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Evaluating Cross-flow in Commingled Completions through Integration of Production Logging (PL) and Formation Pressure Data: Case Studies from Western Offshore

Abstract:

Development of multi-layered reservoirs in brown fields is challenging as it involves assessment of layer-wise hydrocarbon saturation through petro-physical evaluation as well as assessment of pressure depletion of each individual layer of the reservoir. The commingled completion strategy in such reservoirs should be carefully devised so as to avoid cross-flow between the layers. A comprehensive understanding of layer-wise Formation Pressure in the area is essential for designing an effective commingled completion in multi-layered reservoir. Ignoring the differential layer depletion can lead to cross-flow during production. The present paper deals with case studies of two wells which were completed in multiple layers of different pressures. Production logging results in these wells have shown cross-flow between the different layers.

Introduction:

Formation pressure measurements provide vital information about the flow potential of sub-surface reservoirs both in exploratory and development areas. In brown fields, the pressure data helps in evaluating the layer-wise depletion of multi-layered reservoirs. The following case studies of two wells (ABC-5 and XYZ-9) of western offshore highlight the importance of incorporating the pressure data in completion decisions.

Case Study-I (Well ABC-5):

ABC is a giant oil field in Western Offshore of India. The main reservoir in the field is a multi-layered carbonate consisting of 12 layers separated by thin shales. The field was put on production in 1976 and the initial reservoir pressure was 2230 psi at 1315 mts tvdss. Most of the wells in the field are on commingled completion in these layers. The various layers are differentially depleted and in some parts of the field, some of these layers are at low pressure, as low as 1100 psi.

The present study is concentrated in the north-eastern part of the field. Figure-1 shows the pressure data of different layers recorded in the wells drilled in the area from 1984 to 2014. It can be seen that in wells drilled after 2003 (ABC-3 to ABC-8), the pressure recorded in layers X2-V and X2-VII is lower compared to the overlying layers.

The well ABC-5 was drilled in the year 2012 and was completed in X2-II and X2-V, where the pressures recorded were 1775 psi and 1695 psi respectively. Subsequently in well ABC-8 drilled in 2014, the pressures of X2-II and X2-V were 1695 psi and 1491 psi respectively.

PLT was carried out in well ABC-5 in 2018. It was observed that there was significant cross-flow of liquid from X2-II layer to X2-V layer in shut-in condition (Figure-2). Marginal cross-flow was also seen in flowing condition thus confirming differential layer depletion. The decrese in cross-flow in flowing condition as compared to shut-in condition is on account of the drawdown in the well. Although both the layers are comparable in terms of petrophysical character, only the top layer (X2-II) is contributing to production.

Minimal cross flow from X2-II to X2-V in flowing condition indicates that the current formation pressure in X2-V is less than the flowing bottom-hole pressure. The bottom layer X2-V will contribute to production in this well if the drawdown against the perforated layers can be increased. However it is

necessary to provide pressure support to the low pressure layers X2-V and X2-VII in this area for better reservoir health.

