2019 SPWLA Formation Testing SIG Meeting
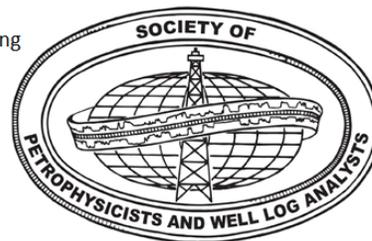New technology, applications and case studies in formation testing

7:30 am - 4:30 pm
March 6th 2019
BP Helius Plaza Auditorium
201 Helios Way, Houston, TX 77079

Time	Affiliation	Speaker	Topic
7:30			**Breakfast and registration**
8:00	BP	*Wilson Pineda*	Introduction
8:10	Halliburton	*Jones, Christopher*	Predicting Reservoir Fluid Sample Contamination Using an Advanced Equation-of-State Based Model
8:40	Repsol	*Gil, Jose*	Formation Testing for Integrated Reservoir Characterization of a GoM Wilcox Development
9:10	UH	*Economides, Christine*	Differences between MiniFrac, DFIT and MicroFrac
9:40	Schlumberger	*De Santo, Ilaria*	Coupling downhole and surface fluid measurements to reveal and assess complexities in reservoir fluids distribution in real time, while drilling
10:10			**Break**
10:30	BP	*Cedillo, Gerardo*	Formation Sampling While Drilling in Challenging Environments. Deepwater Gulf of Mexico Value of Information Case Study on LWD Sampling
11:00	UT	*Gelvez, Camilo*	Study of the Efficiency of Fluid Cleanup in Heterogeneous Formations with Various Formation-Testing Tools
11:30	UT	*Schroeder, Colin*	Understanding and Improving Formation Fluid Sampling While Drilling Using Numerical Simulations
12:00			**Lunch**
1:00	Schlumberger	*Mullins, Oliver*	Connectivity analysis in a large reservoir by integrating concepts in petroleum systems, reservoir fluid geodynamics and structural geodynamics
1:30	Halliburton	*Dai, Bin*	Digital sampling: An Equation of State, Machine Learning, and Pattern Recognition, a Real Time Approach to Formation Fluid Property Assessment and Use
2:00	MPC	*Proett, Mark*	Automated Workflows for Planning Formation Testing & Sampling
2:30			**Break**
3:00	Schlumberger	*Garcia, German*	Let's Disrupt the Wireline Pressure Testing Practices, Shall We?
3:30	BGHE	*Amin, Asif*	Estimation of Typical Total Dissolved Solids in Water from Downhole Ultrasonic Sound Speed Formation Tester Survey
4:00	BGHE	*James Xu*	Closing Remarks

Although the organizing team makes every effort to follow planned schedule, we recognize that factors beyond our control may cause changes. We thank you for your understanding.

Christopher Jones, Halliburton

Predicting Reservoir Fluid Sample Contamination Using an Advanced Equation-of-State Based Model

It is well known that the acquisition of representative formation fluid samples is essential for reservoir management and development. However, because of overbalance pressure in the mud column, mud filtrate invades and contaminates the reservoir fluid during the drilling process but before the mudcake around the wellbore is properly formed. Although water-based mud (WBM) is immiscible with formation fluid, oil-based mud (OBM) is miscible with it. Samples with OBM contamination levels greater than at least 10% for oils and 3% for volatile oils and gas condensates might be considered unusable because the OBM contamination alters the formation fluid properties, preventing an accurate characterization of the reservoir fluid. Despite a large body of research, it is difficult to prevent contamination. Unfortunately, openhole sampling is usually a single opportunity event; by the time the laboratory analysis is complete, it is not possible to acquire additional samples. Consequently, it is important to be able to measure the contamination level of the reservoir fluid as accurately as possible in real time before taking the sample. In addition, by knowing the contamination level in real time, the optimal timing of sampling can easily be determined, which reduces rig time/cost and potential fishing risks. Current techniques to estimate contamination nearly ubiquitously rely on curve fitting of measured properties, such as density, fluid compositions (including gas/oil ratio [GOR] and asphaltene content), or color. These techniques, however, suffer from several shortcomings, such as tool drifting, dependence on end-member filtrate, and formation fluid properties. In all techniques, the measured properties are assumed to asymptotically approach the clean fluid properties.

This paper proposes a method to estimate the drilling fluid contamination levels and characterize reservoir fluid in real time using the formation tester tool measurements of the fluid. Although the equation-of-state (EOS) method has been previously proposed, in this approach, a combination of a multi-point EOS, distribution function of formation fluid, inherent geochemistry principles, and empirical correlations are used. This EOS method has been validated with laboratory and field data.

The algorithm developed uses an inverse method to compute reservoir fluid contamination. It takes as inputs the downhole fluid composition, including C1, C2, C3, C4-C5, and C6+ saturate, aromatic, resin, and asphaltene fractions, and fluid properties, such as GOR, density, bubble-point pressure, compressibility, and mud filtrate composition. Using an iterative process, an optimum combination of formation and filtrate fluids whose properties best match the fluid properties supplied to the algorithm is determined.

