PS A Change in Formation Evaluation Strategy to Enable Making Key Investment Decisions Faster*

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Abstract

An extensive exploration and appraisal campaign was conducted over the last four years onshore in the East African Rift System. From the numerous wells drilled and evaluated, the formation evaluation program included a wireline formation tester equipped with a standard, large faced or elongated packer to conduct the extensive pressure testing and sampling programs. In the initial phases of data acquisition, the role of fluid sampling via wireline testing was primarily to confirm the mobile fluid type leaving fluid samples for PVT analysis to be collected during flow testing of the wells.

In the later stages of the program, a change of strategy was necessary to gain wireline formation tester samples of sufficiently high purity and quality for PVT analysis. This was primarily due to there being insufficient time between drilling wells and making key investment decisions to enable well testing samples to be acquired and results fed into this process.

Through extensive experience, it has been observed that pressure profiles are not always conclusive to determine fluid unit content and contacts alone. Sampling and fluid ID pump-outs were used extensively to help determine the mobile fluid phase and hydrocarbon extent. It was also concluded that at a certain mobility cut-off, getting any sample was near impossible due to fluid viscosity and drawdown limitations. When conducting sampling, the colouration and properties of the OBM made trend evaluation and contamination determination extremely difficult. On the spectroscopy front, the optical density trends were often for the most part linear, and the GOR evaluation was difficult as the acoustic fluid response at the reservoir pressure and temperature was below that of the OBM. The density measurement followed the same linear trend, with only the viscosity and refractive index at times giving any meaningful trend to establish potential cut-off periods on the pump-out. From PVT analysis undertaken on samples acquired it was obvious that no matter how long the pump-out and how flat the sensor responses were, contamination was typically between 12-15%.

The service provider was challenged to overcome these obstacles and capture clean samples and pump-out zones with low mobility to evaluate the extent of the hydrocarbons. For three wells, a formation tester equipped with a large area concentric packer was proposed and used. On the

first well, due to the 4.5x larger flow area and split dynamics, trend evaluation and concentric flow standard patterns were established which were completely different from the standard straight-line patterns from before. The ability to flow the hydrocarbons at reasonable rates in the very low mobility units enabled the operator to prove extent of the hydrocarbon columns in the wells more accurately, which was impossible with the standard equipment. The ability of using large flow area concentric packers over standard and inflatable packers in this type of environment has been crucial in the last stage of the campaign and coupled with superb interaction with the operator and field crew delivered flawless execution exceeding the challenging objectives set out at the beginning.

A Change In Formation Evaluation Strategy To Enable Making Key Investment Decisions Faster

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Abstract

An extensive exploration and appraisal campaign was conducted over the last four years in the East Coast of Africa. From the numerous wells drilled and evaluated, the formation evaluation program included a wireline formation tester equipped with a standard, large faced or elongated packer to conduct the extensive pressure testing and sampling programs. In the initial phases of data acquisition the role of fluid sampling via wireline testing was primarily to confirm mobile fluid type leaving fluid samples for PVT analysis to be collected during flow testing of the wells.

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Through extensive experience, it has been observed that pressure profiles are not always conclusive to determine fluid unit content and contacts alone. Sampling and fluid ID pump outs were used extensively to help determine the mobile fluid phase and hydrocarbon extent. It was also concluded that at a certain mobility cut off, getting any sample was near impossible due to fluid viscosity and drawdown limitations. When conducting sampling, the colouration and properties of the OBM made trend evaluation and contamination determination extremely difficult. On the spectroscopy front, the optical density trends were often on the most part linear, and the GOR evaluation was difficult as the acoustic fluid response at the reservoir pressure and temperature was below that of the OBM. The density measurement followed the same linear trend, with only the viscosity and refractive index at times giving any meaningful trend to establish potential cut off periods on the pump – out. From PVT analysis undertaken on samples acquired it was obvious that no matter how long the pump- out and how flat the sensor responses were, contamination was typically between 12 – 15%.

