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Formation Testers Minimize Uncertainty in a Marginal Field with a Thin Oil Rim: Case Study from Western Offshore India

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Abstract:

After giant oilfields in western offshore India reaching tertiary development stage, there is major stress on development of small marginal fields. There are multiple small hydrocarbon pools flanking the giant Bassein field. These wells have been drilled to primarily target the Eocene Bassein and Oligocene Mukta limestone reservoirs, which have been long producing hydrocarbons in commercial quantities from the main structure. These untapped reservoirs are widely different from the known field. They are typically characterized by a very thin oil rim between a gas cap and an aquifer in a very low mobility setting. The need to exploit oil here typically necessitates drilling horizontal wells, to be able to maximize surface area running the length of the oil zone. Identifying the landing depth is a critical decision for these horizontal wells. Optimal landing of the well in the oil rim greatly influences the volume of oil that can be recovered before water or gas breakthrough. Pre-completion characterization of the movable fluid in these transition zones is imperative for most favorable landing of the lateral.

Fluid identification from even most advanced petrophysical measurements is a big challenge here due to various mineralogical effects. Typically, pore pressures measurement using wireline formation testers have been used indicate fluid gradients, and corresponding fluid contacts. But owing to relatively tighter facies and the oil being restricted to a very thin band, the uncertainty in the gradients and associated fluid contacts is very high.

In this paper various case studies will be presented, where a workflow integrating gradient analysis and extensive sampling was executed for successful downhole fluid typing in minimum possible rig time. This greatly aided in successful layer identification for placement of drain holes, leading to optimal exploitation of reserves, finally adding value to the proposed viability of the marginal field.

Introduction

Marginal fields are those fields/ discoveries for which the economies of development are marginal. Such fields typically require minimal investment, quick recovery to remain viable. Exploitation of these fields is significantly affected by complexity of structures and produced fluid types. One such marginal field cluster off the western coast of India is the B-193 cluster of fields.(Fig 1(a)) These fields close to Bassein gas field have considerable oil locked up in a very thin rim with a major gas cap. The development has been planned in two phases where in the first phase, the oil fields are planned to be developed, followed by the gas fields in the later stage. (Rajiv Nischal, Sudhir Vasudeva, et al 2012)

To exploit the thin oil rim effectively, the wells have been considered as high angle or horizontal in order to achieve more drainage area and enhance productivity. However, the need to place a lateral in thin oil rim overlain by a gas cap and underlain by formation water, brings along its own set of challenges. Optimal placement of lateral in the oil rim becomes critical to avoid problems such as early water or gas breakthrough in the wellbore. For this purpose, extensive and accurate fluid type and contacts determination throughout the well section bears critical importance. The cluster field lithology is primarily carbonates, which renders traditional fluid type and saturation determination techniques invalid. Matrix complexity, pore size distribution heterogeneity, pore shape and distribution, variability in formation salinity and uncertainty in true formation resistivity measurement are some of the key factors that make determination of Archie variables m and n difficult and values change rapidly throughout the reservoir, leading to gross errors in fluid saturation calculations. (Archie GE, 1952)

Gradient Analysis using valid reservoir pressures measured across the depth of the well section has been typically used in such cases to evaluate fluid density and fluid contacts from formation tester pressure surveys .Pressure profiles and fluid density gradients can provide valuable information for reservoir evaluation and management. Numerous regression schemes and models are available for pressure gradient analysis such as ordinary least squares, robust estimation, least square errors on pressure and depth, and polynomial methods. The pressure gradient can be interpreted in terms of formation fluid density, and hence it can provide an indication of the type of fluids which are present. The intersection of two lines corresponding to different pressure gradients then represents the interface or fluid contact between different phases.

In low permeability formations, older generation tool techniques required that wireline tool be stationary for relatively long periods of time while testing the formation and rig time and tool sticking considerations have limited data gathering. A newer generation of wireline formation tester dedicated to pressure only measurement, was designed to decrease rig time, reducing sticking risk and improving pretest quality in tight formations. The pretest improvement uses a novel electromechanically controlled device that provides accurate control of the pretest flow rate down to extremely low values, enabling the pretest sequence to be tailored to the formation mobility (Fig 2). Modern wireline formation testers are equipped with quartz pressure gauges of high accuracy, resolution and repeatability (RFT essentials, 1981). Gradient analysis post a quick pretest data acquisition run is a very efficient method of fluid type determination in case of thick reservoirs, where quick pretesting and mobility profiling along the wellbore, utilizing combinability with the standard openhole log can yield fluid densities and indicate possible fluid contacts in very less rig time.(Y.Manin, Jacobson 2005)

