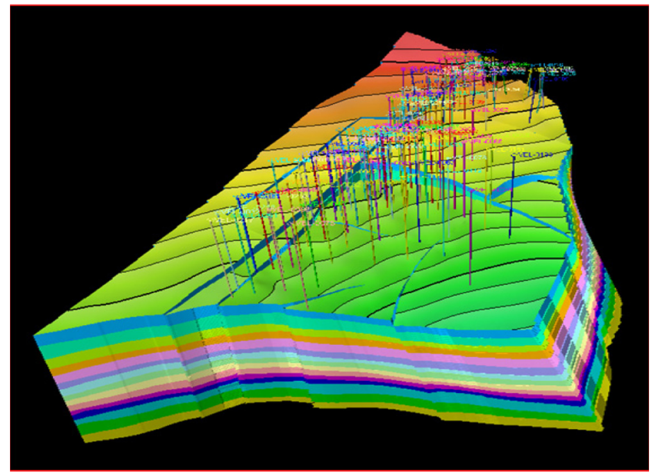

Figure 18 Three-dimensional structural model of G#Fm.

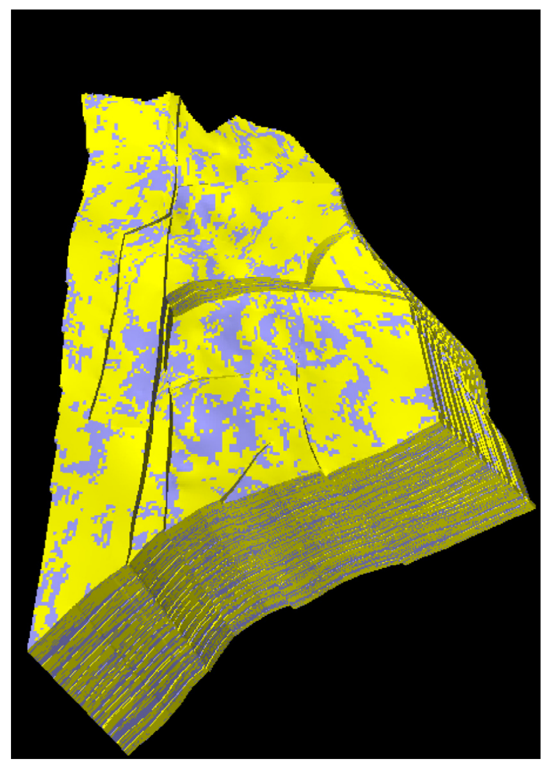

Figure 19 Lithology model of G#Fm.

4.11. Establishment of facies models

The purpose of this study was to realize the facies-controlled modeling through the establishment of lithic facies model. It mainly includes dividing a single well of the research area into sandstone and mudstone, and carrying out lithofacies classification for a single well; through the research on surface distribution of layer sand body, prepare the sand distribution maps for different zones; collecting data about extension length, width, extension direction of sandstone facies, proportion of rock facies and rock facies thickness parameters based on lay-