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Introduction

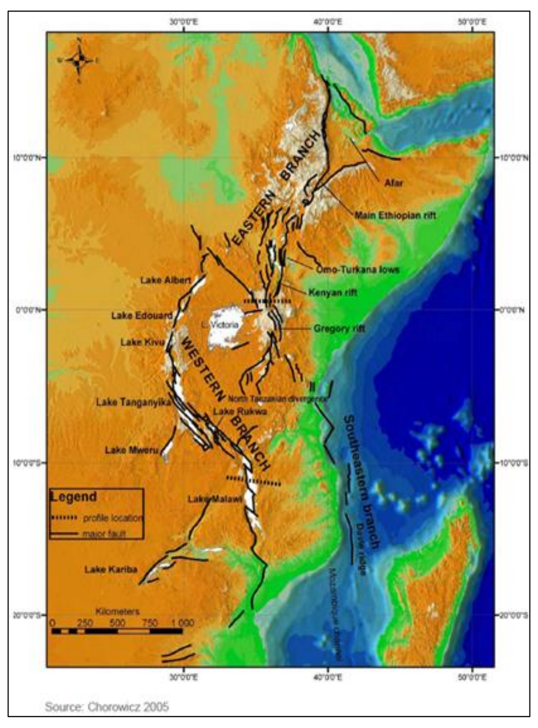
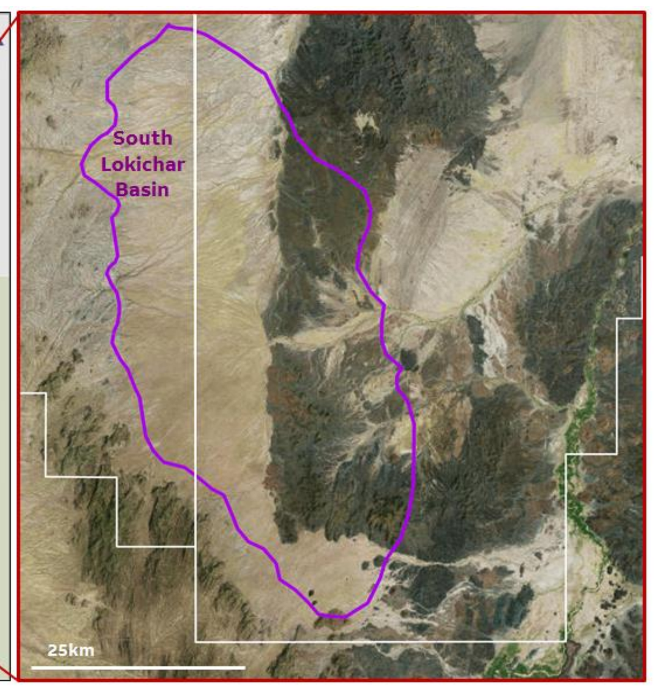


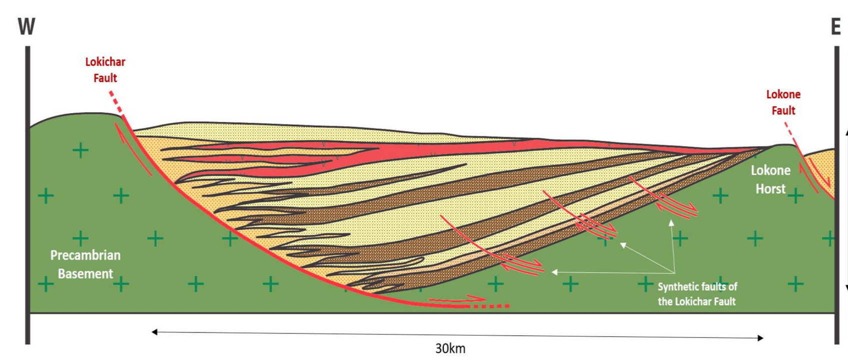
Figure 1. Eastern African Rift System map

