ID: 142

VISUALIZING GOGD IN A NATURALLY FRACTURED CARBONATE RESERVOIR IN THE SULTANATE OF OMAN USING STATIC MODELING METHODS

Sharif Al Bahri

Petroleum Development Oman LLC, Muscat, The Sultanate of Oman

ABSTRACT

Effective surveillance of oil rim thickness and depth is crucial for managing NFA wells and planning future development opportunities within the, Cretaceous aged, naturally fractured Natih carbonate reservoir in Fahud field.

Gas Oil Gravity Drainage (GOGD) is the primary recovery mechanism in the field and is a challenging process to spatially visualize for reservoir surveillance due to the vertical connectivity between layers through major fracture corridors.

The novel modelling workflow presented in this paper attempts to overcome this challenge and is based on the concept that production data, within a fixed time frame, can be modelled within a geo cellular grid and produce trends similar to static reservoir properties. The result of the workflow being a three dimensional representation of the GOGD system in the Fahud Field.

The model is based on a simple grid which was created with two horizons and no faults and with a defined cell thickness of 5 m. in Fahud, the vertically persistent fractures fall within two main trends, Alpine 1 and 2, and they are the main conduits for GOGD. In order to capture this vertical communication, the structure was modelled as one zone and in order to simulate undisturbed fluid contacts the grid cells were oriented flat and parallel to the horizontal plane and not parallel to structural dip.

The model input was in the form of point attribute data assigned to each currently active oil producer in Fahud at a depth and location consistent with the producing open hole. This modelling method inherently contains several assumptions and uncertainties such as well test accuracy and the position of the data point along the completed zone, however the workflow does incorporate mitigations.

The output of the model is aimed to support business decisions such as those taken during WRFM reviews and well picks. The sources of gas, water and even oil rim sweet spots may be identified and visualized in three dimensions and offers an effective data integration tool when analysed in tandem with other surveillance data sets such as pressure surveys and RST logs, at no additional cost. This method may be most effective in mature fields with dense well spacing with good vertical connectivity. Maintenance the model and keeping it evergreen may be achieved through automation when compiling the input data and importing it through a predefined workflow in Petrel.

EXTENDED ABSTRACT

Introduction

Effective surveillance of oil rim thickness and depth is crucial for managing NFA wells and planning future development opportunities within the, Cretaceous aged, naturally fractured Natih carbonate reservoir in the Fahud oil field, located in the Sultanate of Oman. Gas Oil Gravity Drainage (GOGD) is the primary recovery mechanism in the field and is a challenging process to spatially visualize for reservoir surveillance primarily due to the vertical connectivity between layers through major fracture corridors.

With regards to oil rim management in Fahud, a more conventional individual layer based approach has up until recently been utilised for reservoir management and development which assumes a uniform rim based on a limited number of observation well results.
In reality the GOGD system creates local variations in rim thickness due to varying levels of offtake across the field along with other factors such as water injection/disposal and gas injection.

The novel modelling workflow presented in this paper attempts to better capture this variation which would in turn allow for better decision making. The method is based on the premise that production data such as water cut and Gas Oil Ratio (GOR), within a fixed time frame, can be modelled within a geo cellular grid and produce trends similar to static reservoir properties. The result of the workflow is a three dimensional representation of the GOGD system in the Fahud Field. Through the model, Sources of gas, water and even oil rim sweet spots may be identified and visualized and offers an effective data integration tool when analyzed in tandem with other surveillance data sets such as such as gradio surveys and RST logs, at no additional cost.

Method

The AOI is 16 km long by 3 km wide. A simple grid was created with two horizons modelled as a single zone with no faults, this is a simplification of the FDP model which has 8 zones. A finer cell thickness relative to the current working FDP model was used for better vertical resolution of the production trends, 5 m was eventually selected. It was decided to orient the grid cells flat and parallel to horizontal plane and not parallel to structural dip (like the current FDP model). This is because fluid contacts if undisturbed are essentially horizontal. The main input data for upscaling and subsequent property modelling was in the form of point attribute data. The field has a dense coverage of 450 active horizontal wells and the first

step was to assign a point to each active producer in at a depth and location which is consistent with each wells producing zone in the reservoir (see figure 1).
After generating the point sets, attributes were then created based on monthly well test data such as water cut and formation GOR. In the field some stable wells are tested at a frequency less than once a month and in order to incorporate these wells in the model consistently a 6 month running average was used as the modelling Input. Doing this step increased the number of data points to approximately 300 well tests creating a more robust model in terms of both point density and data point uncertainty.

