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Influence of natural fractures on oil production of unconventional reservoirs

Chérif KHELIFA[a], Aziez ZEDDOURI[b] *, Fayçal DJABES[c]

[a,b,c] *Université Kasdi Merbah Ouargla, 30000, road of Ghardaia, Ouargla, Algeria*

Abstract

In recent years, awareness of the role of fractures on the production and recovery of hydrocarbons has become increasingly strong in the oil community.
To shed light on this question, this paper examines the fractures characterization and their effects on production and enhanced oil recovery; also, it deals with characterization of specific features of fractured reservoirs, using different tools as cores analysis and 3D imagery.
The effect of fractures on well productivity is explained and in this point, we have taken the data of wells production from a single reservoir to put these wells at the same overburden conditions. We have selected as example “El Gassi” field to follow the evolution of gas/oil ratio (GOR) according to wells daily production.
To analyze the effect of the injection on the daily production of the field, we have compared the evolution of the production of three tanks, two fractured reservoirs and a third non-fractured (consolidated). We took the “El Gassi” and “Rhourde El Bagel” fields as fractured reservoirs, and “Hassi Berkin” field as consolidated one. Then we have treated the impact of fractures on assisted oil recovery; we have studied the response of production at “Rhoud El Bagel” field after gas injection.
Data analysis of the production of these three Algerian fields shows that there is no direct apparent relationship between the intensity of fractures and average production. A change in the recovery mode is required by the orientation to water injection or water alternating gas “WAG” process.

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Keywords: fractured reservoirs ; fractures characterization ; cores description ; imaging tools ; enhanced oil recovery

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1. Introduction

Oil is today the world's leading source of energy; the 21st century will be marked by the scarcity of hydrocarbons (oil and gas) that currently provide about 62 % of global energy consumption. On the other hand, the global daily oil

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consumption will rise from 72 million barrels / day in 2001 to 85,500,000 barrels per day in 2010 to 112 million b / d in 2020 (International Energy Agency), or an increase of 55 % in twenty years. To meet the global energy demand growth, it is necessary to discover new reserves and especially exploit the mature fields, the new discoveries being made increasingly rare. The exploitation of unconventional reservoirs is, at present, a major challenge for oil companies. [4] The production of these reservoirs inaccessible or very compact in low-permeability reservoirs, the presence of a network of natural fractures is critical for the operation, since it determines the network flows of oil or gas. Naturally fractured reservoirs contain a significant proportion of global oil reserves. The production of this type of tank is a challenge for reservoir engineers in this section we will try to highlight this type of tanks [2].

2. Methods of detecting fractures

Detection and evaluation of fracturing done during the various phases of operations in exploration and production of oil field development include the following techniques:

- Observation and core analysis: it allows deducing the origin of fractures and is also used to verify the results of imaging logs and production.
- Imaging logs: they are a way for the orientation, density, and spacing of fractures. However, their precision is limited in the case of gas inlets or fractures with limited openings.
- Sonic Logs: are used to estimate the permeability of fractures around the wells, and the orientation of the stresses and fractures.
- Study of constraints: To know the origin of fractures according to the state of stress and the effect of stress on the fracture conductivity. Moreover, the stress distribution diagram of the said distribution of faults and fractures.
- Logs of production: Connect with the flow direction, the density and the results of imaging logs; they also serve to estimate the apparent permeability of fractures [1].

The techniques most commonly used in the field are imaging logs, core analysis, which is why in this work we will build on these two techniques.

2.1 Imaging logs

Recording images of the borehole wall is provided by two types of tools including:

- Electric tools (FMI, FMS, Earth imaging): Whose principle is based on measuring the micro resistivity layers with an electrical signal.
- The acoustic tools (UBI, CBIL): based on the emission of acoustic waves on the wall of the hole and record the frequency and amplitude of the reflected waves.

The selection of the tool is based primarily on the nature of the mud used in drilling. For this purpose the use of electric tools is limited in the case of a salt-based mud (conductive) and acoustic tools, used in the case of oil-based mud (nonconductive).

At our study area, the nature of the drilling mud is used in the oil base, this will require the use of acoustic tools (CBIL), applied in recent wells [5].