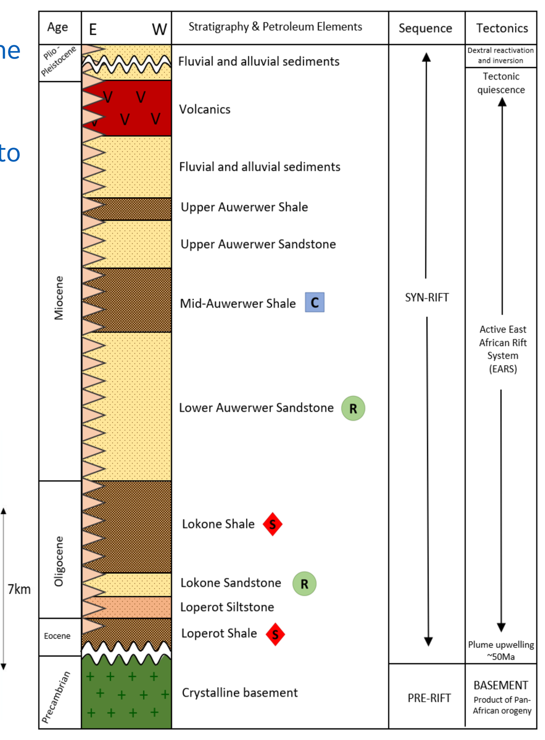
The East African Rift System (EARS) is in the order of 50–150 km wide, elongate system of normal faults that stretches some 3,500 km across Eastern Africa. It can be separated into two rift trends, the eastern and western branches (Figure 1). The eastern branch is located north and east of Lake Victoria, is a volcanic-rich system that was initiated in early Miocene and forms the Kenya and Ethiopian Rifts. The branch is dotted with relatively small lakes and Lake Turkana is the sole large lake in the eastern branch. The Kenya Rift has separate sub-basins with distinctive structure and geological setting. The western branch is associated with much less volcanism initiated late Miocene and it is composed of series of extensive deep and shallow lakes (Figure 1).



South Lockichar Basin Geology

- The South Lockichar Basin forms part of the Eastern branch of the EARS and lies to the southwest of lake Turkana.
- Deepest and oldest expression of Tertiary rifting in Turkana.
- NW-SE trending half-graben, basin-bounding fault (Lokichar Fault) to the west, flexural margin (Lokone Horst) to the east.
- 30km wide and 70km long with up to 7km basin-fill (approx.).
- Fluvio-lacustrine sediments capped by flood phonolites.



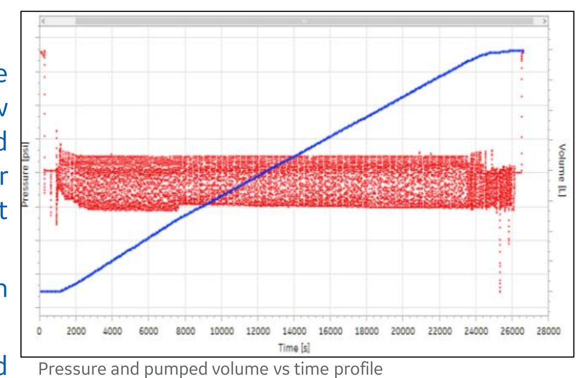


Data Acquisition (Initial stage)

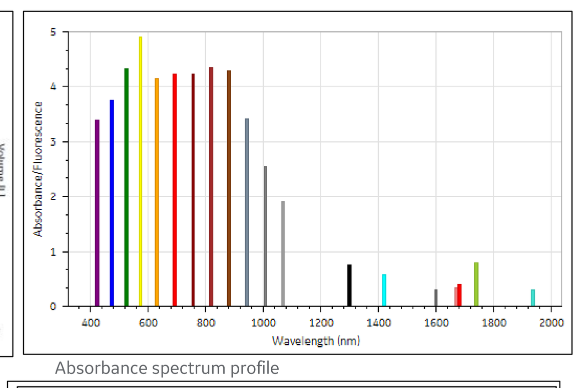
- Numerous wells drilled in this area had wireline formation tester in the formation evaluation program
- Main objective of wireline formation tester was to acquire pressure data and confirm mobile fluid by pump out and taking samples at some stations
- PVT samples were taken during flow testing
- Wireline formation tester was equipped with one of the following conventional packers:

Challenges

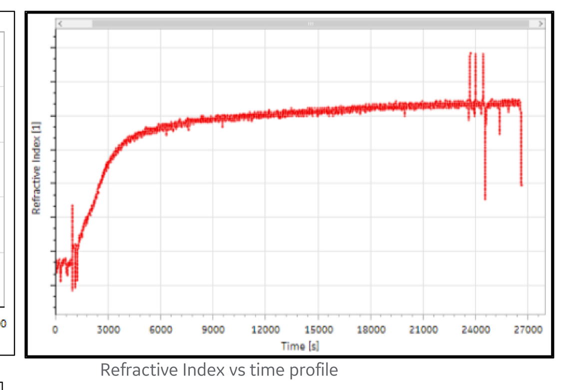
- Quite a few challenges were encountered during fluid identification and sampling in the initial stage of data acquisition. These included long-pump out, pump limitation in low mobility zones, low difference between OBM and formation oil (coloration, density and viscosity), GOR evaluation difficult as the acoustic fluid response at the reservoir pressure and temperature was below that of the OBM and waxy/high pour point formation oil (certain temperature and pressure)
- At times only viscosity and refractive index were giving meaningful trends to establish potential pump out cut off time
- The near-infrared spectroscopy was mainly used for fluid identification and contamination however at times the coloration and properties of OBM filtrate made the trend evaluation and contamination determination difficult.
- The optical density trend was often linear making it difficult to determine pump out cut-off and fluid identification. The coloration of dark hydrocarbon, the mud and filtrate was very similar



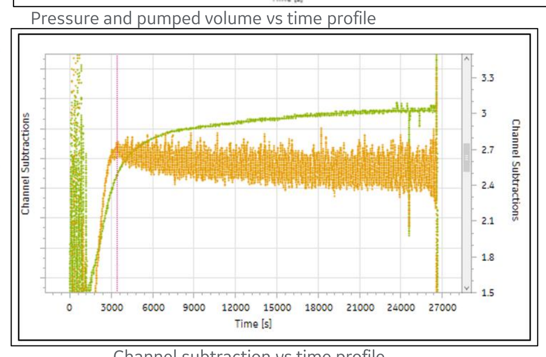
Pressure and pumped volume vs time profile



