Karst feature in Mishrif Reservoir and effect on drilling and production in Zubair oil field, Southern Iraq

ظاهرة التكهف في مكمن المشرف وتأثيرها على الحفر والأنتاج في حقل الزبير، جنوب العراق

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Abstract:

Karst features in the upper part of Mishrif carbonate reservoir can commonly create substantial vugs, pores and fissures and, thus, increasing the porosity and enhancing reservoir connectivity and permeability, this features were formed normally as a result of the carbonate rocks dissolution under the action of meteoric waters during very long periods of emersion spanning from Late Cenomanian to Turonian (about 4.5 Million years). This study deals with the presence of the karst features in Zubair oil field, southern Iraq, where Karst features were observed in the center and northern parts of the field close to the top of Mishrif Formation in most of the cored wells. Characterization of that feature can be achieved from static data at wellbore scale from core, and logs (conventional and non-conventional), and dynamic data such as mud losses, well tests combined with production logs (PLT) in addition to Seismic data. Beside the positive and economic effect of Karst, there is negative effect which includes causing mud losses during drilling in Mishrif Formation because of low reservoir pore pressure, Therefore, acid soluble cement plugs were used to heal that losses to continue drilling.

Key words: Karst, Mishrif reservoir, mud losses, water cut.

Introduction:

The term Karst in Carbonate rocks is normally refers to the landscape that been formed by the carbonate rocks dissolution under the action of acidic water [1]. The dissolution process can create substantial pores, vugs, and fissures, forming or developing high quality reservoirs [2]. Karst improvement take place when acidic water starts to break down the surface of bedrock near the bedding planes or the cracks of the rock, the cracks with time get larger, and lastly creating a subsurface drainage system which will accelerate the development of karst formations. Karst process is mainly due to chemical weathering (Carbonation), in this process a chemical reaction between carbon dioxide (CO_2) and water (H_2O) occur producing carbonic acid (HCO_3) which react with carbonate minerals of the rock causing weakness of the rock as follows:

$$CO_2 + H_2O \rightarrow H_2CO_3 \quad (1)$$

$$CaCo_3 + H_2CO_3 \leftrightarrow Ca^{++} + 2HCO_3^- \quad (2)$$

Carbonation occurs mainly in moist and wet climate because the cold water had higher concentration of CO_2, and the deeper H_2O, the more CO_2 absorbed making it more acidic [3].

Mishrif reservoir is one of the important carbonate reservoirs in middle and southern Iraq beside the Middle East. This study highlight the presence of Karst in the upper part of Mishrif reservoir, that existence of Karst can be seen directly in vugs and channels in core samples and/or image logs, or indirectly from observing high permeability and production zones identified from production logs and well test beside its economic impact on increasing the non-productive time (NPT) during drilling new wells due to possible mud losses, also its effect on significant improvement of reservoir capacity, permeability and production rates.

Study area:

Zubair is a supergiant oil field discovered in 1949, it is located 20Km to the west of Basrah city in southern Iraq, and encompasses an area of 900 Km^2. It forms an 60Km north/south anticline, The field is near the Kuwaiti border in the north-east part of the Arabian Peninsula Figure (1), it is made up of four domes from south to north (Safwan, Rafdhyia, Shuaiba and Hammar) respectively.

