# Everything Formation Testing

**Thursday 14th December 2017**

*The Geological Society, Burlington House, London*

| | Start time | End time | Name | Company | Talk Title |
|---|---|---|---|---|---|
| | ***09:00*** | ***09:30*** | | | ***Registration*** |
| | 09:30 | 09:45 | ***Michael O'Keefe*** | ***LPS*** | ***Welcome & Introduction*** |
| *1* | 09:45 | 10:15 | **Mike Millar** | *Independent* | Formation Pressure Testers, Back to Basics: A review of the acquisition, quality control and use of formation pressures |
| *2* | 10:15 | 10:40 | **George Stewart** | *RGS Consulting* | Milestones in wireline formation testing development as seen through Field Examples |
| *3* | 10:40 | 11:05 | **John Bennett** | *Independent* | Modelling Formation Pressure Measurements: What is really possible from Pressure Tests? |
| | ***11:05*** | ***11:35*** | | | ***Break*** |
| *4* | 11:35 | 12:00 | **Lachlan Finlayson** | *Petrofac* | Draw down mobility from formation testers |
| *5* | 12:00 | 12:25 | **Shyam Ramaswami** | *Shell* | Nice buildup, but what next? Examples of how integrate discrete Formation Testing Pressure Transient data to arrive at well scale dynamic behaviour estimates |
| *6* | 12:25 | 12:50 | **Richard Jackson** | *Schlumberger* | A New Approach to Extend the Limits of Formation Transient Testing |
| | ***12:50*** | ***13:00*** | | | ***Presentation of SPWLA Gold Medal for Dick Woodhouse to his family*** |
| | ***13:00*** | ***14:00*** | | | ***Lunch*** |
| *7* | 14:00 | 14:25 | **Vladimir-Andrei Hanumolo** | *Weatherford* | Effects and solutions to improve efficiency of formation testing in thick mud cake environments |
| *8* | 14:25 | 14:50 | **Russell Gray & Tushar Patil** | *Total & Baker Hughes GE* | Doing More With Less - Unconventional |
| *9* | 14:50 | 15:15 | **Alyn Carrahar** | *Weatherford* | Wireline formation testing without the wireline |
| | ***15:15*** | ***15:45*** | | | ***Break*** |
| *10* | 15:45 | 16:10 | **Adriaan Gisolf** | *Schlumberger* | Advances in Quantification of Miscible Contamination in Hydrocarbon and Water Samples From Downhole to Surface Laboratories |
| *11* | 16:10 | 16:35 | **Gavin Sibbald** | *Baker Hughes GE* | Applications of SoundSpeed for contamination monitoring and water analysis (quantifying total dissolved salts, chlorides) |
| *12* | 16:35 | 17:00 | **Yon Blanco** | *Schlumberger* | Real-time fluid mapping-while-drilling service enhances well placement and maximizes production potential |
| | **17:00** | **17:10** | ***Michael O'Keefe*** | ***LPS*** | ***Closing Comments*** |
| ***17:10 onwards*** | | | | | ***Presidents Evening at The King's Head!*** |

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The aim of these presentations is to provide reasonable and balanced discourse on the titled subjects. Consequently it cannot consider in detail all possible scenarios likely to be encountered and caution is encouraged in apply these principles. Neither the LPS nor the authors can be held responsible for consequences arising from the application of the approaches detailed here.