Nomenclature adopted by fractures BAKER ATLAS is based on the amplitude of the reflected waves, and the continuity of fractures relative to the borehole, which are:

- High amplitude fracture: these are the fractures that have a high acoustic wave's reflected character they correspond to closed fractures or clogged with compact cements (eg quartz).
- Low amplitude fracture: these are the fractures that have a low acoustic character they correspond to fractures.
- Mixed fracture: these are fractures where the acoustic nature is twofold; they correspond to partially open fractures.
- Continuous Fracture: These are fractures, open or closed, covering the entire circumference of the hole.
- Fracture discontinuous: it fractures are open and closed, which do not completely cover the circumference of the hole. [5]

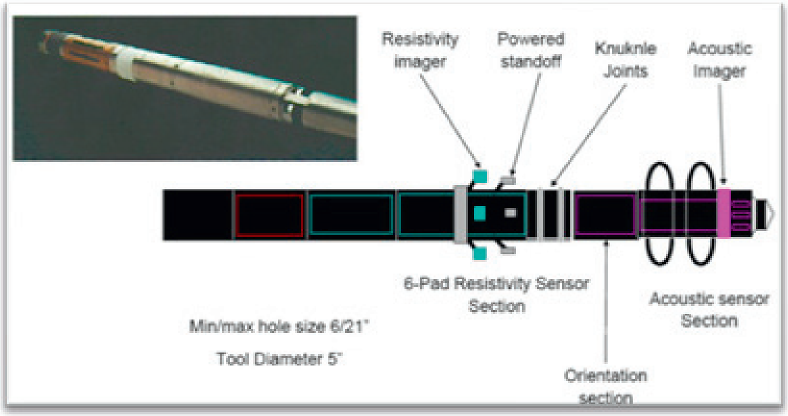

Fig. 1. Description of the acoustic tool « CBIL ».

The picture provided by the imaging tool (CBIL), can help geologists identify different types of structures shown on the wall of the hole and orientations such that the sedimentary structures (sandstone bench, clay seals ...), tectonic structures (faults, fractures ...).

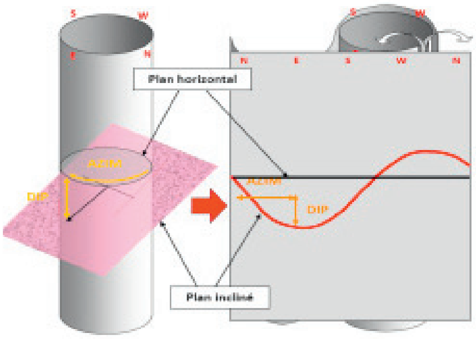

Fig. 2. The image recording

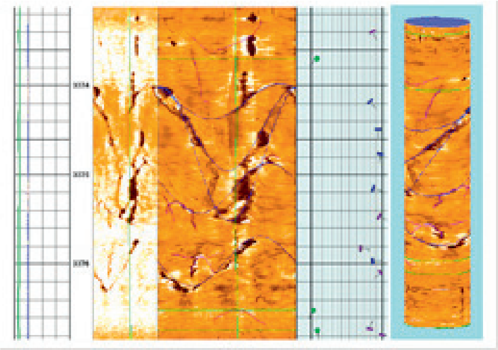

Fig. 3. Background image of an open fracture (in GS-37 well)

- The sedimentary layers: the image from the tool (CBIL) shows several benches layer (clay , sandstone) that are differentiated by their acoustic characteristics , such as sandstone are recognized by a light color and clays identified by a darker color.

Either sedimentary layers can appear as a horizontal plane and the answer is a straight line or a tilted and his answer will be a sinusoid plan online.

- Natural fractures: Acquired the well bottom image, we can detect several types of fractures; these fractures are given to reflections of acoustic waves:
- Open fractures: These are fractures that their reflection acoustic wave is attenuated.
- Closed fractures (sealed): These are fractures that their reflection acoustic waves is high.
- Partially open fractures (partially clogged): These are fractures that their reflection of the acoustic waves is higher in one-half of the fractures and low in the other half.

By imaging logs, recognition of the natural fracture is due to its sinusoidal shape whose amplitude is directly related to the low or high angle. Fractures closed by the non-existent space between two edges is recognized when the open fractures is represented by a dark color corresponding to the opening edges.