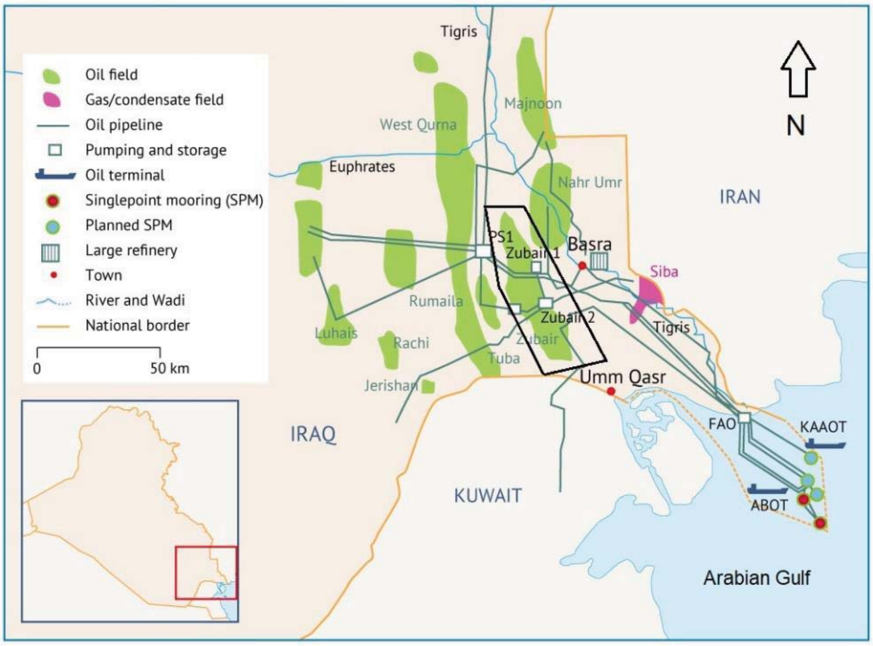

Fig. (1) Location map of the study area

Methodology:

The methodology to achieve the goals of the study involved the following:

- Identified 13 wells with sufficient data to perform analysis (drilling reports, mud logging data, oil production, water cut history, well tests, production logs and core data).
- Summarized daily and final well reports and reviewed mudlogs data to track losses events while drilling in Mishrif reservoir in Zubair oil field.
- Recognized high permeability zones in upper part of Mishrif reservoir from mud losses during drilling events, PLT data, core data and formation tester log.
- Monitor oil production history and water cut levels in the wells that have Karst feature.

Results and Discussion:

Karst in Mishrif Formation:

Mishrif and Rumaila Formations in southern Iraq were firstly described by Rabanit (1952) in well ZB-3 at the Zubair oil field [4]. Owen and Nasr (1958) choose this well later as the type section for these two formations and several other Cretaceous formations in south of Iraq [5, 6]. Mishrif Formation (Cenomanian–Early Turonian) was deposited in a widespread shallow water carbonate platform linked with an intra-shelf basin [7]. The lower contact of Mishrif Formation is usually conformable with the open marine sediments of the Rumaila Formation, the upper contact is regionally unconformable with Khasib Formation Figure (2), that unconformity had been observed in several locations along the Arabian Plate, Mishrif exposure was a result of tectonic uplift due to the ophiolite obduction along north-east Arabian Plate margin during the Mid-Turonian and a global eustatic fall in sea level [8].