## The following pages contain the Abstracts


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# Formation Pressure Testers, Back to Basics: A review of the acquisition, quality control and use of formation pressures

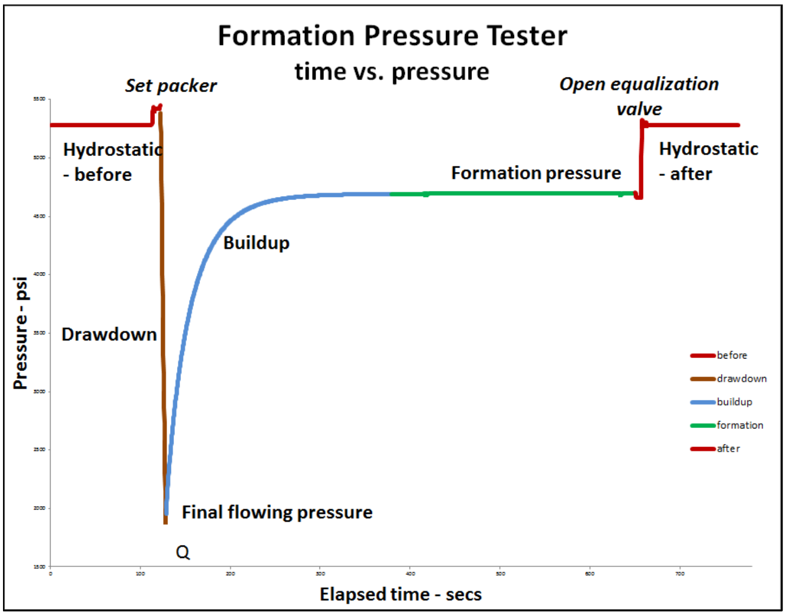

***Mike Millar, Independent***


This presentation will take a 'back to basics' look at the planning, acquisition, quality control and use of formation pressure tester data, whether logged by LWD, Wireline, or any other conveyancing method. Using real examples of good and bad data, the talk will give the tools and insight petrophysicists need to have the confidence that the formation pressure data they use is fit for purpose.

The presentation will emphasise the fundamental importance of the operating companies working closely with the service providers during the planning and acquisition of Formation Pressures to ensure that the very best quality data are acquired in a safe and cost effective manner.

Drilling a well changes the rocks and fluids that are drilled through and we will look at how pressure and temperature measurements can be affected by the drilling process. FPT tools are designed to be run in specific ways under specific conditions, and we will explore how variations from these can materially affect the reliability and accuracy of the data acquired.

Unless we know where the pressure measurements come from they have little value, so depth measurement reliability is just as important as accuracy in other log measurements, and is just as subject to uncertainty and potential error.



# Milestones in wireline formation testing development as seen through Field Examples


***George Stewart, RGS Consulting***


Anomalous Pressure Gradients and Invasion Effects

The occurrence of fluid hydrostatic gradients is the base case for pressure-depth diagrams. However there are circumstances where this is not the case, the first example being the presence of paleocontacts. Field examples from dynamic situations where the aquifer is in motion leading to tilted contacts are now well known e.g. Sunrise-Troubador in the Timur Sea. In the North Sea unproduced reservoirs show pressure changing with time due to aquifer depletion from influx into neighbouring fields. Thin-bed reservoirs (LR-LC systems) exhibit gradients greater than water hydrostatic due to over-pressuring increasing with depth e.g. Barbara NW in the Adriatic Sea. The pressure registered by a WFT survey may be different from the true fluid hydrostatic pressure due to capillary pressure shifts associated with invasion. Field examples of such effects are presented.

Mini-DSTs

The new generation WFT tools (NGWFT) with pumpout and straddle packers allow mini well tests to be carried. The depth of investigation of such tests is limited but the mini-DST has become the layered reservoir method of choice. Examples of mini-DSTs from CBM wells in Australia and tight gas formations in Canada are presented. A detailed study of a well in the Caspian Sea has shown that the results of mini-DSTs are comparable to those from classical well tests. The thin-bed tight reservoirs require pumpout tests to establish pressure-depth profiles; probe tests are too supercharged to be of use. Simple fluid analysis allows the nature of the fluid produced from a thin bed to be identified. Pumpout also may remove capillary pressure shifts.

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# Modelling Formation Pressure Measurements: What is really possible from Pressure Tests?

***John Bennett, Independent***

Formation Tester pressure measurements are often analysed by regressing lines of best fit to determine Free Water Level.