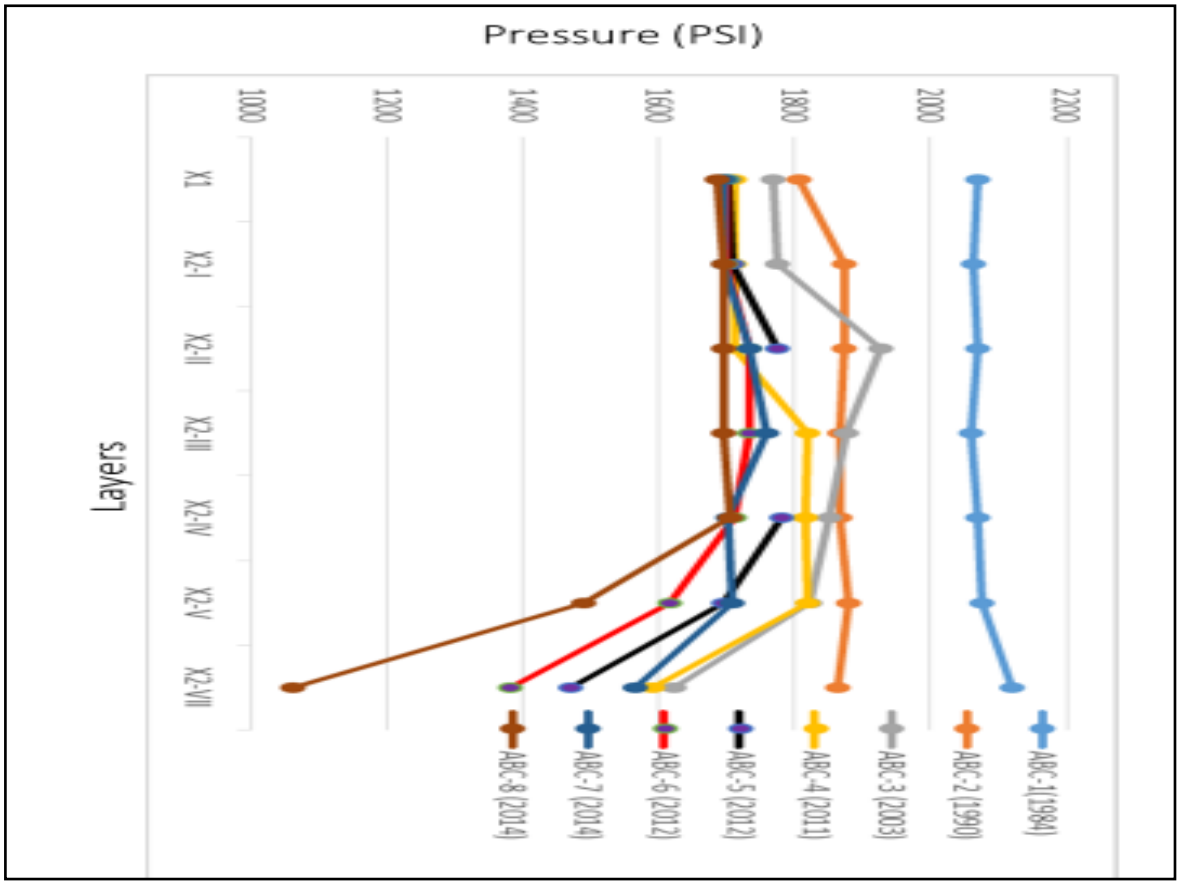

Figure-1:Pressure data in different wells show higher pressure depletion in Layers X2-V & X2-VII