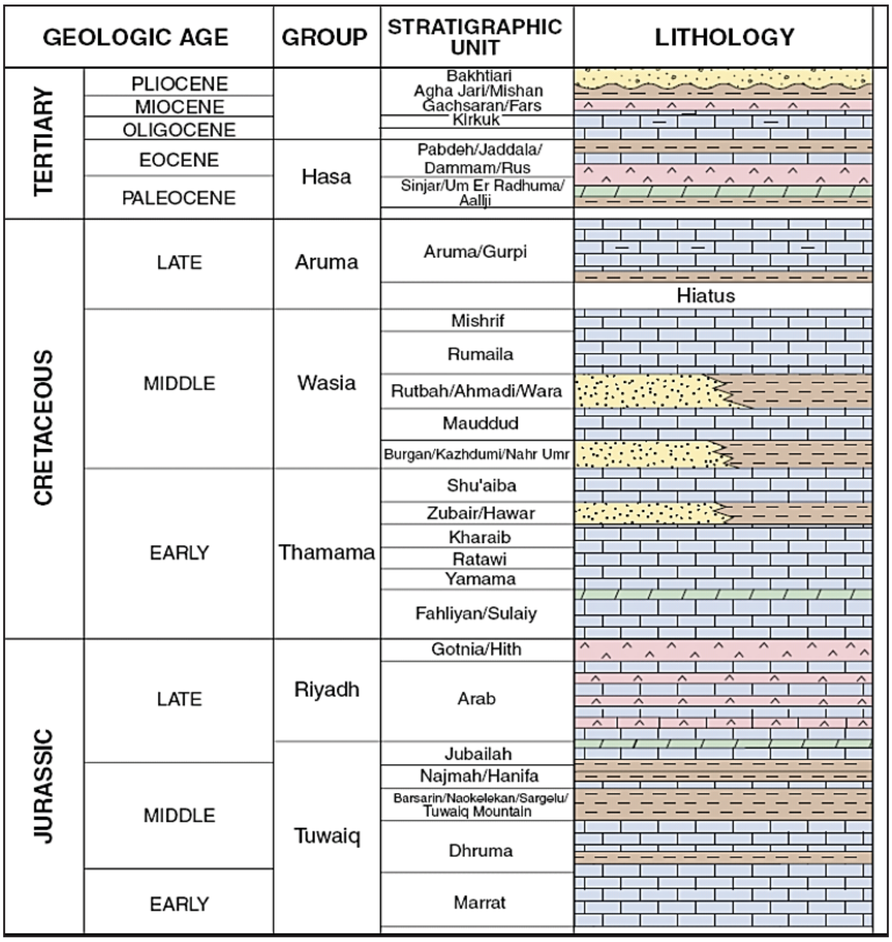

Fig. (2) General stratigraphy for the South Iraq [7]

The exposure and meteoric diagenesis effect on the top of Mishrif is more distinct than the disconformity in the middle Mishrif, that can be referred to the very long period of exposure (4.5 millions of years) during the Turonian [9]. After the exposure and final karstification of Mishrif Formation in the later Early Turonian, the topography of its upper boundary was covered by the shales deposited during the Khasib Formation transgression Figures (3 and 4).

Fig. (3) Core sample (left) and Image log (right) illustrating karst in Mishrif reservoir

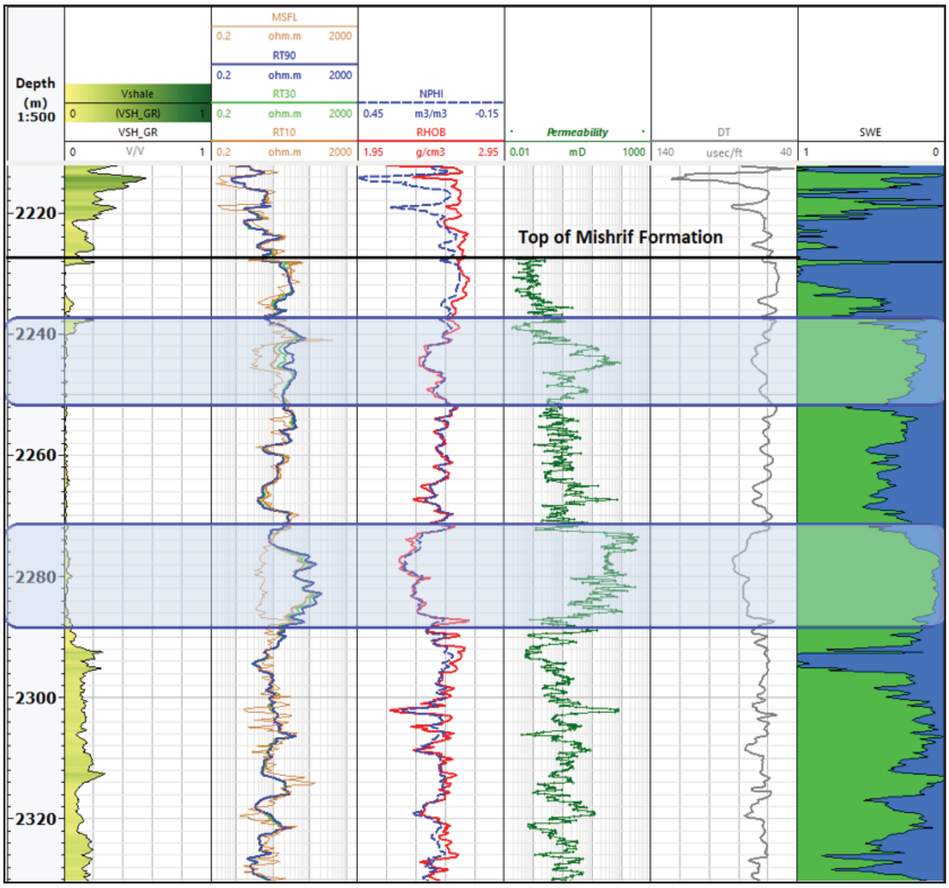

Fig. (4) High permeability Karst zones in well L

The Karst zone in Zubair oil field was observed in the area between the coordinates: 3364000 to 338600 North and 744000 to 757000 East (WGS-1984 coordinate system), that zone was identified using integrated 3D seismic survey results, core data, Image log, production logs and well tests, it was found also that the thickness of karst zone within Upper Mishrif unit varies from 5m to 60m Figure (5).