This talk starts with modelling fluid gradients, then discusses the sources of error in the measurement, and ends with an uncertainty analysis of gradients and contacts.

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# Draw down mobility from formation testers

***Lachlan Finlayson, Petrofac Engineering & Production Services***

Formation Testing tools provide several supplementary pressure and temperature measurements in addition to those directly related to formation properties. These measurements, acquired at the same time as the Formation Tester Pretest, are primarily used for Quality Control but also provide an indication of reservoir quality. Wellbore temperature and pressure profiles from Formation Testers may also be valuable to others working the subsurface including wellbore construction and geoscience specialists.

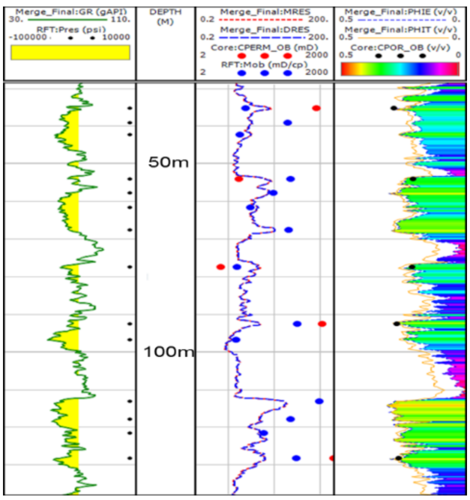
The focus of this presentation is on the Formation Tester pressure data acquired during the Pretest, in particular the calculation of draw-down mobility which is closely related to formation permeability. Draw-down mobility data may be useful for several reasons including:

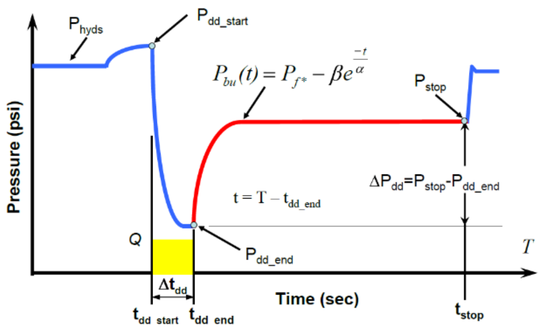
- Verifying the integrity of formation pressure measurements
- Improving the interpretation of fluid gradients and contacts from pressure data
- Allowing better selection of potential fluid sampling depths
- Providing an indication of permeability in the absence of core or well test data

The presentation will discuss how mobility is calculated from the draw-down data using examples in high and low permeability formations. Calculation of mobility from different types of Formation Tester will be shown including both old and new generation tools. Drawdown mobility from Formation Testers will be compared to core permeability.

Several aspects of job planning will be discussed including some suggestions on data acquisition which may provide better quality pressure and mobility data.

In the absence of other direct measurements of permeability, draw-down mobility from the Formation Tester provides an estimate of reservoir quality which can be useful in real-time operations, pressure and fluid interpretations and also an input into subsurface models.





# Nice buildup, but what next? Examples of how integrate discrete Formation Testing Pressure Transient data to arrive at well scale dynamic behaviour estimates

***Shyam Ramaswami, Shell***

The use of dynamic flow behaviour information from Wireline Formation Testing tools has had mixed usage globally. While the acquisition of pressure transient information, particularly build-ups, has increased, the way this information is integrated into subsurface workflows is not always optimal. This talk aims to illustrate a few examples on how Wireline Formation Testing derived dynamic flow information can be integrated into subsurface workflows, hence informing immediate project decisions.