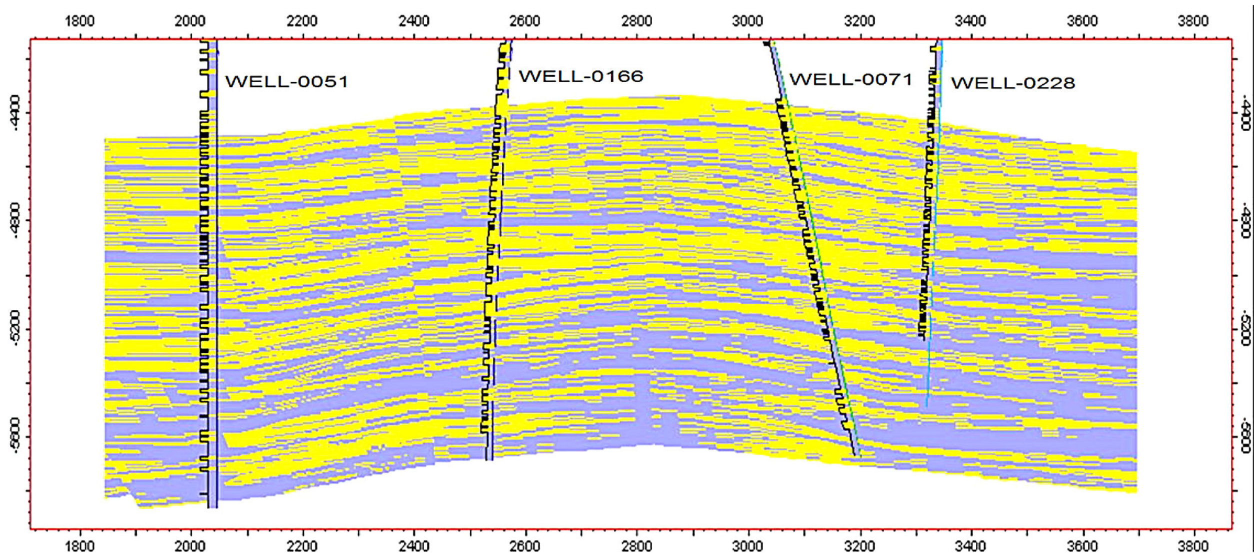

Figure 20 Connecting well lithofacies section of G#Fm.

ers; inputting statistical parameters into variation functions, using well-point data as hard data and the sandstone plane distribution map of small layers as constraint, and applying sequential indicator simulation method to establish rock facies model for 15 layers of G#Fm (Fig. 19).

It can be seen from Fig. 20 that sand layer at the bottom is thin with relatively weaker continuity. At the same time, the upper sandstone is developed relatively well with better continuity.

5. Reservoir numerical simulation and remaining oil distribution regularity

5.1. Selection of simulation area and establishment of reservoir numerical models

J#Field is a complicated faulted block reservoir with several oil-water systems, and the numerical simulation area is selected according to the reservoir engineering analysis on the remaining recoverable reserves and the potential. From the evaluation results, the remaining recoverable reserves is 88.2 MMbbl, in which 43.8 MMbbl is from the major potent blocks – block J48 and block J45, accounting for 49.7% of the whole oilfield; while that in G#Fm in block J48 and block J45 is 40.1 MMbbl, accounting for 45.4% of the whole oilfield, and the formation is the main adjusting potential layer, thus G#Fm in block J48 and block J45 is chosen for numerical simulation.

6. Well spacing between injector and producer

6.1. Well pattern optimization: well pattern designing

Five sets of injector-producer patterns are designed to be optimized for the G-IV–G-V in block J45 covering 30 years duration. The 5 options above are calculated in the model. The results are shown as follows (Figs. 21–23, Table 4).

The recovery percentage can be only 26.40% (Option 0) in 30 year because of pressure reduction and production decreasing if maintaining the current production manner. The initial production increased rapidly and reached the peak production of 2069 bbl/d because of re-perforating and drilling new well. But the production decreased rapidly and kept almost the same level as the base case (Option 0) without energy supplement. And the recovery percentage is only 27.70% (Option

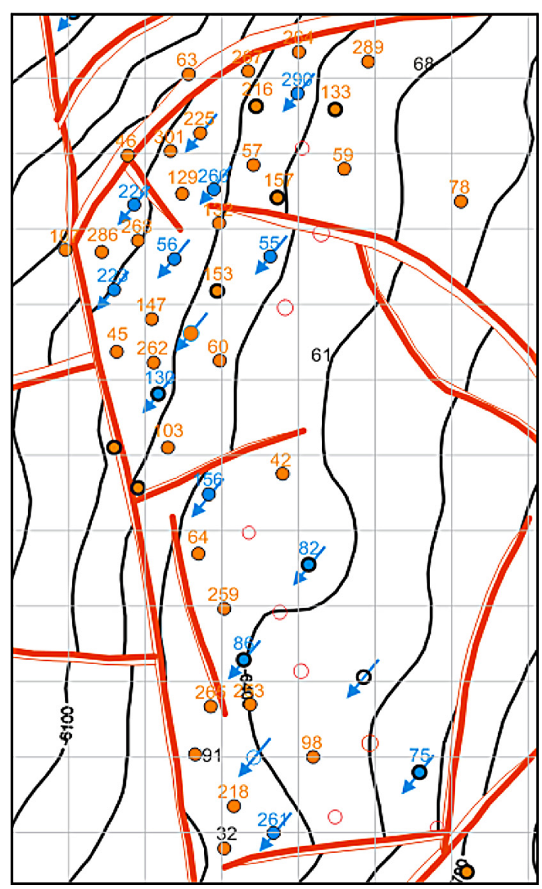

Figure 21 The well pattern of Option 1 & 2.