Jose Alberto Gil, Repsol

Formation Testing for Integrated Reservoir Characterization of a GoM Wilcox Development

In reservoir characterization, it is routine to consider the depositional setting of the relevant formations as well as the geodynamic processes that these formations undergo. "Structural geodynamics" includes many processes such as subsidence, deformation, compaction, tilting, faulting, and cementation. While the timing, type and volumes of fluids that charge into the reservoir are usually covered in Petroleum System evaluations, there is little accounting of the processes that the reservoir fluids regularly undergo after trap filling to present day; these reservoir fluid 'alterations' can yield viscosity and GOR gradients, mobile bitumen, tar mats and are responsive to the structure of the reservoirs. As such, accounting for these fluid alterations is key to understand both fluid and the structural complexities of oil reservoirs and the associated impact on development strategies.

Reservoir fluid geodynamics (RFG) is a recently launched formal technical discipline that accounts for fluid redistributions and phase transitions including tar formation in reservoirs during and after trap filling. Because RFG process often lead to equilibration; thus, determination that reservoir fluids are equilibrated is a strong

indicator for reservoir connectivity, a primary analysis objective of RFG. Elements of RFG, such as analysis of biodegradation, have long been in place; nevertheless, RFG is now strongly enabled by recent developments: 1) downhole fluid analysis (DFA) allows routine elucidation of reservoir fluid gradients, 2) the development of the first equation of state for asphaltene gradients allows identification of equilibrium vs. recent or ongoing geodynamic processes of reservoir fluids and 3) RFG analyses of more than 40 oilfields systematize a multitude of RFG processes and show their direct impact on wide-ranging production concerns. Thermodynamic analyses identifying reservoir fluid geodynamic processes rely heavily on measurement of fluid gradients to avoid ambiguous interpretations. The unique role of asphaltene gradients and their integration with other data streams are the focus herein.

The presentation will show a case study from Gulf of Mexico of integration of these two workflows, "structural geodynamics "and "reservoir fluid geodynamics". The RFG workflow showed the extent of reservoir connectivity and identified a potential late gas charging after the faulting event among the fault blocks, with integration of the advanced DFA (Downhole Fluid Analysis) data from wireline formation testing, and laboratory PVT data. Additionally, the great reservoir parameters in the block vs analogs, such as high initial pressure, good permeability, uniform vertical pressure distribution in the main block and excellent mobility, allow inferring high productivity in the area. This is confirmed with excellent flow-back results of the wells.

Jesús Alberto Cañas Triana is RE Team Leader and Reservoir Fluid Geodynamics HUB coordinator for Schlumberger. He has been a RE Advisor with SLB in the US since 2012. He worked in Argentina, Bolivia, Venezuela, and Brazil from 1997 to 2012. He started his career with Ecopetrol in Columbia in 1986 after earning his MS in Petroleum Engineering from Texas A&M University and BS from American University (Columbia).

Christine Ehlig-Economides, University of Houston Dept of Petroleum Engineering

Distinctions and differences between MiniFrac, DFIT and MicroFrac

Tests designed to provide reservoir and geomechanical parameters needed for hydraulic fracture design include minifrac, diagnostic fracture injection test (DFIT), and microfrac. The minifrac and DFIT are typically associated with fracture injection testing performed during the completion of the well and frequently used prior to hydraulic fracture completions in cased hole environments. MicroFrac is associated with wireline formation testing in openhole environments using much lower injection flow rates, volumes and shorter testing times. This presentation will illustrate with data the differences between these tests and which parameters each test can reveal. It will also explore ways that modern technologies might improve on traditional testing approaches.

Ilaria De Santo, Schlumberger

Coupling downhole and surface fluid measurements to reveal and assess complexities in reservoir fluids distribution in real time, while drilling

Obtaining information on fluid distribution across reservoir has always been of paramount importance for any O&G Operator. Getting such information early enough during the life of the reservoir allows optimizing data acquisition programs and reducing uncertainties on well completion and field development. When production starts, being able to map differential depletion and compartmentalization across the field becomes a complex task, as vertical and lateral reservoir heterogeneities and pressure support strategies might complicate the picture. For this reason, complementing traditional pressure measurements with surface and downhole fluid analysis has become more and more important.

Although surface and downhole fluid analysis can both be performed while drilling, the two data streams are very different in terms of acquisition practices, properties and interpretation, hence their integration requires a specific set of tools and skills, which are finally becoming available.