However, in reservoirs that are highly variable in terms of connectivity, permeability and fluid properties, the accuracy of gradient construction is doubtful. In formations with low permeability, mud filtrate invasion continues into the formation and supercharging occurs. Supercharging is elevation of near wellbore pressure due to wellbore fluid leak off (Phelps, Stewart et al 1984). With elevated pressures, constructing gradient using linear regression estimates can give rise to misleading results. In addition, formation thickness and fluid density are two other important factors affecting the accuracy of constructed gradient (Stewart and Ayestaran 1982) (Fig 1 (b)). Pressure gradient construction becomes trickier in case of very less viscous and highly compressible formation fluids. In such a case, downhole fluid sampling becomes a better alternative for efficient and efficient fluid identification.

Wireline formation testers have been typically associated with delivering fluid samples that were more representative than those captured on surface. However, obtaining a representative fluid sample can be a challenge as determining when the flow stream is sufficiently purged of contaminants is necessary. The flow from the reservoir streams in a conical volume toward the probe and draws contaminants from the near wellbore invasion zone as well as vertical distance along the wellbore. The outer edge of this flow stream may contain significant non reservoir fluids which may then require extended periods of time to be pumped away. One of the recent innovations in WFT design, the focussed probe for sampling provides shorter clean-up times and ensures representative fluid samples using the ‘focussed flow’ technology. This probe uses two concentric sampling areas through which pumped fluids enter the tool. The outer ring is a conduit for the more contaminated outer segment of the flow stream which is discarded to the wellbore. The inner probe draws fluids from the more representative inner section of the conical flow, which may then be diverted into the WFT sample bottles. (Fig 3)

Case Studies

Marginal cluster field satellite to mammoth Bassein field is mainly a faulted carbonate structure with varied development of different limestone layers. To tackle the known issue of thin oil rim identification for optimal landing of further lateral sections, a robust formation testing program was designed proactively; utilizing the most state of the art pretest acquisition and sampling technology. The program included the latest generation electromechanical pretest tool combined with openhole log run for quick formation pressure acquisition profiling, supplemented with practical pumping near transition zones at the sweet spots to eliminate ambiguity in fluid contact estimation. Decision of running pretest acquisition tool for pressure and mobility profiling prior to sampling run hugely paid dividends as focussed sampling plan was optimized to target strategically most important zones. The workflow ensured high quality data acquisition in minimal possible logging time.

In well A, the conventional openhole log indicated fairly evident transition zones in the Bassein layer showing a clear oil rim overlain by a thick gas cap, underlain by formation water, with apparently clear fluid contacts. However due to mineralogical effects, the density and neutron logs showed a continuous crossover throughout the layer, making it difficult to distinguish hydrocarbon from formation water bearing zones. A quick pretest data acquisition helped to construct fairly reliable oil and gas gradients. However, the mobility data near the fluid contact region was low, leading to a fluid uncertainty zone of about 6metres to be able to determine the GOC (Fig 4). Optimal placement of the drain hole safely equidistant from gas and water zones was imperative to ensure avoiding gas or water coning in the production stage. A quick sampling run using focused inlet probe was attempted at selective stations near the fluid contact uncertainty zone, at the depths where relatively better mobility was indicated by the pretest run.

The drain hole was placed 2m shallower than originally planned, as oil was sampled shallower than the estimated regional GOC depth (Fig 5).

Well B from the same structure was drilled across Bassein and Mukta layers which were the objective targets. From the openhole log density neutron and resistivity response, a huge transition zone spanning more than 20m was evident. It was decided to go directly with an extensive sampling program owing to expected fluid uncertainty in the thick transition zone. Although very thin oil streaks were observed on the downhole spectrometer till the bottom of the section, the empirically calculated equivalent water salinity from resistivity readings helped distinguish between water based mud filtrate and formation water, clearly marking the beginning of moveable water in the transition zone. The formation water was found to be moveable 3m above the indicated drop in resistivity on the openhole log. A subsequent pretest run further confirmed the findings upon gradient construction, as shown in Fig 6. This data turned out to be a critical pre completion input for the well. The perforation interval was restricted to 3m shorter than the interval planned before the formation tester run, in order to avoid the moveable water zone. (Fig 7)

Following the success of formation testing strategy in these two wells, similar logging suite was adopted for data acquisition in 3 more wells in the same platform. Uncertainty in fluid contacts was resolved convincingly for all 3 wells, providing vital completion inputs for optimal placement of lateral in oil rim and perforation interval for maximising oil production. As of today these wells are producing oil with zero water cut and low quantities of GOR.