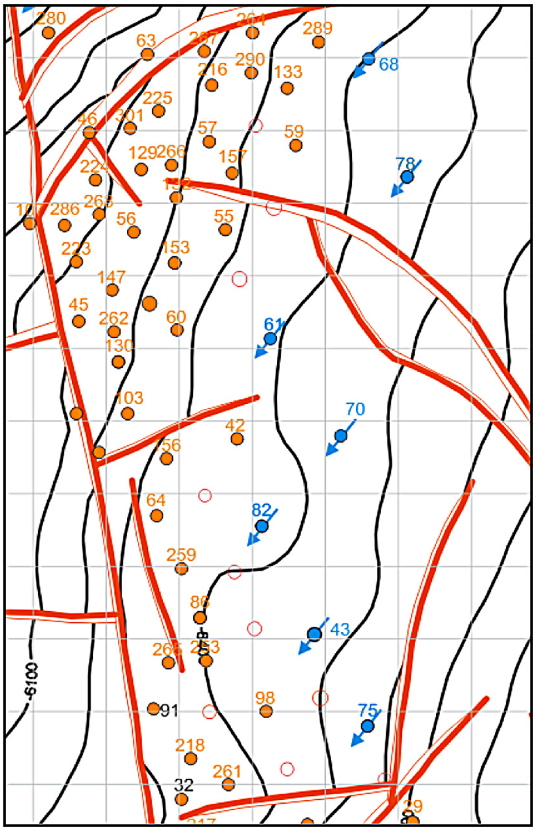

Figure 22 The well pattern of Option 3.

1). It is shown that the potential is limited only by drilling new well or re-perforating.

In the other 3 injection cases, the indexes between marginal injection (Option 3) and marginal flooding with moving the waterline (Option 4) and are approximate with recovery percentage 36.2% and 35.4%, respectively. Though water cut rising rapidly, the degree of production increasing of pattern flooding is greatest than others because of complete injection-production pattern. The peak production can reach 4662 bbl/d and decrease slowly. The recovery percentage is 41% in simulation duration, 14.6% higher than base case's.

Analysis on the five options above, injection is the most effective method to increase the production in J#Field oilfield. Flooding pattern (Option 2) was recommended from the study.

6.2. Manner of injection

Uneven production is mainly caused by many layers commingling developed and interfered each other, thus influenced the recovery degree of each layer. To resolve the interference problem, we put forward layer separated injection with two injectors to ensure the injection pressure can be adjusted easily. In order to analyze the different effects between commingled injection-production and separated injection- commingled production, we designed two sets of injection schemes.

Option 5: Commingled production with commingled injection.

G-I–G-V commingled production with 38 producers. G-I–G-V commingled injection with 14 injectors, stable BHP of producer and THP of injector.

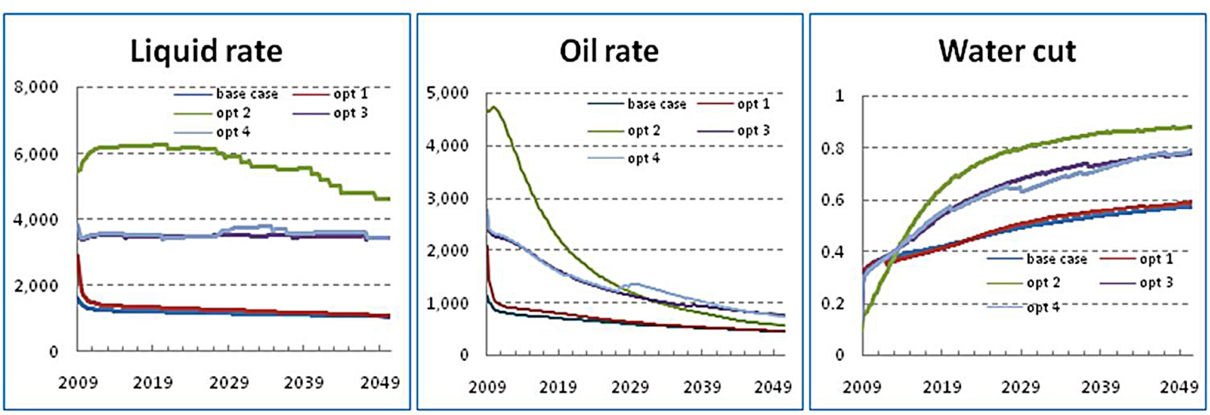

Figure 23 Prediction plots between flow rate (MMbbl) and time (year).

Table 4 The indexes of five options by contrast.