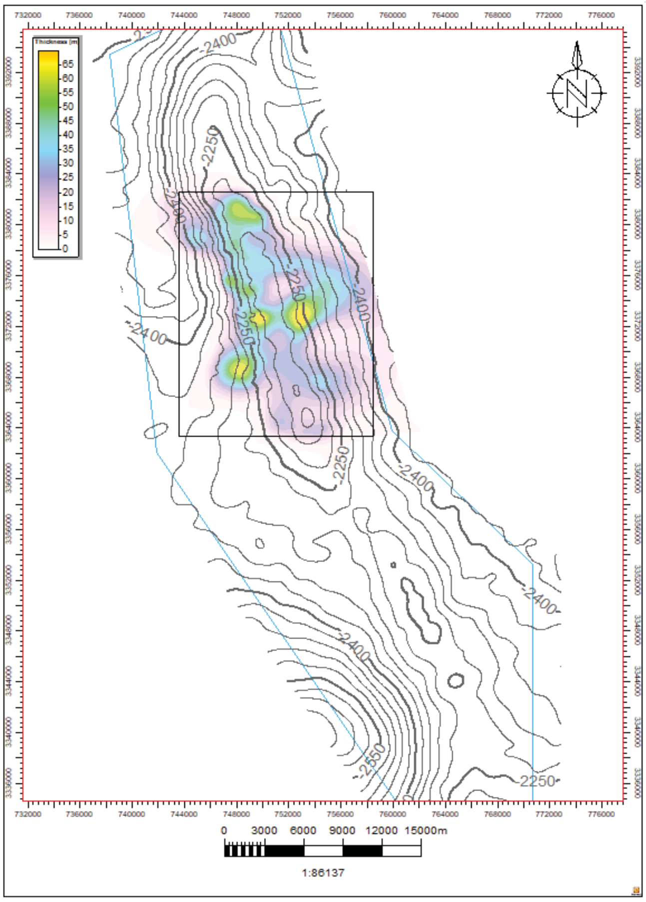

Fig. (5) Karst thickness map for Zubair oilfield [10]

Karst have an effect on the drilling and production in Zubair oil field:

1- Karst effect on drilling operations

Karst feature in subsurface formations may result in a variety of solution cavities of various sizes with distinct characteristics both in the surface and subsurface geological structures. Due to the creation of a series of underground solution cavities with strong inter-cavity connection, this type of thief zone can accommodate huge volumes of drilling mud. Selection of well site location away from the karstified formation will reduce the scope of massive loss of circulation while drilling [11] Loss of circulation while drilling is one of the most important drilling issues faced by the region since the commencement of drilling operations, and is also one of the main drilling problems that increases the NPT dramatically [12].

The phenomenon of lost circulation happen when the drilling mud flows into the geological formations rather than returning back to the annulus and surface. Mud losses occurs when the mud pressure is by far greater than the pore pressure of the formation [13], as a result of that, the oil and gas industry suffers the loss of more than one billion dollars every year in rig-time, materials, and other financial resources [14]. It is common to observe mud loss issue during drilling depleted reservoirs, high permeable formations, and fractured or cavernous formations Figure (6) [15].

