ID : 2023-A-115-AAPG

Integration of Downhole LWD Dual Imager and Log Data While Drilling for Characterizing Fracture Network at Late Jurrasic Tight Carbonate in Horizontal Well Placement - A Case Study from Northern Field Deep Gas Development in Middle East.

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ABSTRACT

Tight carbonate reservoirs of North Kuwait present many challenges for field development because of the inherent low porosity/permeability characteristics. It is characterized by an average matrix porosity from 2 to 6% and permeability from 0.01 to 1.5 mD. Natural fractures play a primary role in the producibility of these reservoirs. High angle well is being planned to intersect as many as the fracture systems for the production improvement. Acquiring important downhole data for formation evaluation and maintaining the well on the targeted layer is a challenged because of the harsh environment and the potential drilling risk associated with high angle well and presences of fractures.

The fit propose solution to characterize the fractures is to use LWD (Logging While Drilling) high resolution dual images which can work with synthetic oil base mud with extreme high Mud Weight to ensure of successful data acquisition without jeopardizing borehole risk and potential well control situation. The well also geo-steered with Ultra Deep Reservoir Mapping to enable the position the well at the target layer inside Najmah Limestone. The Ultra deep reservoir mapping was deployed in while drilling, enable to map boundary for placement the well at the target zone.

The complete set of the formation evaluation consists of the LWD oil base mud imager, LWD Multi-Function porosity tool and LWD sonic tool were lowered down after drilling reached liner depth. The acquired downhole data were integrated with drilling data such as mud losses event and gas show from mud logging. These sequences of the data acquisition were designed with full engineering analysis such as torque-drag to ensure of completing the well and acquire downhole data successfully, hence increasing the operation efficiency.

Two major fractures corridor were revealed from the d LWD borehole images at upper and middle part of Najmah limestone. The integration from the borehole images data with images from Ultra Deep Reservoir Mapping enhanced the structural dip information of Najmah Limestone and the fractures geometry information, hence enabling of the adjustment decision on the subsequent lateral section strategy.

EXTENDED ABSTRACT

The Jurassic formations in North Kuwait have proven hydrocarbon potentials for gas, condensate and volatile oil. There two group of formation units in all Jurrasic formation for the exploitation and evaluation strategy. Primary exploitation commences from Early Jurassic and secondary exploitation and further extensive evaluation is focused on the middle to late Jurassic Najmah limestone formation (Fig-1).

The case study well-A is located at the northern part of the country and the reservoir section is at the Late Jurassic rock. It is a tight carbonate with called Najmah Limestone with ranging porosity from 2 to 6% (Fig-1).

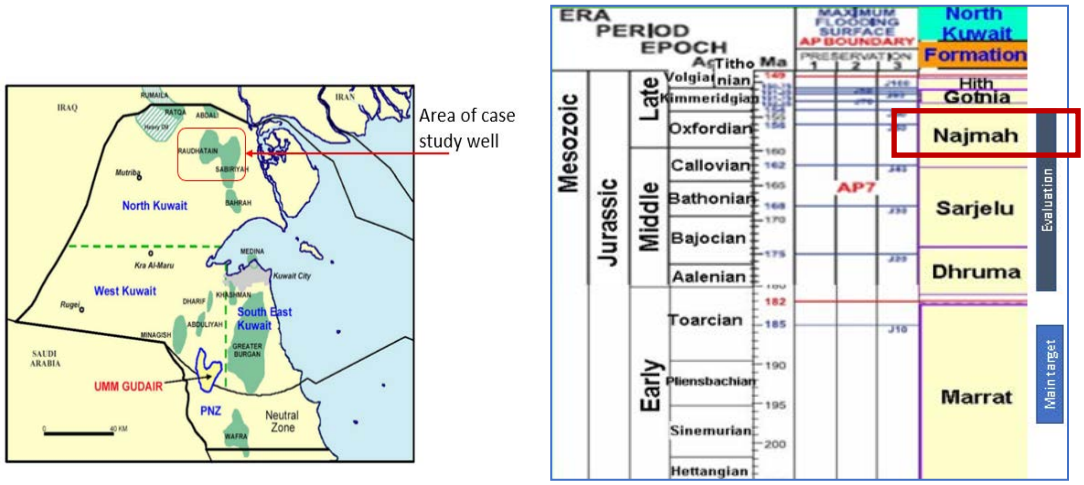

Fig-1. Well location and geological stratigraphy

The upper Najmah Limestone has thickness ranging from 30 to 40 ft true vertical depth (TVD) and is divided into five flow units. The zone interest thickness is approx. 10-ft TVD; however, the productive fracture zones are located in a 2- ft TVD window.