- The breakouts: Appear as a deformation of the elliptical section of the well shape, said deformation after a compression of both sides of the wall, it is perpendicular to the major stress (sigma 1) and parallel to the stress minor (sigma 3). [5]

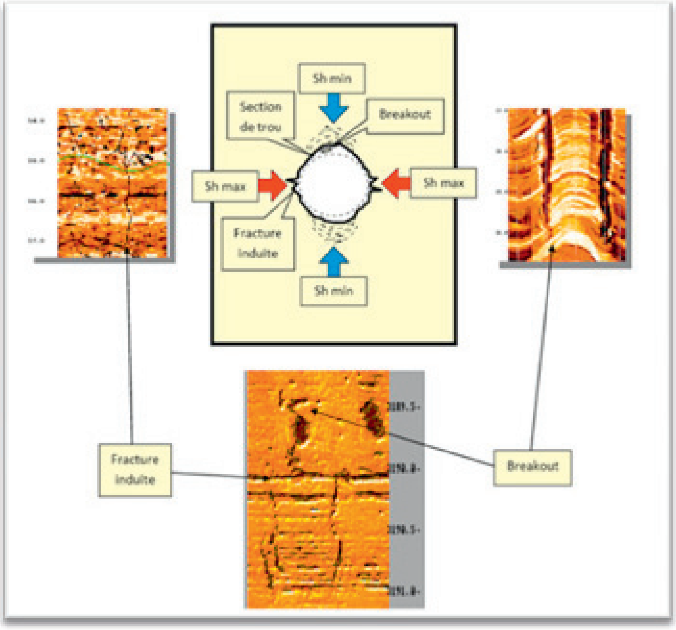

Fig. 4. CBIL image of breakouts and induced fractures

2.2. Cores analysis

The best method to detect fractures tank is by observing the core area of interest provided fracturing is not strong enough to prevent core recovery.

At the core analysis we identified all observable namely structural objects:

- The stylolites: they are structures shaped columns, interpenetrating in rocks (limestone, marl and limestone) by drawing irregular joints.

These figures correspond to surfaces of pressure dissolution, and in particular, to determine the direction of compression that gave birth to and parallel to the elongation of columns.

Stylolithic joints of parallel sedimentary origin stratification is plentiful and well marked in the most clay layers.

- Fractures (type, width and length).
- Sealed fractures: These are closed fractures filled by several clogging:

Silica: It usually clogs the fine fractures represented by quartz grains of microscopic size.

Clay: It is difficult to identify the main clay cements are kaolinite and illite.

Pyrite: Its presence usually indicates the flow of sulphidic water.

The spacing of these fractures is from 1 mm to 3 mm, against their length is between a few millimeters to several centimeters (cm times 70) [2].

- Gaps: The gaps are generated to highly tectonized places; they met in the areas of milling [3].

3. Methodology

Our study is organized as the following:

Part 1: the effect of fractures on well productivity , in this point we must take the data from the production wells of a single tank to put these wells the same overburden conditions, that 's why we chose as an example the El Gassi field.

Part 2 : To know the influence of fractures on the production of tanks , which is why we will compare the evolution of the production of three tanks , two fractured reservoirs and a third non-fractured (consolidated) . We took the El

Gassi and Rhourde El Bagel field as fractured reservoirs, and Hassi Berkin field as consolidated tank.
Part 3: the impact of fractures on assisted oil recovery , we will study the response of production Rhour field El Bagel following the injection of gas.

4. Impact of fractures on production wells (study around El Gassi field)

4.1. Relation between production and fractures intensity

In this section, we will try to find a relationship between the production and the degree of fracturing using data from the table below (Tab1):

Table 1: Intensity of fractures and the average production

Production >1000 bbl/d		**Production <1000 bbl/d**	
well	**Intensity of fractures**	**well**	**Intensity of fractures**
GS-17	***	GS-05	*
GS-14	***	GS-07	***
GS-15	***	GS-11	*
GS-06	***	GS-09	***
GS-18	*	GS-13	*
GS-20	*	GS-08	**
GS-21	**	GS-04	***
GS-01	**	GS-12	*
		GS-03	**

*** : strongly fractured wells.
** : moderately fractured wells.
* : weakly fractured wells.

Table one notice from the wells strongly, moderately and weakly fractured are producers whose average exceeds 1,000 bbl / day well good. From the same table we also see that the poor production is represented by wells that are highly, moderately and slightly fractured [6].
The interpretation of this table suggests to us that there is no direct relationship between the intensity of fractures and average production.