The point attributes were up scaled as continuous data and petrophysicaly modelled using the Gaussian random number simulation algorithm. The lateral variograms for both minor and major orientations were left isotropic and the ranges were left large in order to ensure coverage across the structure. The vertical variogram range was increased to allow for extrapolation into the gas cap/top shallow crestal area where data is scarce.

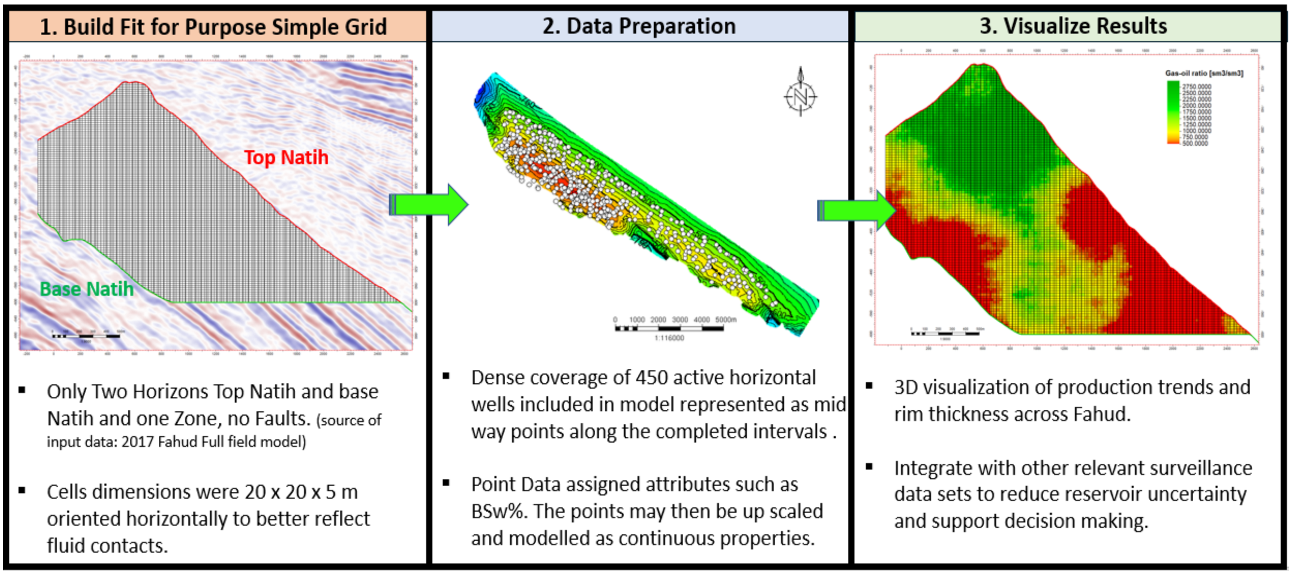
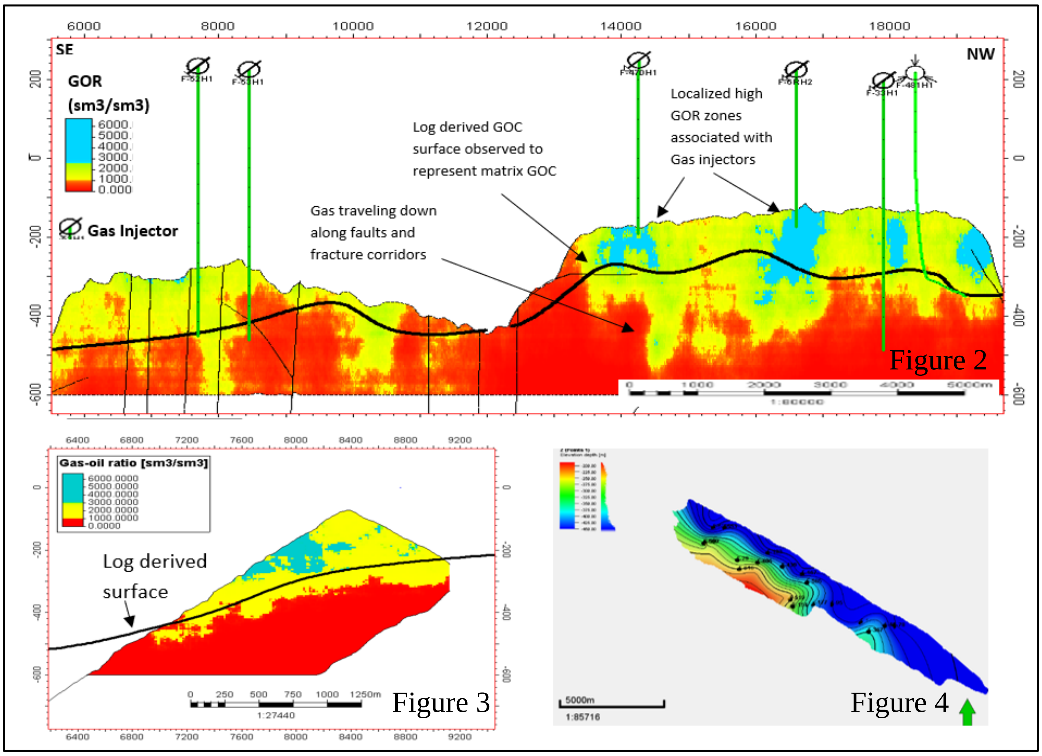