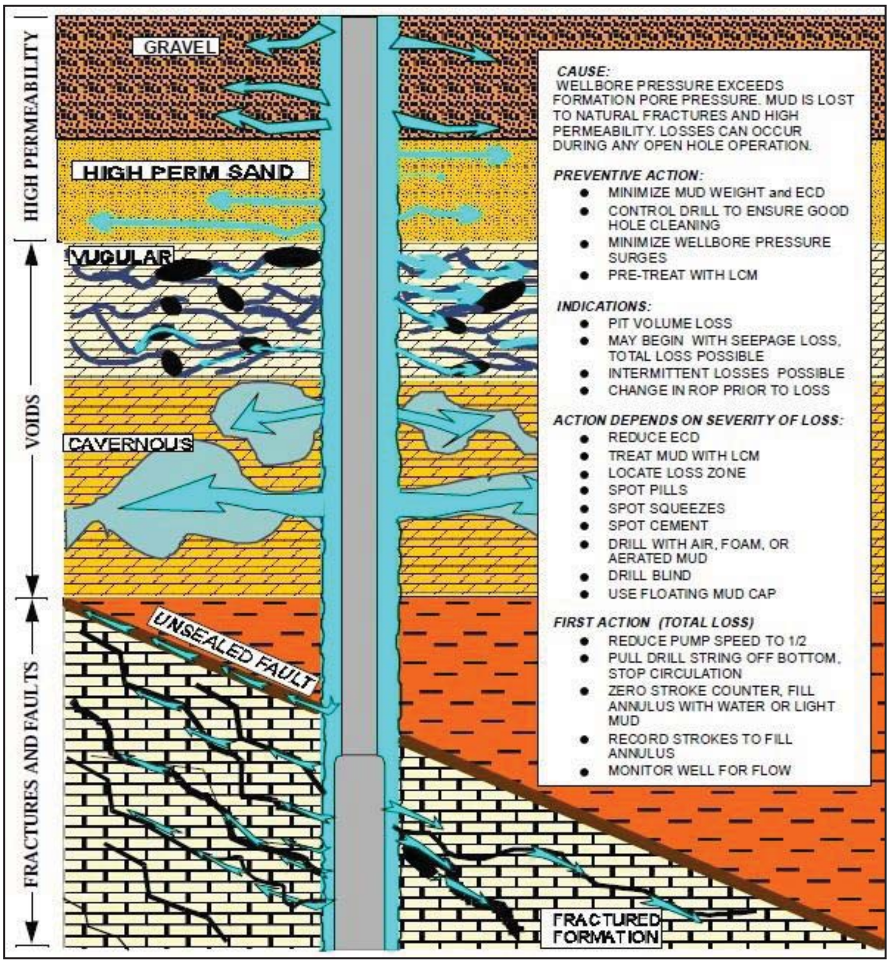

Fig. (6) Mud losses events and proper treatment [16]

In Zubair oil field many wells experienced different types of mud losses (seepage, partial and complete losses) during drilling the Mishrif Formation causing non-productive time (NPT) and delay in well delivery and to put the well on production (POP). Table (1) summarize an overview of mud losses events in nine wells from Zubair oil field, in these wells it's observed that lost circulation of mud occurred during drilling the upper part of the Mishrif Formation (mA unit) due to Karst feature, the three categories of losses are:

- Seepage losses: ratio of mud losses is 5-10 bbl/hr (normally cured by pumping high viscosity mud).
- Partial losses: ratio of mud losses is 20-50 bbl/hr (in most cases can be cured by pumping high viscosity mud as first option, when failed to cure losses then acid soluble cement plug is used)
- Complete losses: complete loss of mud circulation (no return), acid soluble cement plugs are used to cure losses

Table (1) Mud losses events in some wells located in Karst zone, Zubair oil field

Well	Top of Mishrif MD (m)	Mud loss start depth MD (m)	Type of Losses	Mud weight (gm/cm^3)	Total losses (m^3)
A	2192	2226	Partial	1.16	100
B	2467	2468	Partial	1.26	102
C	2198	2203	Complete losses	1.18	236
D	2236	2270	Partial	1.16 - 1.2	60
E	2375	2409	Partial	1.3	292
F	2193	2410	Partial	1.08	107
G	2220	2234	Seepage	1.16	3.9
H	2206	2221	Partial	1.18	16
I	2277	2297	Partial	1.2	25

When lost circulation occurs, sealing the zone is necessary except if the geological conditions allow blind drilling, which is unlikely in most cases remediation of mud losses. It becomes mandatory during severe lost circulations to use various plugs to seal the lost zone. It is also vital to know the lost circulation zone depth before setting a plug. In Zubair oil field the most common practice to heal losses in Mishrif reservoir with limited reservoir damage is through using acid-soluble cement plugs, this type of plugs can be dissolved later by injecting acid (HCL) to react with cement and open channels into the reservoir, other possible mitigation for the lost circulation in Karst zone is to use managed pressure drilling (MPD) which is kind of under balance drilling, in this type the applied pressure of light density drilling mud is less than formation pressure, and to ensure pressure control, a rotating control head with a rotating inner seal assembly is used in conjunction with the rotating table, this type of drilling technique can decrease conventional drilling problems, for example lost circulation, minimal drilling rates, differential sticking, and formation damage. Moreover, underbalanced drilling gases cool the bit while quickly and removing cuttings which extends the life of the drill bit.