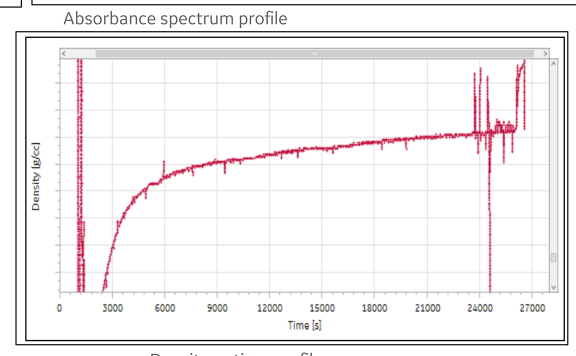
Absorbance spectrum profile



Refractive Index vs time profile



Channel subtraction vs time profile



Density vs time profile

Fluid Analyser

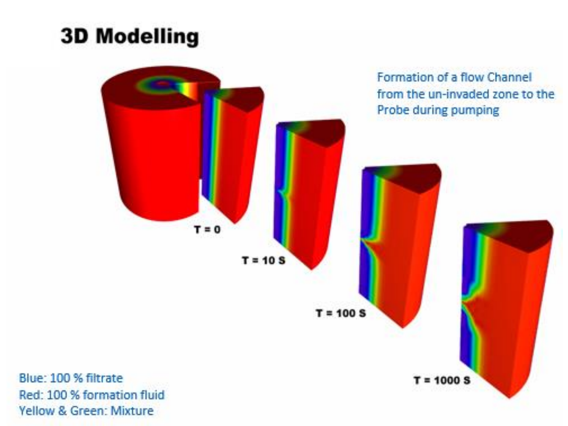
- Downhole fluid analysis module main purposes is to identify fluid, monitor contamination of the pumped fluids and measure in-situ fluid properties in real time
- In real time, fluid identification and contamination is performed using near-infrared spectroscopy, refractive index and fluorescence spectra sensors
- These sensors can distinguish mud filtrate from reservoir fluids being pumped through the tool (water, gas and liquid hydrocarbon)
- 19 channels near infrared, indicates light absorption based on colour and asphatenes concentration. These include two water channels and one hydrocarbon channel. Asphatene colour response is be used to monitor the rate of change of clean up from OBM filtrate to formation hydrocarbon
- Five-channel fluorescence spectrometer, characterize fluid based on their fluorescence spectra. Hydrocarbon with no aromatics does not fluoresce (i.e. dry gas and synthetic based muds)
- Continuous Refractive Index – refractive index is based on reduction in light intensity measurement of the reflected wave. Ideally suited for sampling water in water based mud
- The in-situ real time measurements of fluid properties and composition measurements are made based on the resonance characteristics of a vibrating turning fork measurement and an acoustic transducer sensor in contact with the fluid
    - These measurements include density, sound speed and other fluid properties
    - The sound speed along with density can be used to calculate continuous fluid compressibility and the GOR with time
    - The changes in density, viscosity and sound speed in time can be used to monitor the cleanup process

Change In Data Acquisition Strategy

- At a later stage of data acquisition, there was a change in data acquisition program. The service provider was challenged to come up with a solution to overcome the challenges
- The first step was do to sampling pre-job modelling using the available reservoir data from the pervious wells

Sampling Pre-Job Modelling

- Modeling is based on reservoir, fluid and wellbore properties (3D numerical simulator)
- The main objectives of modelling :
    - Determine the most efficient packer type for sampling
    - Simulate the contamination variation during pumping
    - Determine the most efficient pair of pumps to be used in focused sampling
- Extensive sensitivity analysis is performed to cover wide range of reservoir and fluid data.



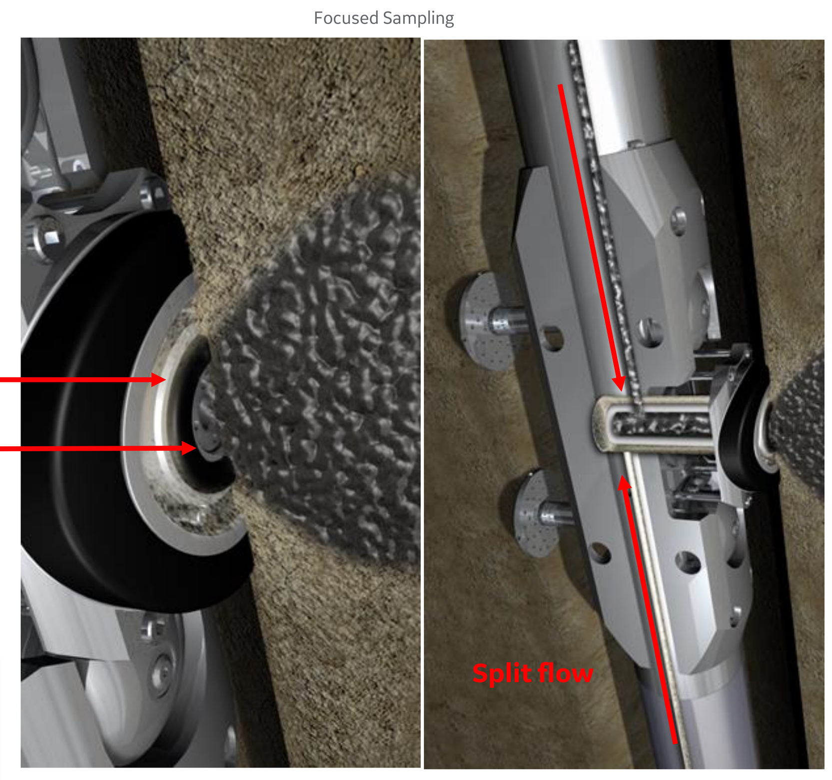
Deliverables

- Optimum DD rate
- Required pump out time to reach at certain contamination level
- Required pump out volume
- Estimated pressure drawdown during cleanup and sampling