Conclusions

As described, precise pressure measurement using latest generation pretest tool for quick gradient analysis and mobility profiling, followed by an optimized focussed sampling program for efficient fluid identification is an efficient combination for characterizing reservoirs with thick transition zones, even in the face of ambiguous petrophysical characteristics of the formation. Successful fluid identification in such an environment provides important control points for future field development programs.

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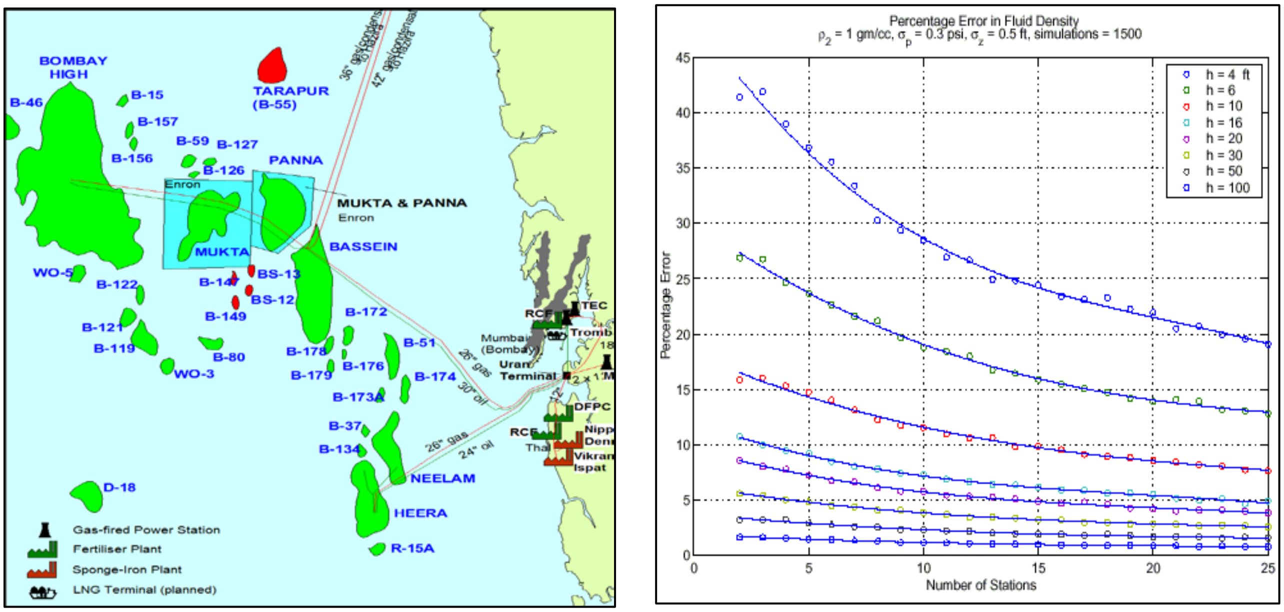

Fig1a: Left: Map showing location of giant Bassein field, off western coast of India and marginal pools surrounding the main structure. Right: Graphical Correlation Depicting Percentage Error in Gradient Computation with number of pressure points and bed thickness

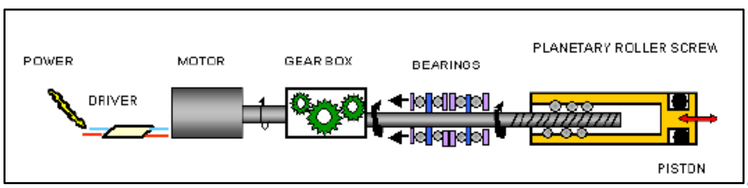

Fig 2: Latest Generation Pretest Acquisition Formation tester with Electromechanical System