Najmah formation contains a mixture of limestone and has highly organic rich argillaceous and calcareous clay as explain at paper by Mihira N. Acharya et.all, SPE 2009. The presence of the fractures is one of important factor is being studied on the characterization field study especially on the determination of the productivity at this formation. The strategy to develop the field to increase the gas production was to drill horizontal well in Najmah Limestone to intersect as much as possible of the fractures presence.

The well-A plan to be drilled to NNW direction at the crestal part of the structure (Fig-2)

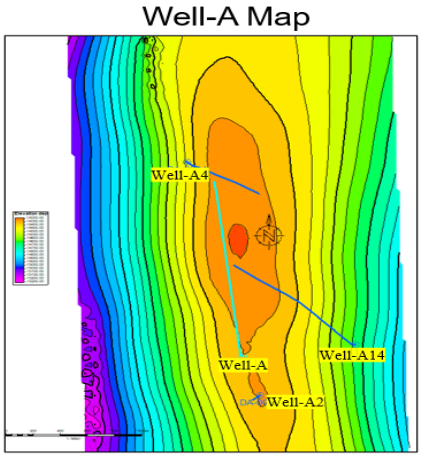

Fig-2. Well-A structural map

Data Acquisition

The placement of the well-A initially is to target Najmah limestone unit-2 and need to drill minimum 2000 ft of lateral. The lateral section will be 6in of hole size while the landing section was drilled with 9 ¼ in. of hole size.

The LWD borehole images was run in the lading section of 9 ¼ in. hole size to investigate the fractures presence from op of Najmah limestone (unt-6) until the landing section at Najmah limestone unit-2. The Ultra deep reservoir mapping also run at the landing section to understand the "big picture" of the structure geometry and follow in the lateral section for the geosteering of the well.

The acquisition of the borehole images done together with the LWD porosity tool, sonic tool in one single run. The bottom hole assembly can be seen as below:

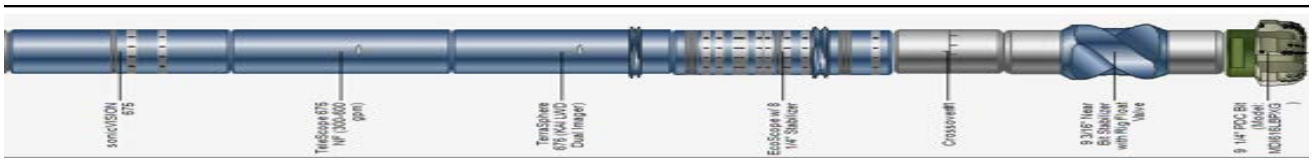

Fig-3. Bottom Hole Assembly for the Data Acquisition

The well profile of the well-A can be seen on Fig-4 below

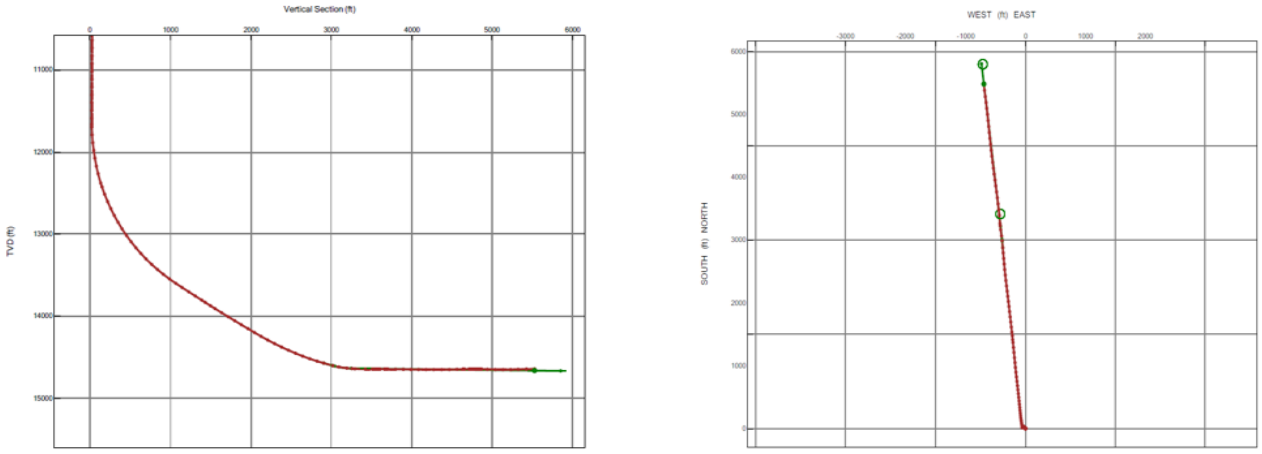

Fig-4. Well-A profile (Vertical Section and Plan View)

Result

The well was landed at top Najmah limestone unit-2 as per planned and it position was 1 ft TVD from top Najmah limestone unit-02. During the course of the landing in realtime, Ultra Deep Reservoir Mapping was mapped the structural geometry from the most top Najmah limestone until the high resistive marker as the top of Najmah limestone unit-2. Given the overall big structural dip information from Ultra Deep Reservoir Mapping enable the drilling process to navigate the well pro-actively and minimizing the hole tortuosity because of required of short distance of landing section in order to maximize the length on lateral section.

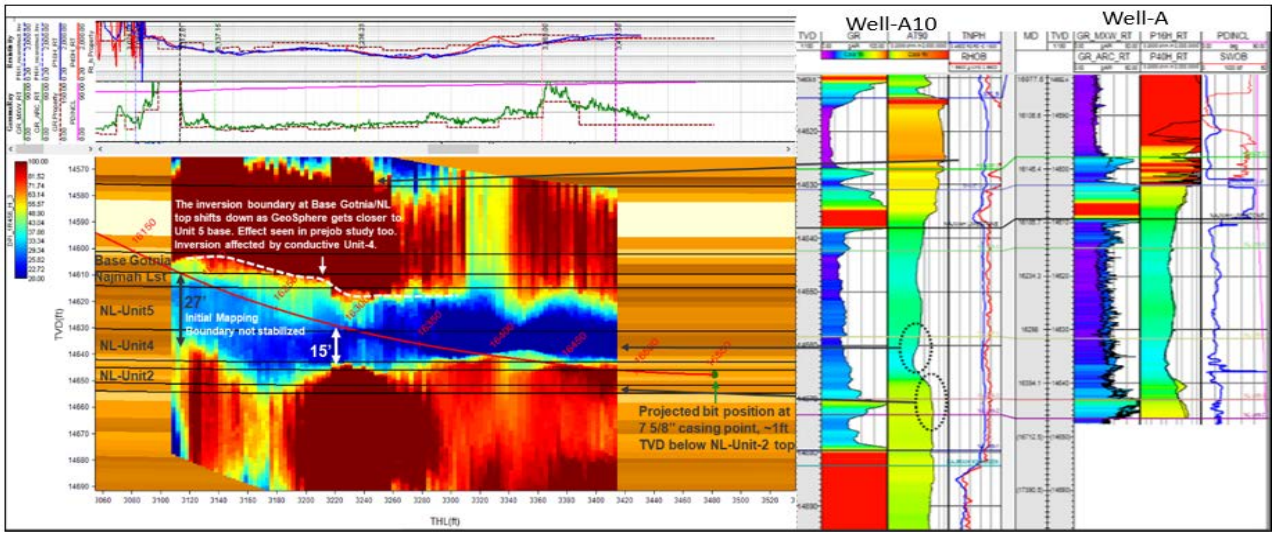

Fig-5. Well-A landing section at the top Najmah limestone unit-2

The borehole images and other formation evaluation such as porosity tool, sonic tool were acquired and shows the matrix porosity is low with average 3 pu. The elemental capture spectroscopy from LWD multifunction tool revealed of dominant limestone rock with some traces clay (Fig-6).