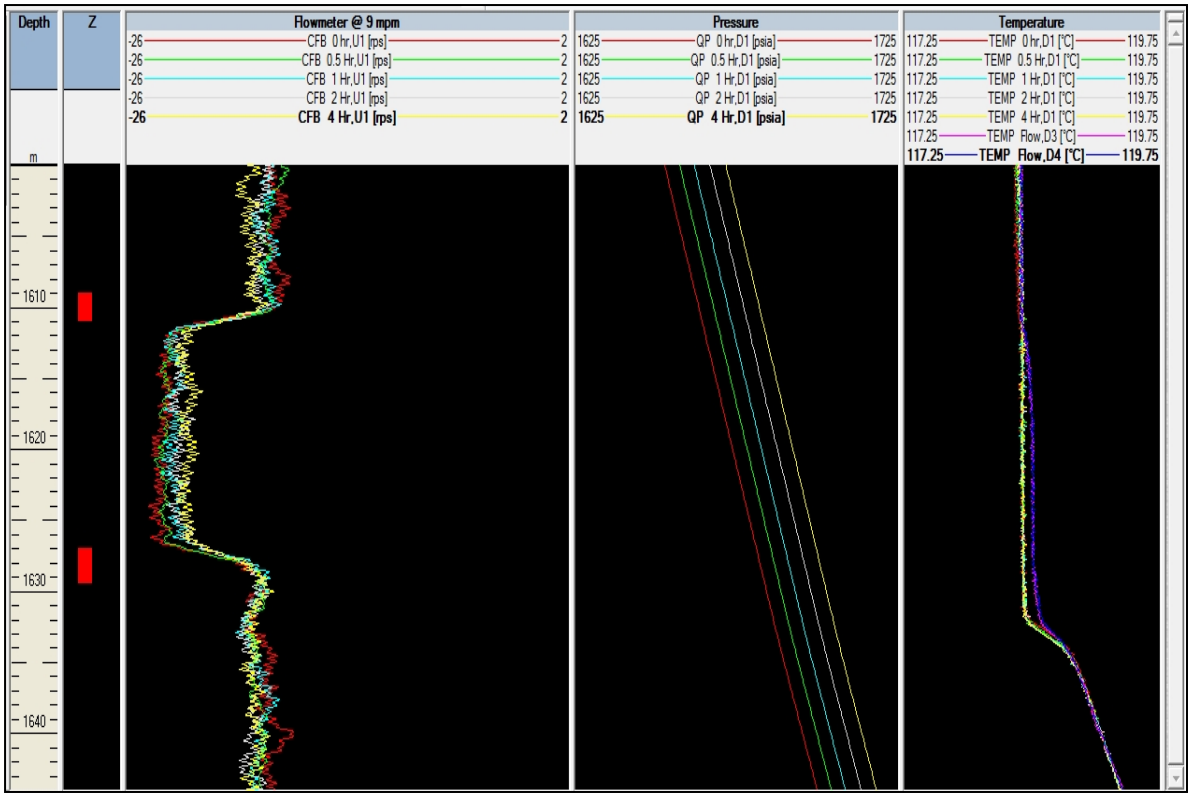

Figure-2: Production Logs in Well ABC-5 show cross-flow between X2-II and X2-VII

Case Study-II (Well XYZ-9):

XYZ is an offshore oil field in the in western continental shelf margin of India. It has multi-layered carbonate reservoirs of Lower Miocene and Upper Oligocene age. There are three producing pays in this field – Upper Pay, Middle Pay and Lower Pay; The Upper and Middle pays belong to the Ratnagiri Formation of Lower Miocene age while the Lower Pay belongs to the Panvel Formation of Upper Oligocene age. The oil produced in this field has a low bubble point pressure. The wells in this field have been competed on commingled production from multiple layers and were initially flowing on self. Of late, these wells have been put on ESP for increasing the production. Since most of these wells are completed in multiple layers, periodic production logging surveys are carried out to evaluate the health of the reservoirs.