Options	Active Producers (well)	Active Injectors (well)	Peak Production (STB/d)	Cum. oil in 5 yrs (MMbbl)	Cum. oil in 10 yrs (MMbbl)	Cum. oil in 15 yrs (MMbbl)	RF (simulated) in 20 years	RF (simulated) in 30 years
Base case (Option 0)	14	–	1769.50	50.45	51.78	53.24	23.10%	26.40%
Option 1	52	–	2069.00	50.91	52.42	54.03	24.10%	27.70%
Option 2	38	14	4662.50	56.8	61.93	65.91	35.40%	41.00%
Option 3	48	7	2690.80	53.06	56.38	59.49	29.30%	35.40%
Option 4	48	7	2760.70	53.12	56.41	59.56	29.50%	36.20%

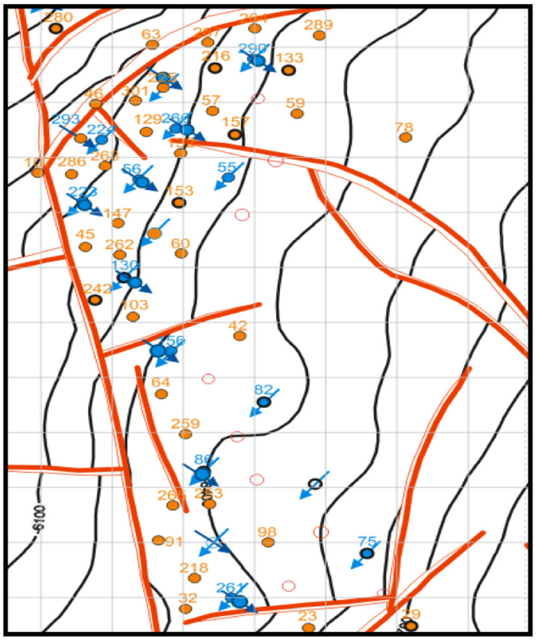

Figure 24 Separated injection with commingled production pattern (Option 6).

Option 6: Commingled production with separated injection.

The pattern is the same as that of Option 5 with 38 producers. Layer separated injection is implemented by two injectors to inject water into G-I–III and G-IV–V respectively. There are 10 injectors to G-I–III and 14 injectors to G-IV–V whose injection pressure is higher than formers' (Fig. 24).

The results of options 5 and 6 are calculated in the model and shown as follows. Fig. 25 shows the results of 5 options above and Table 5 presents the development index of later 2 injection manners.

6.3. Prediction plots between flow rate (MMbbl) and time (year)

The oil rate of Option 6 is higher than that of Option 5 (peak production is 9178.16 bbl/d, 7533.85bbl/d, respectively) because of formation pressure increasing obviously for the case of commingled production with separated injection. The incremental of cumulate oil and recovery percentage is 3.07 MMbbl, 1.2%, respectively. So the technology of commingled production with separated injection (Option 6) is recommended from the study.

7. Results and discussions

The research showed that the J#Field is featured with large reserves and high exploration and development potential. It was suggested from the study to put the old wells in high structure positions into production and drill new delineation wells at the low positions. Considering the information and reservoir features, based on the four-property relationship study, logging interpretation models were established and oil/water interpretation standards were determined. The detailed structure interpretation has indicated that, the study area is a faulted block structural belt in a monocline which is high in the northwest and low in the southeast, and includes six faulted blocks such as J48, J45, J19, J83, J88 and J1 from north to south.

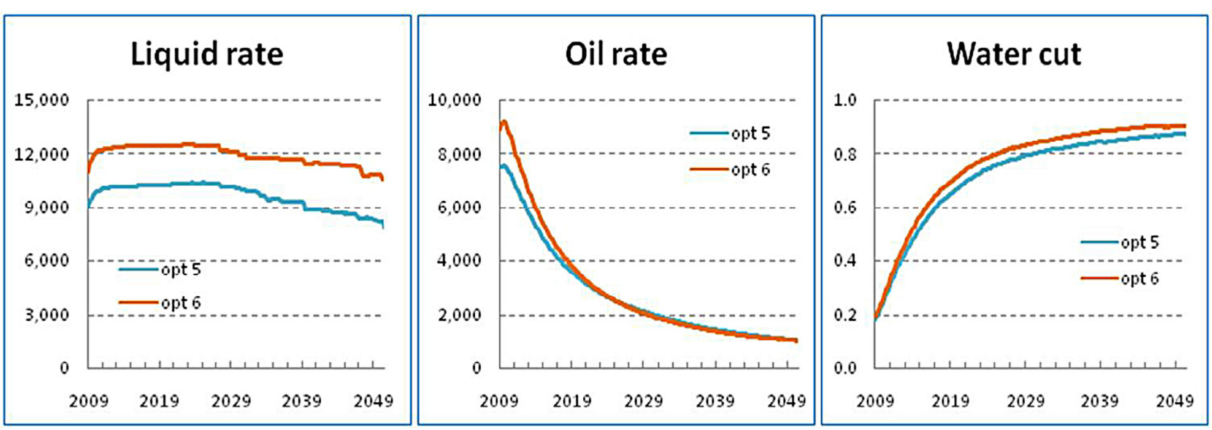

Figure 25 The results of different injection manners (Option 5–Option 6).