4.2. Relationship between production and types of fractures and faults

Nevertheless, a type of fracture can control the production, namely: open fractures and partially open and distance from wells to major accidents affecting the reservoir.
The data on these criteria are summarized in the following table:

Table 2: fractures Settings and average production

Well	Proximity of faults	Intensity of fractures	Type of fracture	Average production
GS-03	E-W	average	closed	bad
GS-04	E-W	strong	closed	bad
GS-21	N120	strong	partially open	good
GS-08	E-W	average	partially open	bad
GS-07	E-W	strong	partially open	bad
GS-15	N120	strong	open	good
GS-17	N120	strong	open	good
GS-14	N120	strong	open	good
GS-11	E-W	average	partially open	bad

According to table 2, it is seen that the wells have a good production wells are characterized by high fracture strength and a type of open fractures open and partially ex: 14-GS, GS-17, GS-15 and GS-21.

Can be seen on the same table as these wells are near accidents N120, unlike wells near EW accidents are bad production.

We can conclude from this interpretation that the production is linked to the types of fractures as well as the proximity of the fault management NI20.

5. Impact of fractures on reservoir production (studied fields: El Gassi, Rhourde El Bagel, Hassi Berkin)

In this section we will compare the data from the previous production fields, to find a relationship between changes in production and the presence of the fracture.

To analyze the data, we can draw the graph as following:

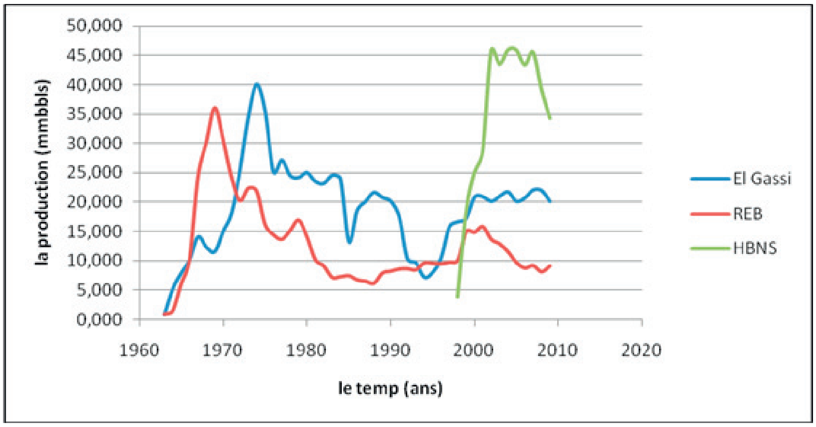

Fig. 5. Production evolution in the fields El Gassi, REB and HBNS

From the curve shown above, we can really see the difference between a compact tank and a fractured one. Production of a fractured reservoir drops rapidly after a sudden increase (peak) and this is clearly shown on our graph. This indicates the assumption that the production of fractured reservoir comes from fractures (cracks). The permeability of cracks is much greater than that of the matrix and since the oil follows the path less resistant while the greatest amount of oil produced fractured reservoirs (98%) comes from the cracks. Once this amount (cracks oil) to decrease, the total production of tank drops sharply as it well as exactly clear on our graph. By cons, in the compact tank, production comes from its matrix pores while production remains constant and given the lack of data from Hassi Berkin (we do not have data since its inception) but the curve of this field shows that production remains constant (for almost 2000-2010) and even lower production comes from its sweeping effectiveness.

6. Impact of fractures on secondary recovery (study around Rhourd El Baguel field)

In fact, this study gives us a descriptive diagram of the state of Rhoud El Baguel fracturing Field and a draft recovery witnessed between SONTRACH and BP to increase the recovery rate of this field. This project consisted of massive injection of CO_2 -rich gas at high pressure to achieve what is called miscibility after the 8th injection gas year.

But in reality, due to the condition of the tank (fractured of course) this mode of operation is not effective and the graphs that we will show below will validate this theorem.

Right from the start of the massive injection of gas was found negative effect of the injection on the production. It is true that the daily production of crude oil has known a significant increase during the days following the start of the gas injection, but this was not the case unfortunately thereafter, where production has dropped in a huge way.

This impact is evidenced by the increase of free product gas and oil produced in the majority of producing wells decrease.

For example, the amount of field product gas was about 6,000,000 m^3/d in December 1999; it exceeded 19 million m^3/d in July 2003. At the same time, oil production fell 50 000 bbls /d to 32,000 bbls /d and the GOR is mounted in a rapid manner in most of the producing wells and especially those who are close to the injection wells.