Figure 1: Summary of production modeling workflow.

The model was compared with matrix gas oil contact data derived from RST and NEU/DEN logs. The vintage of surveillance data was comparable to that of the well test data used in the model. The data was then gridded as a matrix GOC map (see figure 4). The matrix GOC does not coincide with the fracture GOC, but the two are also not completely independent, where there is gas in the matrix there will be gas in the fractures, but not the other way around, this duality is demonstrated in Figures 2&3.



Figures 2&3 cross sections parallel to both strike and dip displaying modelled GOR relative to log derived surface seen in Figure 4.

Uncertainties and Mitigations

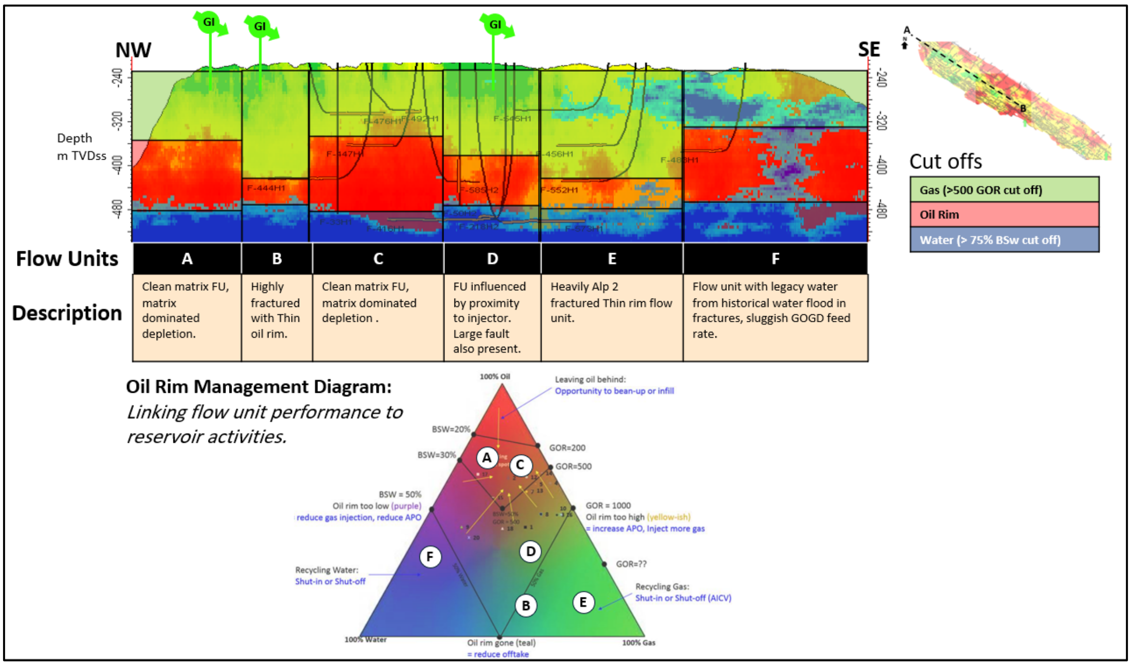
The aim of the model was to qualitatively visualize production trends which may be used as indicators of the fluid distribution. This modelling method inherently contains several assumptions and uncertainties some of which are described below.