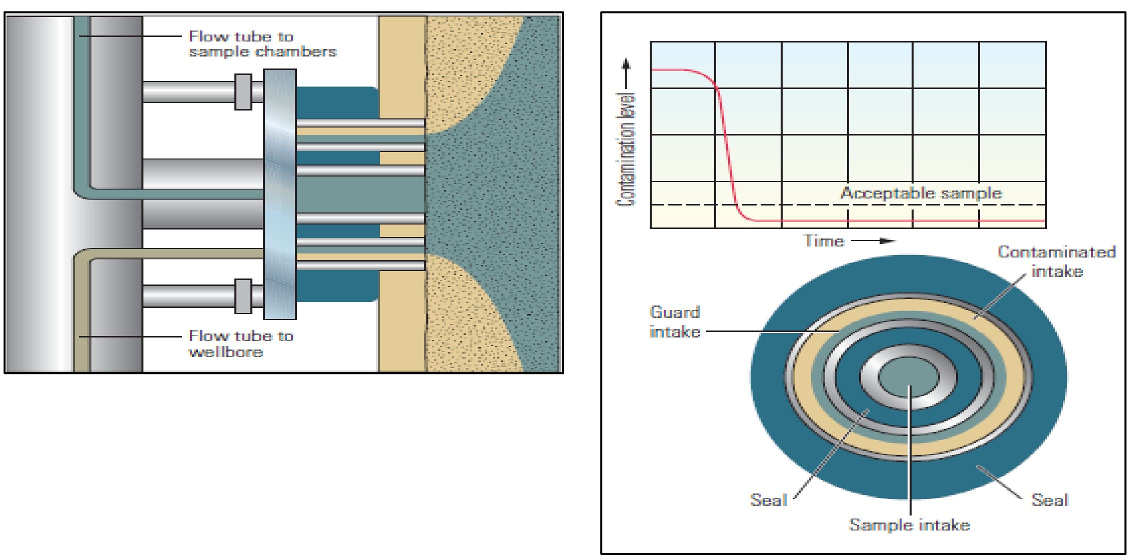

Fig 3: Formation fluid sampling with the focused sampling probe inlet tool. The probe has two intake ports, the guard intake surrounding the sample intake. Packers surround and separate these probes and seal against the borehole wall. Formation fluid is blue-gray and filtrate is light brown. When pumping begins fluid flowing through the sample intake is highly contaminated but contamination levels quickly reach acceptable value.