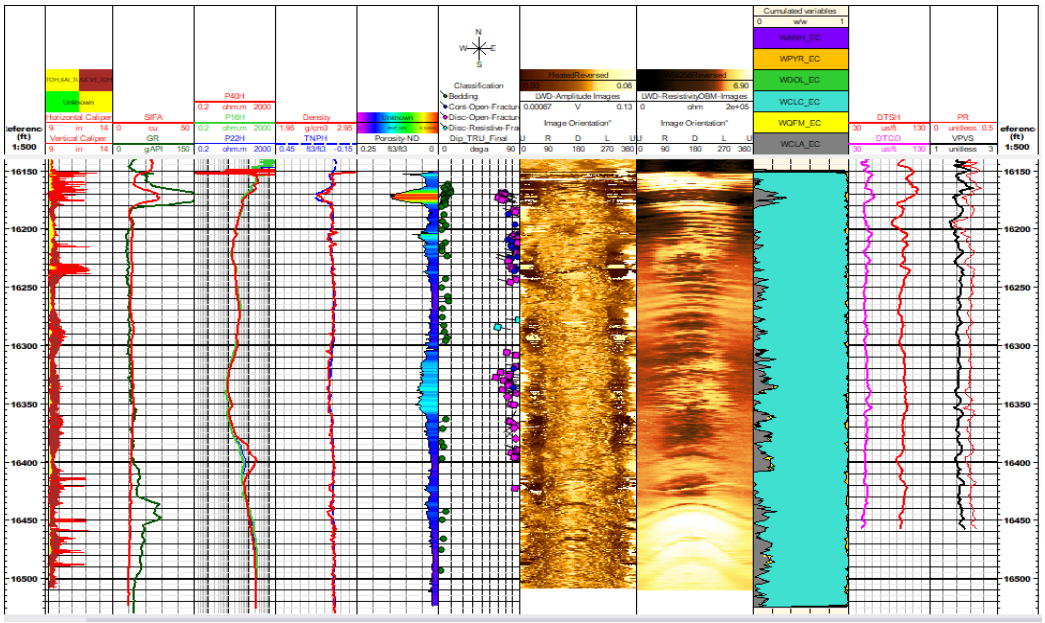

Fig-6. Well-A composite formation evaluation log

Fractures was observed from the LWD dual images can be clustered in 3 zone intervals from Najmah limestone unit-6, Najmah Limestone unit-5 and Najmah limestone unit-4 (Fig-7).