Physically this phenomenon can be interpreted as following:

According to the geological set and when storing oil in fractured reservoirs is in the matrix blocks and the flow in the crack, and after the previous graphs which we've shown, we can justify this drop in production in the field by : injected gas prefers to flow through cracks towards producing wells instead of drying (draining) the quantities of oil in matrix blocks.

This result is clearer in the following graph that showed us the daily quantity of gas produced by contribution to the total amount injected.

The graph below also shows the unexpected result on the GOR training which allowed to drop the total production of the field is now equal about 25 M.bbl/day, which was a quarter of the planned production in 1996, the date of signing the contract.

We can conclude that the injection of gas in Rhoud El Baguel fields is charged inoperative due and as we have already shown to the presence of fractures networks. That enhance the ability of fluid to flow through these drains and as we know, gas mobility is higher than that of oil, which allows us to have a breakthrough gas quickly and also have direct paths from gas injection wells to producing wells. In the case of Rhoud El Baguel field, this recovery mode put the company facing another problem of ensuring a more important storage space for gas recovered, as the volumes sent to the flare are limited.

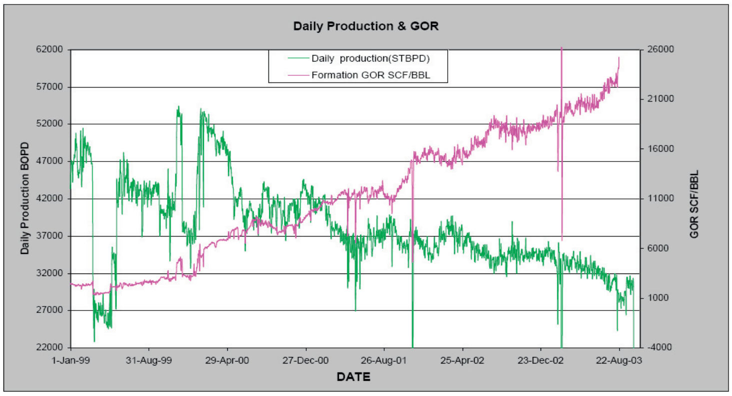

Fig. 6. GOR and daily production evolution

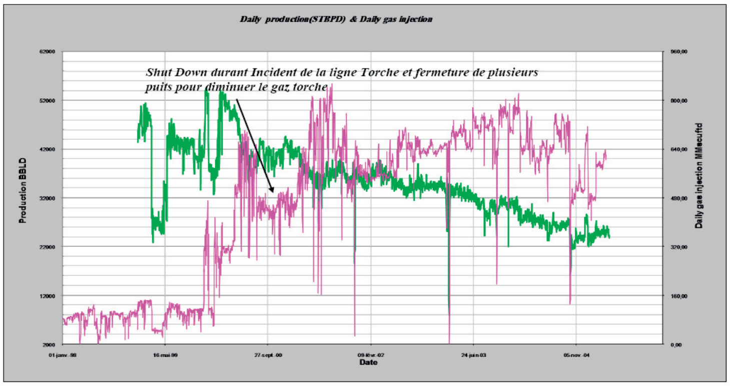

Fig. 7. Effect of gas injection on daily production of the field

7. Conclusion

We conclude that oil tanks strong compactness are a significant part of the current energy reserves. Exploitation thus represents a major challenge for the future. In these reservoirs, oil or gas flows in both media, and given that one can not estimate the rate of production and enhanced oil recovery correctly.

To improve these estimates and optimize production, it is necessary to characterize better the fracture network structure that determines the tank and flows, and ignorance of fracture parameters in studies of oil reservoirs lead to poor study.

In this study and after data analysis of the production of three Algerian fields we find that:

The analysis of oil production shows that there is no direct apparent relationship between the intensity of fractures and average production.

This is not always the fractures have positive effect on the operation of reservoirs.

the gas injection is charged to the fields inoperative due world and as already shown in the presence of fracture networks that improve the capacity of fluid flow through the drain and the mobility gas is raised to that of oil which allows us to have a breakthrough of gas quickly.

According to these problems caused by the injection of gas into the reservoir was fractured a change in recovery mode is essential and attended orientation towards water alternating gas injection will be the most favorable in this case mode [7].

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