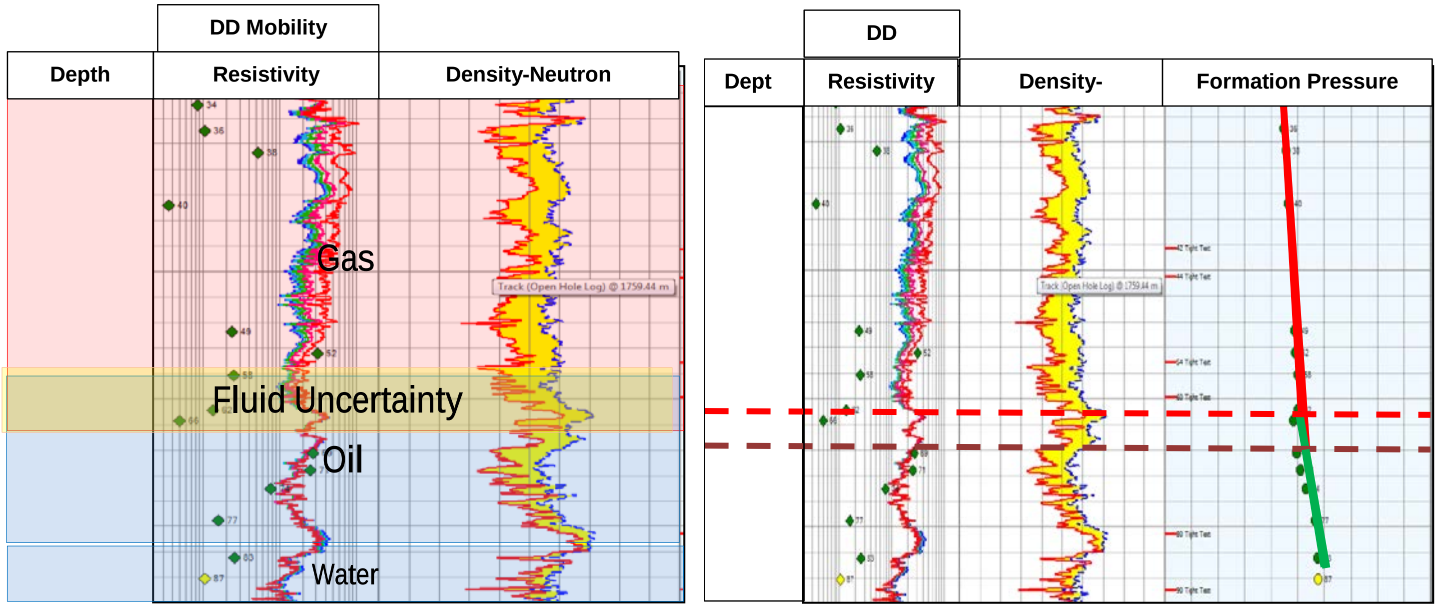

Fig 4(a): Well A: Openhole Log shows crossovers throughout the section. Resistivity hints at transition zone possibility but there is almost a 3m zone of fluid uncertainty to identify the extent of the oil rim. Fig 4(b) Gradients constructed post pretest run can lead to two possible Gas-Oil contacts. Low mobility points near the contact zones make supercharged pressures unreliable, reducing the gradient accuracy. Which of the two possible GOCs is accurate?