# A New Approach to Extend the Limits of Formation Transient Testing


***Richard Jackson, Vladislav Achourov, Thomas Pfeiffer, Vinay Mishra & Simon Edmundson, Schlumberger***


Transient well testing is one of the most critical components of reservoir evaluation due to its impact on key economic parameters for exploration and development projects, such as reserves and producibility. A conventional cased hole well test involves casing the well, installing process equipment, completing the well, perforating, and producing the well to surface while placing gauges downhole and flaring the produced fluids. Although the data acquired from conventional well tests is very useful; many exploration and appraisal wells are not tested due to time, cost, and regulatory constraints. In situations with no well test, operators are obliged to take important decisions from a relatively small amount of reservoir information and hence take risks associated with subsurface uncertainties. To help reduce the development risks, a new pipe-conveyed formation testing system referred as Formation Testing While Tripping (FTWT) was developed (Fig.1.).

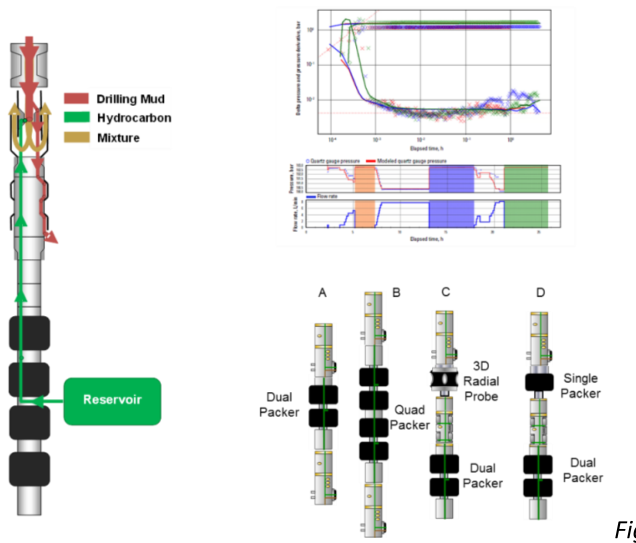



*Figure 1: FTWT testing system shown with circulation unit and various inlet device configurations, together with an example pressure buildup dataset. Configuration options include A: Dual packer with two probes B: Quad-packer with two probes. C: 3D radial probe, probe and dual packer. D: Single and dual packer configurations.*

The new testing system integrates several innovations to enable pumping large fluid volumes at higher rates, extended testing time, noise control, and circulating the produced fluids out of the wellbore during pumping. The new hardware can be combined with sampling and downhole fluid analysis modules used in wireline formation testing to achieve overall well testing objectives, including collecting pressure transient data, real-time fluid typing, and extended fluid sampling, while increasing the radius of investigation compared with conventional wireline formation testing techniques. This new extended formation testing technique has had practical applications by multiple operators, with testing operations performed in the Norwegian sector of the North Sea and offshore Canada.

# Effects and solutions to improve efficiency of formation testing in thick mud cake environments

***Vladimir-Andrei Hanumolo, Weatherford***

In some particular wells it is required special attention when deciding and preparing the drilling fluid due to the issues with formation instabilities, fluid losses or other borehole problems.
Therefore in these wells usually are used different mud additions or chemicals to aid the drilling hazards or prevent the risks associated further.
When using the wireline formation testers in these environments a couple of tool problems or erroneous log responses can appear which will influence the final tester readings.
There are several operational solutions that could be used to reduce this effect and to improve the rate of successful good tests.

**Causes and effects**

Drilling fluids are designed from the start of a well project or while drilling, when unexpected scenarios are occurring, with lost circulation materials (LCM) or other additives with large colloidal particles.
LCM's could be divided into two categories: viscosity-based systems or particle-based systems.

First category functions by increasing the flow resistance of the drilling fluid into the formation. This would not affect too much the final formation permeability's that can be afterwards recomputed with a correct viscosity coefficient.