Table 5 Development indexes for Option 5 and Option 6.

Options	Active producers (well)	Active injectors (well)	Peak production (STB/d)	Cum. oil in 5 yrs (MMbbl)	Cum. oil in 10 yrs (MMbbl)	Cum. oil in 15 yrs (MMbbl)	RF (simulated) in 20 years	RF (simulated) in 30 years
Option 5	38	14	7533.85	61.07	69.07	74.75	36.00%	41.20%
Option 6	38	+ 10(G I-III) + 14(G IV-V)	9178.16	63.19	71.95	77.82	37.30%	42.40%

The sedimentary models were established for the area. The microfacies in the research area contained channel bar, distributary channel, underwater distributary channel, mouth bar and sand bodies are widely distributed. T#Fm mainly consisted of lithic sandstone and arkose quartzite. Kaolinite and smectite contents in G#Fm are higher and might cause bad effect to the injection. The compaction and pressure solution are weak, thus the formation features as middle porosity, and middle to high permeability. An OOIP of 646.8 MMbbl is confirmed. G#Fm and T#Fm are the main oil-bearing formations, and block J45-J48 is the key region where contains most of the OOIP.

Reservoir engineering study showed the reservoir featuring as faulted unsaturated oil reservoir driven by edge water with middle-high permeability. The field has four periods: production improvement (1947–1956), stable producing (1957–1967), production declining (1968–2004) and regulation period (2005–present). It is producing at high water cut level at the end of 2016. Water cut of T#Fm is 85.5%.

Remaining oil of J#Field is 85.2 MMbbl. Block J45 and block J48 are the main potential blocks. The recombination of formation, infill well pattern, injection, reperforation and layer shifting and plugging of water-producing layers etc are suggested by reservoir engineering study and development options optimization.

It is suggested that the field to be produced by three series of layers instead of two. The upper and lower parts of G#Fm will be injected with different injection pressure and produce commingled. 27 new wells are suggested, in which 20 wells are oil producers and 7 ones are injectors. Total 98 wells will be recovered to produce and 57 wells will be converted into injectors, totally 4500 layers will be taken workovers, and 5 wells of T#Fm will be recovered. Oil production is expected 2 times (about 6000 bbl/d)

8. Conclusions

Geological study, geological modeling, reservoir engineering study and numerical simulation were done on the long oil-bearing segments (3000–4000 ft). The seismic study, through detailed structural interpretation and reservoir anticipation verifying the structure characteristics and reservoir distribution regularities, provides foundation for reservoir geological research and geological modeling. Reservoir geological study described the subdivision of layers, sedimentary facies, reservoir characteristics, fluids distribution and reserves calculation in both oilfield scale and detail study in key area. Oil/water and reserves distribution of 26 layers in 11 oil-bearing sand groups in 6 blocks are the objectives of the study, which provides basis for development adjustment and potential layers optimization. OOIP of 646.8 MMbbl has been confirmed, the recovery percent of which is 28%. G#Fm and T-I group are the main oil-bearing layers, and G#Fm in block J45 and block J48 are the major reserves distribution regions and the main potential targets of the adjustment. Geological modeling, in terms of superimposed sands development, complex oil-water relationship and serious water flooding, the 3D geological models of G#Fm in the key selected blocks, J48 and J45 are established through facies controlling modeling and oil-water contact controlling modeling methods, to study the 3D reservoir and fluids distribution.

Study on reservoir engineering and numerical simulation, through single well production performance analysis, development appraisal, recovery factor determination, potential analysis and numerical simulation describes the remaining oil distribution in all layers. The calculated remaining oil is 85.2 MMbbl. G#Fm in block J45 and block J48 is the main target where the major portion of the remaining oil concentrated. Four-spot flooding network is recommended, with a well space of 200 m. The producer to injector ratio is about 2:1.

It is suggested that the field is to be produced from three series of layers: T#Fm, G-I–III and G-IV–V. 27 new wells are suggested, in which 20 wells are oil producers and 7 ones are injectors. There will be 98 wells to be recovered to produce and 57 ones be converted into injectors, totally 4500 layers will be taken workovers. Before the selected option is implemented in the field, a pilot test is planned to be carried out in block J45 to verify the injection results and acquire data of injection volume and pressure, pseudo-injectivity index, injection profile, liquid production profile and water cut.

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