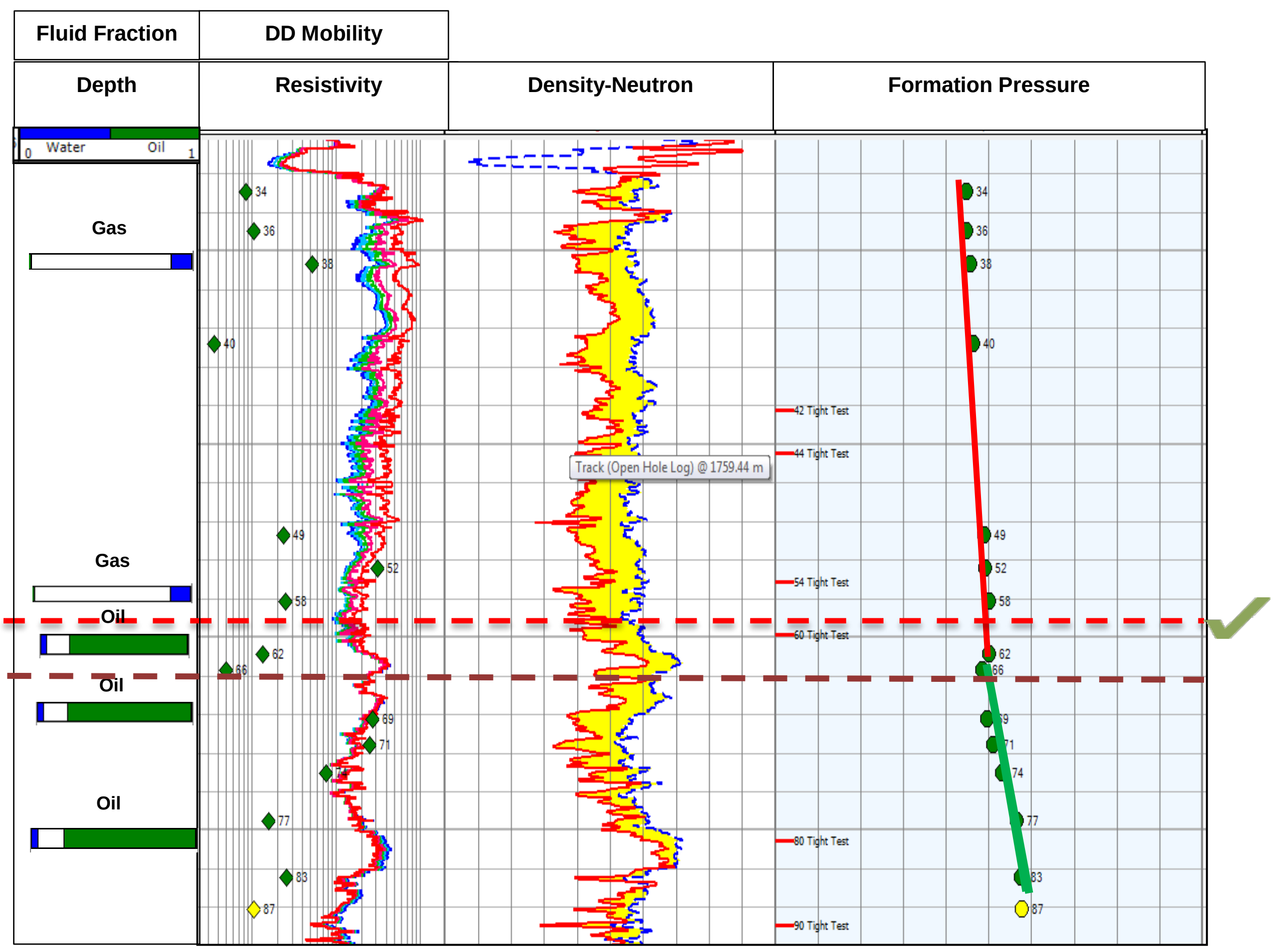

Fig5: Well A: Results post Sampling run. On the left column fluid fractions have been displayed as indicated by the downhole fluid analysis. Oil was identified and sampled beneath the first indicated GOC depth, eliminating all uncertainty in fluid type interpretation.

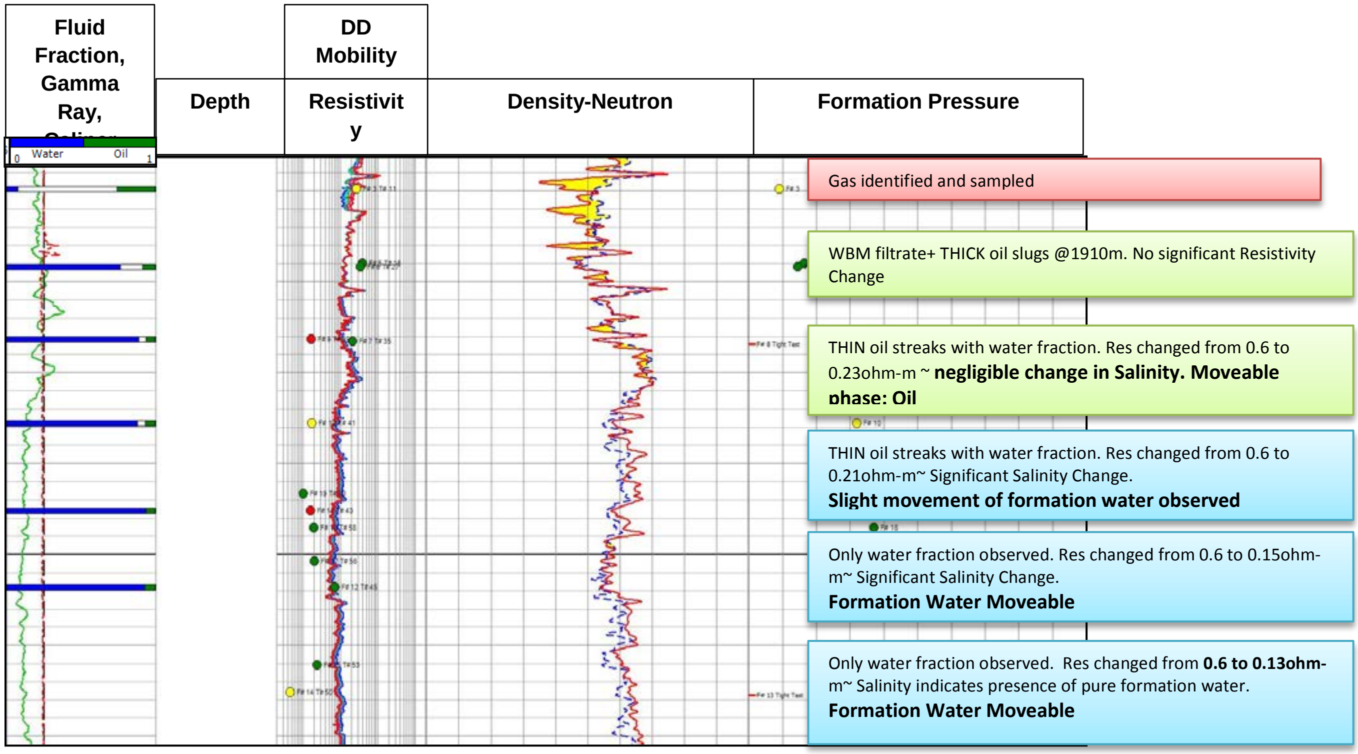

Fig 6: Well B: Significantly thick transition zone observed on the openhole log. Oil streaks were observed at most stations on the downhole fluid analyzer along with water fraction. The challenge was to determine the depth at which formation water becomes moveable. Resistivity measurement at each station clearly indicated cleanup of filtrate by formation water, eliminating all uncertainty in OWC estimation