Second category works by plugging totally the flow paths from wellbore to the formation, frequently exhibiting a very thick mud cake. This second category is having the biggest influence for the formation testing data.
Preponderantly for this category the following materials, but not only, are used as LCM's into the drilling fluids:

- Ground limestone ($CaCO_3$), marble or calcite, in different coarse grades
- Graphite
- Mica flakes
- Barite
- Organic Polymers
- Cellulose or wooden fibres
- Sawdust
- Nut hulls
- Plastic or cellophane pieces

These are chosen depending on mud system (WBM or OBM), applications, mud chemical composition, grinding degree or particle sizes and environmental risks.
Their effects are influencing the testing tools and formation response as:

- Tool total plugging, resulting in tight tests
- Tool partial plugging, affecting the first drawdown. Trapped initial plugs that are washed after a repeated drawdown.
- Formation pores clogging in the invaded zone, with an impact on the permeability calculation.
- Increasing the skin effect, thus influencing the drawdown mobility on the first volumes pulled.

**Solutions, observations and conclusions**

The solutions that could be done to improve the formation pressure response in such an environment can be various, from physical tool modifications up to operational improvements and manual commands, as follows:

1. Snorkel mud plugs or mud excluders type sealing probes

2. Mud cake scraper or ploughs, similar to the ones used for density tools in heavy mud cake. Run in the same tool string above the formation tester. Preferably on caliper tool, with user preferred operational function to scrape just that 0.3-0.5m of formation where the formation tester will seat and seal.

3. Using larger intake pads. This would bring the advantage of having a larger flow area decreasing the chance of clogging completely the intake filter.

4. Several caliper open/close manoeuvres to displace or squeeze mud cake out of the way, before seating finally and starting to test the formation.

5. Pretest injection into formation after seating, to flush out the mud cake or the clogged pores from the invaded zone. This could be done either with a pump out tool string by reversing the pump movement to inject into formation, either by pulling a volume of 20-30cc with the simple pretest chamber from the borehole mud, before opening the caliper to seat and seal the formation. In this scenario with injection there is risk of opening in the mud cake paths that will not assist in achieving a seal.

6. Reducing the drawdown speed and volume. Higher piston speed rates in formations with low permeability will cause bigger differentials which will result in pad being forced into formation and subsequently particles flowing out from formation into the tool. In this case it could result a tool total plugging.

7. Increasing the drawdown piston speed rate, forcing the formation to flow and unclog the flush zone from LCM or the pad intake filters.

8. Pump-out drawdowns for reducing the skin effect or the partial pores clogging.

There are several cases, usually in formations with low permeability, where the initial mobility calculated from pretest drawdown is smaller than after a pump-out drawdown. Flowing out larger fluid volumes from the formation can flush also the clogging particles from the LCM, this will result in showing a real effective permeability of the formation.

The purposed solutions could be chosen depending on each case from various well situations or the LCM type used. Some of the exposed ones are in contradiction but are used for different effects.

There is not such a simple or single answer to aid or resolve the issues in all the scenarios.

From these it could be opted for either individually or combined, in the attempts to improve the tool response and the operational efficiency.



# Doing More With Less – Unconventional

***Russell Gray, Total & Tushar Patil, Baker Hughes a GE Company***

Measuring formation pressure in tight formations has been a significant industry challenge because of extremely low mobilities (<0.01 mD/Cp) and it is typically assumed that these formations cannot be pressure tested accurately. Total as operator of a major North Sea field needed to acquire formation pressure to map the pressure profile through tight formations of the Cretaceous and Paleocene. This information was key to the operator for pore pressure profiles to define drilling windows.

Generally, when tight formations are to be tested the first thing that comes to the mind is to increase the flowing area of the formation tester packer, so that it connects with a larger surface area of the wellbore wall. This could help to draw in more fluid into the tool. So would a tool which is open to the wellbore completely along one meter, a good option to measure the pressure in tight formations such as argillaceous chalk?

This is where “Doing More with Less” plays an important role.