2- Karst effect on production

Karst can have positive affect by increasing the storage volume and substantial permeability conduits for the hydrocarbon flow. On other hand, Karst can have a negative effect through the development of high degrees of reservoir heterogeneity or by providing barriers to hydrocarbon fluid flow. Karst can also influence the in-place distribution and movement of injection water as part of enhanced recovery processes [17]. The productivity of karst reservoirs is closely related with development degrees of caves, dissolved pores, caves, and fractures in the reservoirs. Figure (7) show the effect of Karst on porosity and permeability in one of Zubair oil field wells.

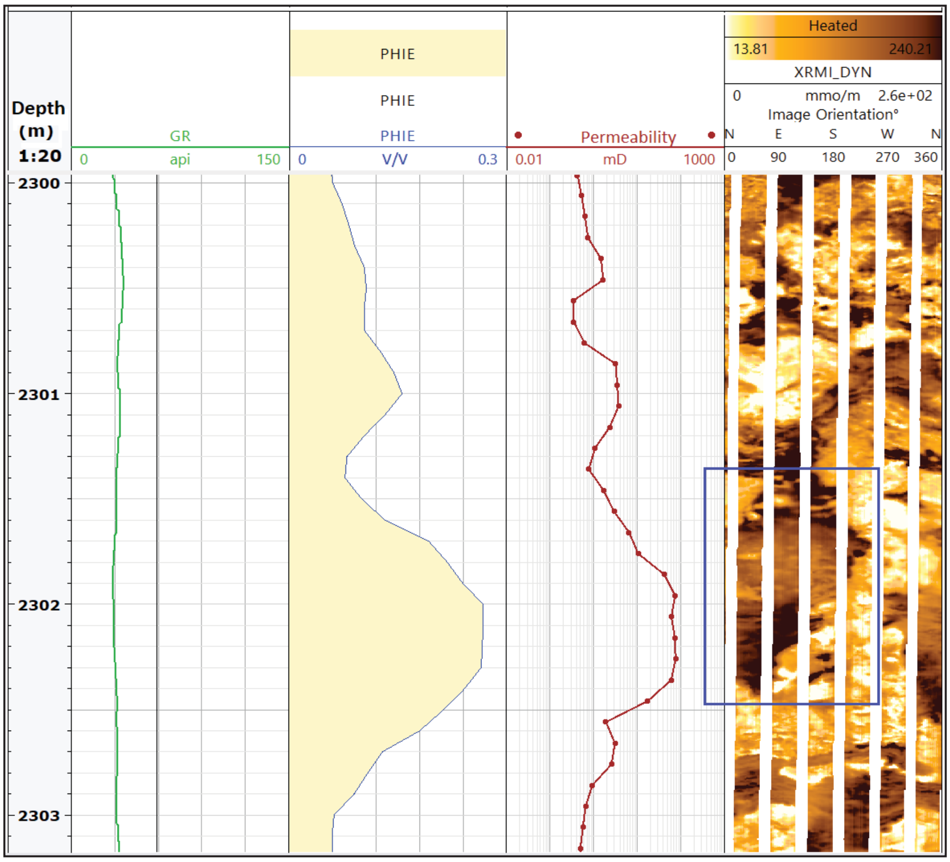

Fig. (7) Solution enlarged fractures clearly indicating the karst in well-L

When monitoring the behavior of wells located in the Karst zone, it's observed that these wells had an average daily oil production ranging from 2000 to 5000 bbl./day which is higher than other Mishrif wells in other zones in the field, also \its noted that the average water cut is less than 5 %, these features of carbonate oil reservoirs of high oil production and low water cut in initial period Table (2).