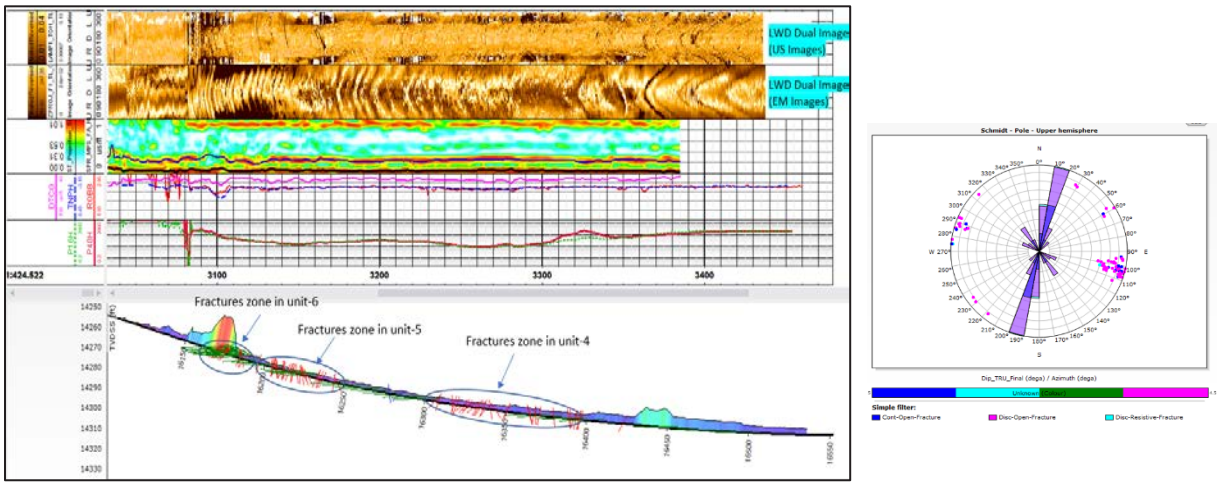

Fig-7. Well-A bed dipping and fractures picked from the LWD dual images

The fractures identified form the images was revealed to have strike direction to SSW – NNE. The fractures were classified into three type fractures based on its continuity and the possible open fractures The classification fractures consist of discontinue open fractures, continuous open-fractures and discontinuous resistive fractures. The identified presence of the fractures from ultrasonic based images while at same time also identified as conductive fractures from electromagnetic resistive based images is an indication open fracture. The presence of mud losses during drilling also other information being used to classify open fractures.

The structural bedding from the dip picked at the LWD dual imager indicates structural bedding direction to the W-SW direction with average 4 deg dipping. The layer bedding projected to the well trajectory direction on NNW revealed relatively flat bedding. This information of the apparent flat

structural bedding projected to well direction had been revealed by Ultra Deep Reservoir Mapping as can be seen on fig-5 with more detail information. The 3- 4deg of formation true dip toward to west direction was revealed from real time 3D mapping of Ultra Deep Reservoir Mapping.

The combination of the near well bore information from borehole images with the deeper images from Ultra Deep Reservoir Mapping enhanced the geosteering decision in real time at the landing section and same time increasing the accuracy of the structural geometry to the subsequent lateral section.

The well was positioned in Unit-2 with approximately 1 to 2 ft TVD below the Unit-2 top and farther steered up to Unit-4. The decision to steer in upward direction to penetrate Unit-4 from Unit-2 in the was driven by the fact that Unit-4 had enhanced fracture presence indicated from the LWD dual imager acquired in the landing section. The real time gas log in 6-in section of Well-A showed the highest total gas in Unit-4, while the resistivity showed lower values (Fig-8). This collected information increase the confident Najmah Limestone unit-4 has better produce-ability than the Unit-2 layer. Hence the all subsequent next well will be developed in the Unit-4.

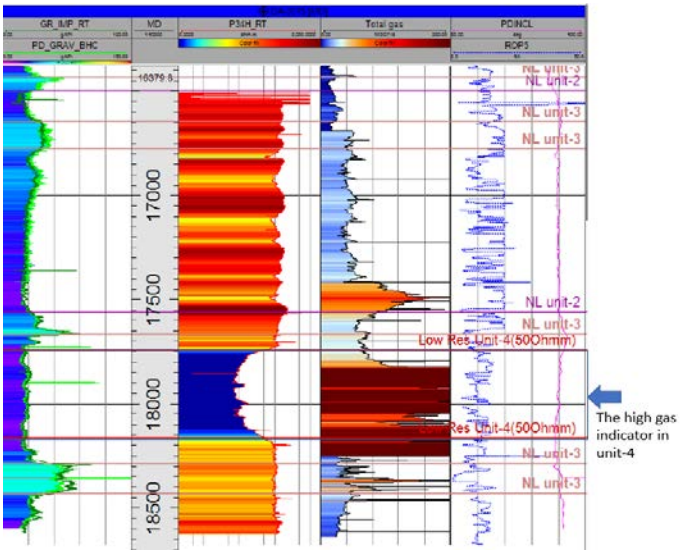

Fig-8. Real time Gamma Ray -Resistivity and Total Gas show from well-A mud log of 6-in drain section. It shows the highest gas flow presence when penetrating the Unit-4 layer

Using the refined 2D grids from the geosteering with Ultra Deep Reservoir Mapping and LWD dual images, 3D structural grids were generated along the well profile. The update structural grids were extended from the well trajectory up to the nearby offset wells.