Solution

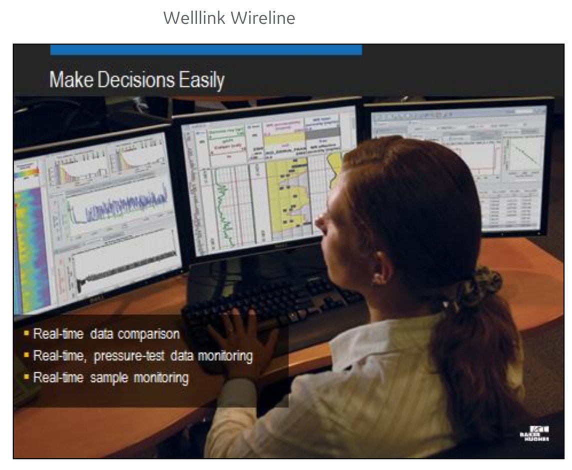
- After completing the modelling , the service provider proposed the following:
- A wireline focused sampling formation tester equipped with large inflow area concentric packer to overcome the challenges faced using the wireline formation tester equipped with standard, large faced or elongated
- Real time data viewing software Welllink Wireline .The software, also useful as a tool for interaction between operator, service provider subject matter expects and field crew
- Dedicated technical advisors in real time to assist in monitoring and making decision easily
- The wireline focused sampling service uses a concentric pad design to isolate the contaminated fluid into a perimeter inlet and allow cleaner fluid to pass to an inner flow area . Two independently controlled pumps optimize the flow rates at the sand face .This ensure that the clean-up time is minimized and we get cleaner and safer samples.