Well test separators, as with most equipment, may produce inaccurate results. While the current well testing procedure does include a validation check done by the field programming team, at times incorrect data may be validated, which would then be incorporated into the model. Well test inaccuracy also increases in low gross wells where small fluctuations in produced fluids can result in significant changes in production ratios such as BSw and GOR on month-by-month basis. Hence using the six month running average as input for the model provided some mitigation by smoothening out small anomalies. For significantly anomalous data, features such as “bulls eyes” which are relatively straight forward to identify, and would prompt further checks and possible exclusion from the model input.
The placement of the data points may carry some inflow conformance uncertainty as it represents all the production from a given well and this point was placed midway along the completed zone. This was done for simplicity and due to the limited number of PLT logs acquired in the field which, if available, may have been used to refine the position of the

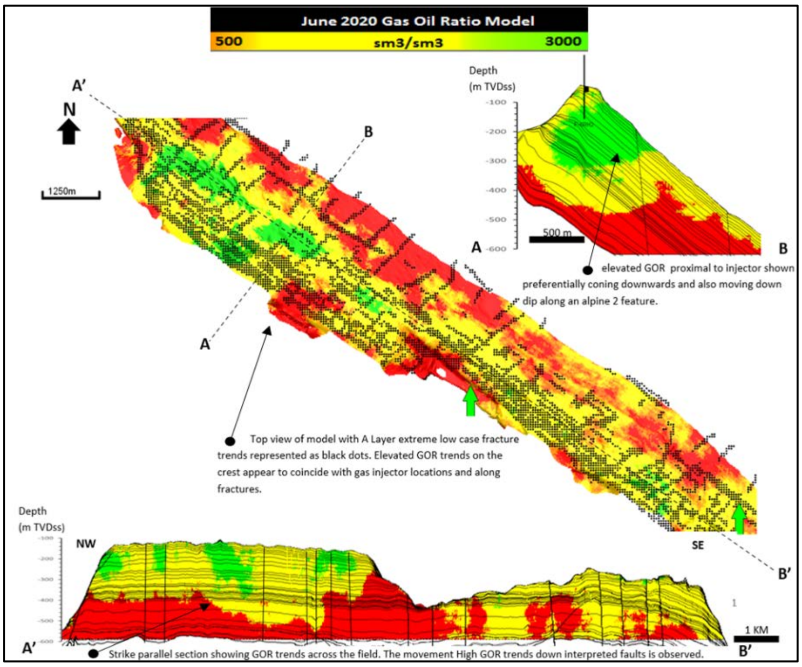
points based on the observed inflow profile. The data bias of the wells tested may also be a factor, as in reality very high water cut or GOR wells are not kept on production for extended periods, due to facilities constraints, and are thus not tested, making the model more optimistically skewed. This was overcome by including dummy points 100% BSW points at depths confident to be below OWC at -550 m TVDss (Ref 1), this was done to balance out the model histogram distribution.