In order to measure formation pressures in extremely tight formations, there are a few characteristics that the formation tester tool should contain. Sufficient flow area (fractional flow area compared to the entirely open tool), accurate drawdown pump (draws exceptionally small increments of fluid into the tool), reduced flowline volume (minimise the compressibility effects of fluids while drawing down and building up). These characteristics put together in the formation tester tool that is slim in size, light in weight and smart, is the ultimate answer to this historical problem. To achieve this with reduced operation time at multiple depths per run requires careful planning and co-operation between all parties. The successful acquisition of valid pressure in very low mobility formations is discussed.

# Wireline formation testing without the wireline


***Alyn Carrahar, Weatherford***


Memory logging obtains wireline quality openhole logs without using wireline. With the wireline out of the way, the formation tester and other measurement tools are safely garaged inside the drillpipe while running in hole. This means we can get the tools to the most hard to reach places such as long reach horizontal wells, past washouts, squeezing formations and into wells prone to differential sticking.

The difficultly with formation testing on memory is that it is an interactive process, therefore we require 2 way pressure pulse communication. This method of acquiring formation pressure data is the preferred technique for multiple fields around the world.

*Figure 1: Formation tester in open hole*

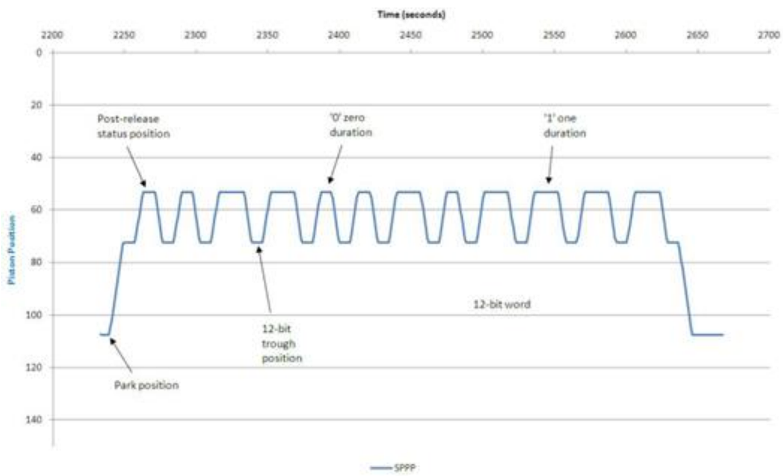



*Figure 2 - Formation pressure encoded in 12-bit binary*

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# Advances in Quantification of Miscible Contamination in Hydrocarbon and Water Samples From Downhole to Surface Laboratories

***Adriaan Gisolf, Schlumberger***

Formation fluid properties are critical inputs for field development planning. Acquisition of representative, low-contamination, formation fluid samples is key to obtaining accurate fluid properties from laboratory analysis. Quantification of oil-based mud (OBM) or water-based mud (WBM) filtrate contamination of hydrocarbon or water samples is still one of the biggest challenges, both during real-time formation tester sampling operations and with surface laboratory techniques. Laboratory sample analysis uses either the skimming or the subtraction method to quantify OBM filtrate contamination of hydrocarbon samples whereas tracers are typically required to quantify WBM filtrate contamination of water samples. Recently, a new real-time workflow has been developed to quantify OBM or WBM filtrate contamination of hydrocarbon or water samples with downhole multi-sensor formation-tester measurements. When discrepancies are observed between laboratory-derived and real-time contamination quantification, it can be challenging to uncover the source of the difference or to identify the most accurate method. This paper evaluates the applicability of different methods.

Surface laboratory methods to quantify OBM filtrate contamination crucially assume that the mole fraction of components in the C8+ portion of uncontaminated reservoir fluids and the corresponding molecular weights (or carbon numbers) follow an exponential relation. When actual fluid compositions deviate from the assumed behavior, a large error in OBM filtrate contamination quantifying can occur. In this paper, more than 20 laboratory-created mixtures of formation fluid and mud filtrate are analyzed to validate the laboratory methods. Errors of 2 to 3 wt% in OBM filtrate contamination quantification were observed for virgin reservoir fluids that follow the assumed behavior. However, much larger errors may be observed for biodegraded oil, oils with multiple charges from different sources, or oil with similarly wide ranges of compositions to OBM filtrate.