Table (2) PLT data showing high oil production contribution from the upper Mishrif related to Karst

Zones m	Qw res. B/D	Qo res. B/D	Qg res. B/D	W O G
Inf. 1 (2385.1-2392.9)	0.00	700.00	0.00	
Inf. 2 (2424.0-2429.7)	410.00	1750.00	0.00	
Inf. 3 (2512.0-2518.0)	500.00	15.00	0.00	
Inf. 4 (2528.2-2534.0)	-500.00	-15.00	0.00	

After a period of high rates of oil production, water cut starts to increase rapidly reaching very high levels (80%) in relatively short time compared with other Mishrif producer wells in other areas in the field. Figures (8, 9 and 10) show the production and water cut for wells A, H and I in Zubair oil field.

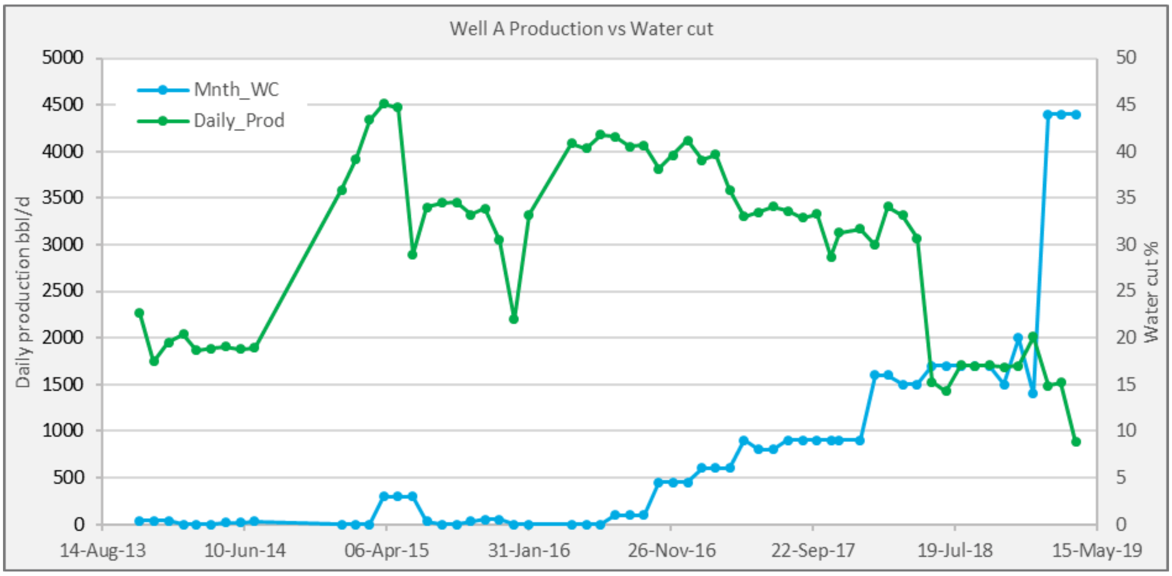

Fig. (8) Average daily oil production and water cut for well A

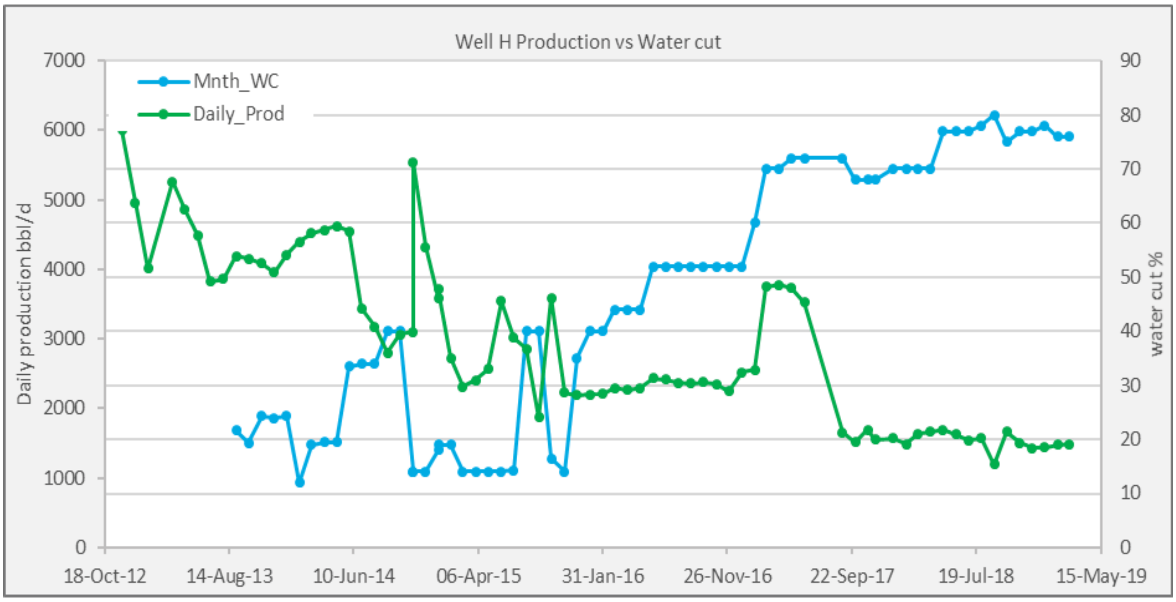

Fig. (9) Average daily oil production and water cut for well H

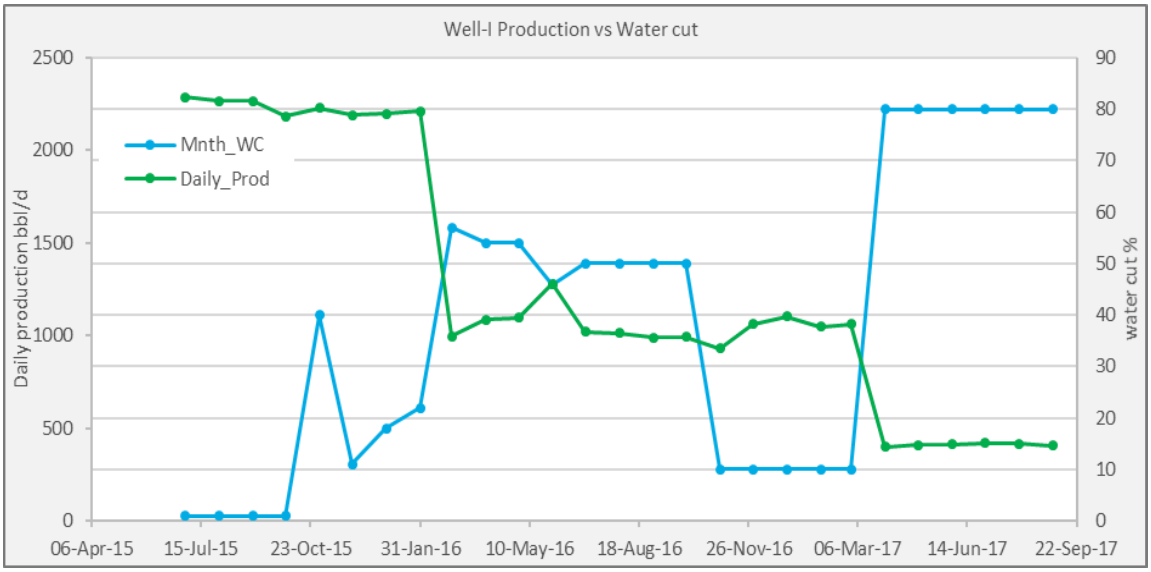

Fig. (10) Average daily oil production and water cut for well I

Conclusions:

- Karst events such as, vugs and solution enlarged fractures, (mostly occurs in the uppermost 20-40m of the reservoir) were a result of diagenetic alterations associated with the unconformity at the top of Mishrif Formation.
- High and enhanced permeability in the upper part of Mishrif reservoir can be identified from combining PLT logs, Image logs, core, well test, and formation tester data.
- Partial or complete mud losses may occur during drilling new wells within the Karst zone area, that's due to low pore pressure in that area. Possible mitigation is acid-soluble cement plugs or under balance drilling (managed pressure drilling MPD).
- High hydrocarbon production rates from Karst zones causes rapid increase in the water cut percentage which at the end reduce the produced oil volumes and lead to shut-in that wells.

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