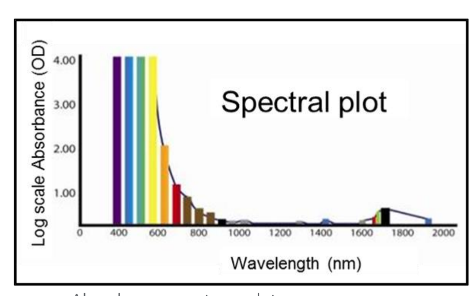
Focused Sampling



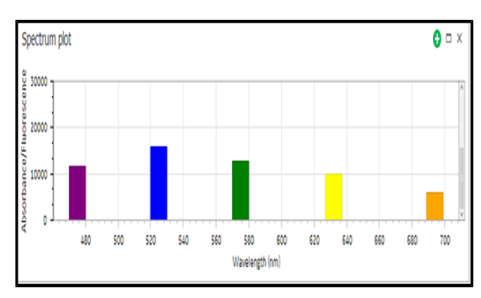
Large Inflow Area Concentric Packer

Welllink Wireline





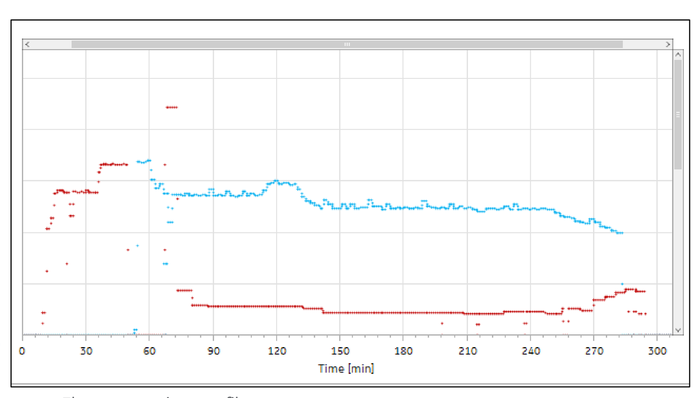
Absorbance spectrum plot



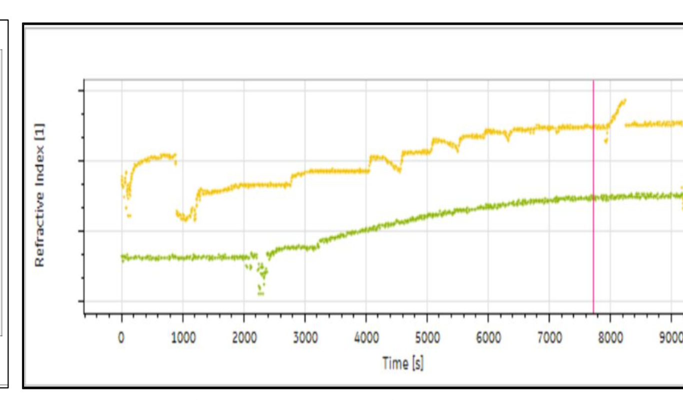
Fluorescence plot

Results and Conclusions

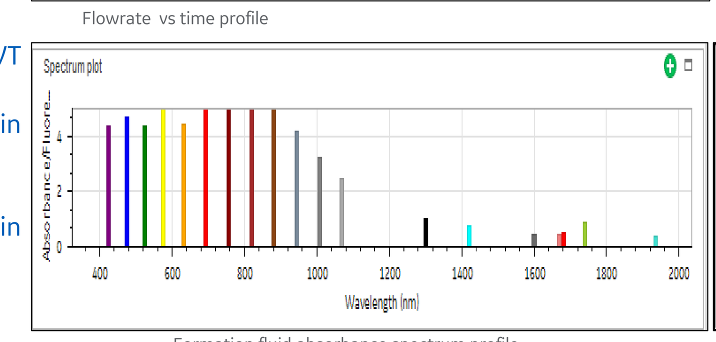
- Ability to pump out at low rates
- Fluid identification and sampling in the low mobility zones which lead to extend reserves calculations for these wells
- Clear trends could be established to determine pump out cut off during fluid identification and contamination determination
- Acquired high quality samples for PVT analysis
- PVT analysis results showed contamination as low as 2% in some zones which was never achieved when using conventional and inflatable packers.
- Technical advisors provided real time support to the operator and field crew
- Wireline focused sampling formation tester equipped with large inflow area concentric packer proved to be suitable for this type of environment:
    - The split flow dynamics help to achieve low contamination samples for PVT analysis
    - Time and money savings as operator does not have to wait for well testing to get quality sample for PVT analysis
    - Fluid identification and extend hydrocarbon estimation for low mobility zones, was near impossible in the initial stage of data acquisition
    - Investment decision could be done quicker than before
- Real time data viewing and monitoring using Welllink Wireline software overcame communication difficulties experienced in the initial stage of data acquisition



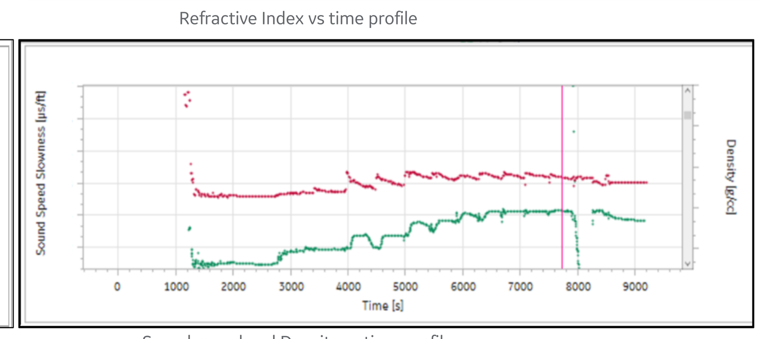
Flowrate vs time profile



Refractive Index vs time profile



Formation fluid absorbance spectrum profile



Sound speed and Density vs time profile

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