Results and business impact

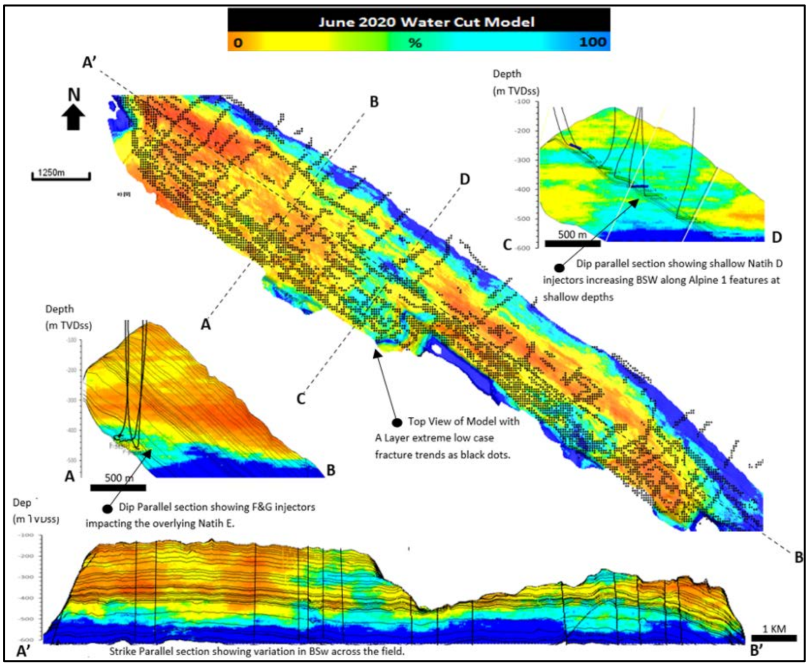
The output of the model is aimed to support business decisions such as those taken during field management reviews and well picks. Sources of gas, water and even oil rim sweet spots may be constrained which may then be checked against other data sets. The output of the model has been observed to show a good correlation with fracture trend maps of Fahud (see figures 6&7). Furthermore, cross sections may be created to visualize production models based on either recent or historical data for comparison. Trends may then be attributed to relevant reservoir features as faults, fracture corridors, proximity to injector wells, etc. Although the model itself does not include the original FDP faults or all the horizons, these can always be displayed as an overlay (as shown in figures 6&7). The model has also been used a powerful reservoir characterisation tool which can be used to better define flow units and visualize production performance to trigger remedial activities (see figure 5).



Figures 5 Composite figure showing how the model may be utilized for reservoir description and characterization.



Figures 6 Showing several sections and views of the GOR model visualizing key reservoir behavior. Fracture overlay displayed as black dots (Ref 5).



Figures 7 Showing several sections and views of the BSw model visualizing key reservoir behavior. Fracture overlay displayed as black dots (Ref 5).

Conclusion

The output of the model is aimed to support business decisions such as those taken during WRFM reviews and well picks. Sources of gas, water and even oil rim sweet spots may be identified and visualized in three dimensions and offers an effective data integration tool when analysed in tandem with other surveillance data sets such as such as pressure surveys and RST logs, at no additional cost. This method may be most effective in mature fields with dense well spacing with good vertical connectivity. The model shows a good correlation when compared to other data sets such as fracture trends and well logs.
Maintenance the model and keeping it evergreen may be achieved through automation when compiling the input data and importing it through a predefined workflow in Petrel.

Bibliography

1) Fahud Study Team, "Fahud Natih E GOGD Field Development Plan," Petroleum Development Oman, Muscat, March 2010.

2) S. Al Bahri and W. Al Subhi, "Fahud E Layer Re Drill New Opportunities," Petroleum Development Oman, Muscat, Sep 2020.

3) C. Griborio, "Gas Injection Redistribution for Fahud field," Petroleum Development Oman, Muscat, Apr 2019.

4) L. Bazalgette, S. al Farsi and S. al Shuaili, "Integrated fracture characterisation and modelling for the Natih reservoirs in Fahud field," Petroleum Development Oman, Muscat, Aug 2016.

5) PDO Field Development Centre, "Fahud Fracture Characterisation Study 2021," Petroleum Development Oman, Muscat, June 2021.