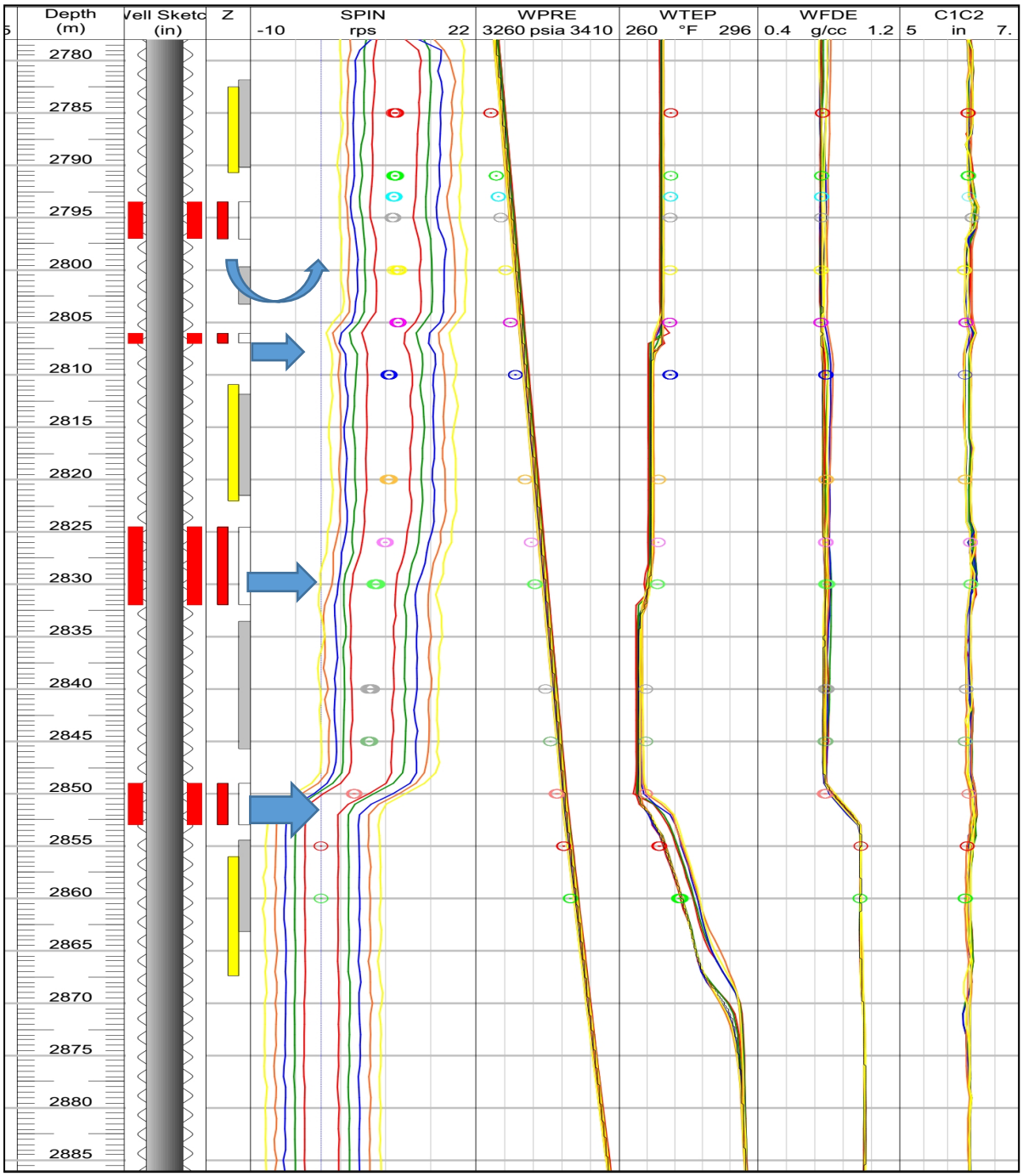

Figure 3: Production Logs in well XYZ-9 show cross-flow into the top perforation

The well XYZ#9 was completed in four intervals of LP-V pay with ESP and put on production on 2nd October 2015.The well has a deviation of 21 Deg, and was completed in 7" liner in four intervals - 2793.5 – 2797.0m, 2806.0 – 2807.0m, 2824.5 – 2832.0m, 2849.0 – 2853.0m. The production rate of the well declined from 2316 to 892 bopd within one year. From the behavior of the well, malfunctioning of ESP was suspected. Production Logging was done in the well with two bean sizes and in both the ½" and 1" bean flowing passes considerable cross flow was observed form the bottom perforated intervals into the top most perforated interval (Figure-4). The cross flow resulted in production loss to the tune of 150 bopd with 1/2"choke, which increased to 350 bopd with 1"choke.

Formation pressure data was acquired in LP-V layer of Panvel formation in this well during open-hole logging. Formation pressure recorded at 2796 mts was 2268 psi, whereas the pressure recorded at other depths in LP-V at 2806.5 mts, 2825 mts, 2829 mts, 2831.5 mts and 2851 mts were in the range of 3800 to 3900 psi. Thus clearly, there is differential depletion within LP-V in this area. However, this fact was ignored at the time of completion of this well. The top perforated interval is at 2268 psi, whereas the bottom three intervals at 3800 to 3900 psi. When zones of such high differential pressure are completed together, cross-flow is expected from higher pressure layer to lower pressure layer. The same was seen in the PL results.

The computed cumulative flow rates from LP-V with ½" and 1" choke sizes was plotted along the X-axis and corresponding flowing pressure was plotted along Y-axis. The productivity Index (PI) computed from selective inflow performance was 11.1 barrels/day/psi. This figure indicated an excellent flow potential of LP-V, which paved the way for increasing the flow rate by higher drawdown. After re-completion on ESP with appropriate frequency based on the Productivity Index, the well has been consistently flowing around 5000 bopd oil with 10% water cut.

Conclusions:

In the above two examples, cross-flow was observed between perforated layers in which there is significant difference in formation pressures. Hence it is important to consider the formation pressures of individual layers in deciding the completion policy and perforation intervals. Commingled completion in layers with large pressure difference can lead to cross flow and loss of production.

References:

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