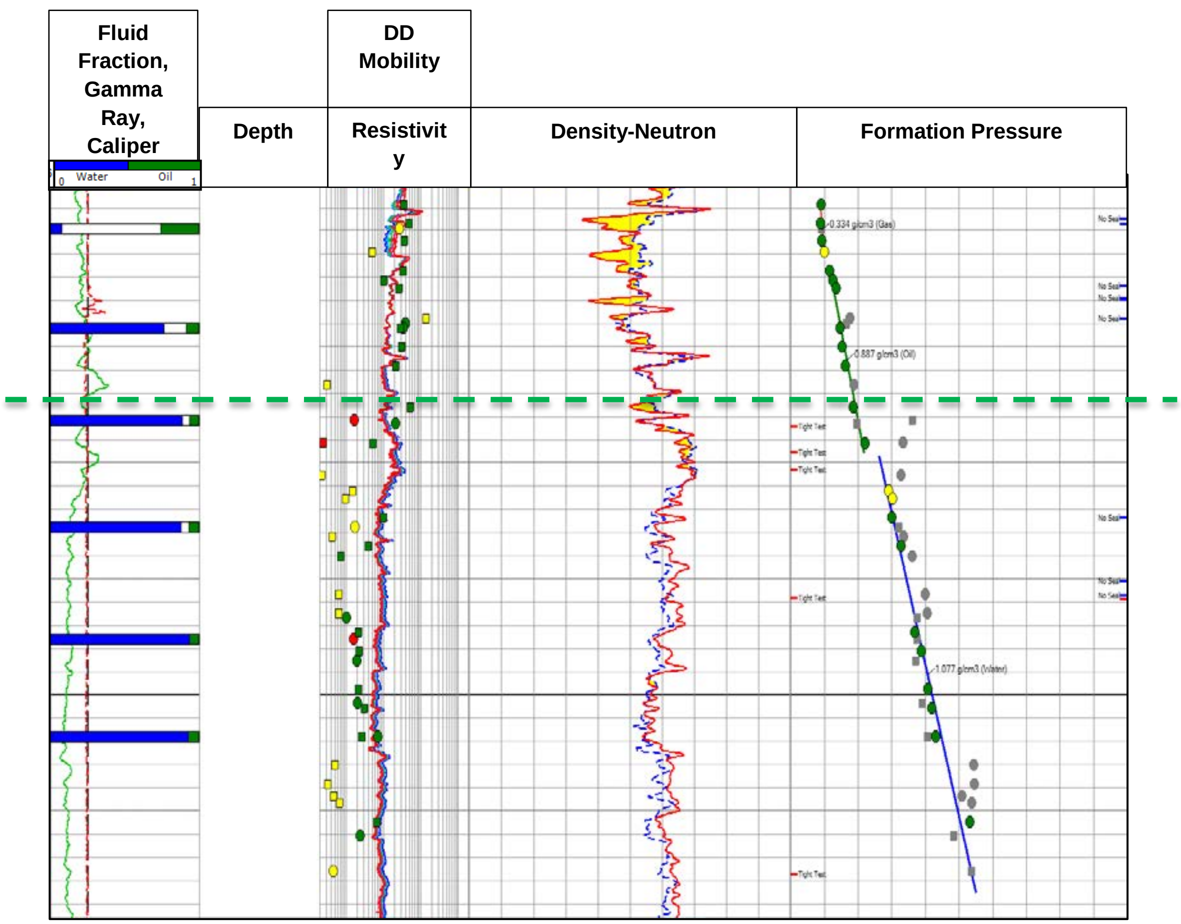

Fig 7: Well B: Further confirmation of OWC was given by the pretest only run. A conclusive water gradient against the lower zones confirmed presence of formation water shallower than indicated by resistivity log. The perforation interval which was decided based on formation testing results was restricted to upper zones where insignificant change in resistivity had been observed while pumping~ indicating mainly filtrate with moveable formation oil, also supported by a clear oil gradient.