A new workflow allows quantification of OBM or WBM contamination using multiple downhole sensors, for real-time measurement, with unfocused and focused sampling tools for water, oil, and gas condensate. The new workflow comprises five steps: (1) data preprocessing; (2) endpoint determination for a pure native formation fluid using flow regime identification; (3) endpoint determination for pure mud filtrate and quality control of all endpoints using linear relations between measured fluid properties; (4) contamination determination in vol% and wt% on the basis of live fluids and stock tank liquids; and (5) decontamination of the fluid properties including gas/oil ratio, density, optical density, formation volume factor, resistivity, and compositions.

The new workflow has been applied to a large number of field cases, with very good results. For most of the cases, the downhole analysis is consistent with the surface laboratory results. When discrepancies between methods are observed, a thorough understanding of the limitations of each technique, as described in this paper, will help to determine which data to bring forward and what to discard.

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# Applications of SoundSpeed for contamination monitoring and water analysis (quantifying total dissolved salts, chlorides)

***Gavin Sibbald, Baker Hughes a GE Company***

The SoundSpeed sensor in the BHGE LWD and WS modules is a unique sensor package that can be used in multiple applications. It is an acoustic transmitter and receiver that sends an acoustic pulse across the flowline and measures the fluid slowness. This measurement is very sensitive to fluid property change, and can be successfully used to monitor clean on a pump – outs. It displays a unique pattern on concentric probe sampling where upon taking samples early can be highly beneficial. The fluid slowness change can help distinguish between OBMF and formation oil, and used correctly give highly effective trend evaluation. The measurement is part of the gas – oil ratio calculation which is an output from the fluid analyser package. The fluid slowness response can also be used to help monitor water analysis, with the temperature and pressure, the SoundSpeed can be used to measure the salinity of the water (quantify total dissolved salts, chlorides)

The presentation will go over the principals, the background on the measurement from various scientific papers, and then look at the application of the measurement on examples from around the globe.



# Real-time fluid mapping-while-drilling service enhances well placement and maximizes production potential

***Yon Blanco, Schlumberger***

Advanced PVT fluid properties play a vital role in estimating reserves, optimizing completions, designing surface facilities, and meeting production goals. However, these datasets are traditionally available only after performing conventional formation sampling.

Building on the experience gained from Wireline sampling tools and Formation Pressure While Drilling, the **Fluid Mapping While Drilling service** enables the acquisition of high-quality formation pressure measurements, in situ downhole fluid analysis, and representative fluid sampling— all in real time, while drilling, allowing better steering decisions and optimize reservoir productivity.

Pre-job clean up models are available to aid in deciding the most suitable sampling time; examples show that starting the clean-up process as early as possible after drilling can significantly reduce the time on station. Data from carbonates to evaluate the flowing fluid as well as low contaminated oil samples in sandstone formations (with comparisons to laboratory results) are shown to highlight the service potential in high angle and high overbalance scenarios.

Examples from different basins show how the Downhole Fluid Analysis (DFA) capabilities of the Fluid Mapping While Drilling service allow Real Time fluid characterization and contamination monitoring to obtain not only representative fluid samples but also to integrate fluid data with static reservoir mapping data for complete understanding of fluid distribution along reservoir to maximize exposure while drilling/steering.

***Yon Blanco*** *is a Principal Reservoir Engineer with Schlumberger based in Aberdeen, UK. He joined Schlumberger in 1994 in Venezuela with Wireline & Testing and held different positions in the field operations, Technical Support (InTouch), Technical management and Sugar Land Technology Center. In 2007 he moved to Drilling & Measurements where since has been supporting the Formation Pressure While Drilling Service and more recently the Fluid Mapping and Sampling While Drilling Service in the Gulf of Mexico and Europe.*