Obtaining information from hydrocarbon dissolved or suspended into drilling fluids is today a reliable way of early assess the type and distribution of reservoir bearing fluids. C1 to C8 hydrocarbon composition can be obtained with excellent level of accuracy, if hydrocarbons are extracted from drilling mud at constant and controllable thermodynamic conditions and once their concentration is calibrated for extraction efficiency. Finally, advanced downhole fluid analysis technologies based on optical spectroscopy have been made available to be deployed while drilling, allowing to precisely characterize fluid composition, Formation Volume Factor, Gas-Oil-Ratio and asphaltene content, in real time. This, combined with the surface fluid logging technologies mentioned above, gives a continuous with depth fluid profile, which allows detecting potential lack of hydraulic communication across the reservoir, reveals presence of vertical or lateral heterogeneities that can explain differential depletion, and de-risks any additional reservoir fluid data acquisition. The comprehensive integration of these data streams, allows optimizing well placement, de-risks field development plans and finally maximizes the amount of reserves that can be accessed and recovered during the life of the field, with positive impact on overall field production.

Gerardo Cedillo; BP Exploration and Production Inc.

Formation Sampling While Drilling in Challenging Environments. Deepwater Gulf of Mexico Case Study on Using LWD to Complement Wireline Fluid Sampling

Fluid samples and core are the two pieces of information allowing representative laboratory experiments of fluid and rock interaction in the reservoir. Fluid samples contain information about reservoir charging history and fluid spatial distribution. Understanding the fluid properties drives facilities design and helps set the production operations constraints. Additionally, information from fluid samples can assist in addressing other issues such as flow assurance which can be challenging in deepwater operations; not only due to the high thermal and pressure change of the fluid from reservoir to surface, but also because of costly rig intervention operations that would be required to remediate fluid assurance problems.

Collecting fluid samples using wireline formation testers (WFT) is a mature process, however the use of sampling while drilling (SWD) technology has not seen widespread adoption. One of the reasons that is keeping SWD from more frequent use – like other logging while drilling (LWD) technologies – is the uncertainty of its performance when it is introduced into a new area. This concern is even greater in complex operations like deep water Gulf of Mexico. When introducing SWD in a deepwater field, planning and execution should take into consideration the aspects related to the new technology, and incorporate the lessons learned from years of WFT sampling in the same area. The planning process should start with building the business case and engaging the stake holders to address their concerns. Modeling should be performed to understand uncertainties. The modeled scenarios then feed into the real-time monitoring phase; supporting the decision-making process and also can identify potential problems during execution.

This paper describes the process applied during the planning a deepwater Gulf of Mexico SWD operation. The intention was not to replace WFT with SWD, but to have both technologies available so the one that best fits each specific sampling scenario is used. The process includes using decision trees to build the business case and modeling the SWD clean out time by using available core and log data, fluid and drilling parameters as some of the inputs. It also includes the modeling of oil-based mud (OBM) contamination effects in the laboratory; establishing sensitivity of the fluid properties needed for flow assurance understanding. Authors build up on the experience and information available from WFT fluid sampling in the same reservoir for several years.

Camilo Gelvez, The University of Texas at Austin

Study of the Efficiency of Fluid Cleanup in Heterogeneous Formations with Various Formation-Testing Tools

This study presents a reliable model to represent various formation testing tools during cleanup and sampling operations. Finding the best tool-probe configuration through a fully-calibrated model has a significant impact on cleanup efficiency. The model is constructed based on a field-case simulation of a water saturated reservoir drilled with a blue dye tracer water base mud (WBM). The tracer allows to track the contaminated zone during mud filtrate invasion and cleanup. Simulation and history match of lab test data and optical analyzer data for tracer cleanup serves to further represent several formation testing tools in a variety of reservoirs and cleanup-sampling schedules. In addition, the simulated contamination cleanup data is a powerful tool to analyze the cleanup derivatives and to evaluate different aspects of reservoirs during real-time cleanup and sampling operations.

Colin Schroeder, The University of Texas at Austin

Understanding and Improving Formation Fluid Sampling While Drilling Using Numerical Simulations

Unlike traditional wireline formation tester (WFT) sampling, conditions in the near-wellbore region during formation sampling while drilling (FSWD) operations are complicated by ongoing mud-filtrate invasion due to the absence of sealing mudcake during cleanup and sampling. Understanding the physical processes controlling dynamic mudcake deposition, mud-filtrate invasion, and formation-tester sampling is therefore paramount to ensuring that high-quality reservoir fluid samples can be acquired reliably and efficiently in the while-drilling environment. For the present study, numerical simulations were performed to identify critical parameters influencing FSWD operations. Using a detailed FSWD case study from published literature [1], simulation results were validated and a baseline reference case for sensitivity analysis was established. Borehole, reservoir, and mud properties were subsequently perturbed to identify primary factors controlling cleanup and sampling in the while-drilling environment.

Oliver Mullins, Schlumberger

Connectivity analysis in a large reservoir by integrating concepts in petroleum systems, reservoir fluid geodynamics and structural geodynamics

The Ivar Aasen reservoir on the continental shelf of Norway is laterally extensive (>10km) and has major reservoir sections that are characterized by moderate to poor net to gross. Reservoir connectivity had been one of the most important reservoir risk factors. Different gas-oil contacts (GOC) in different sections of the field exacerbated connectivity concerns. A systematic evaluation of all fluid properties was carried out to address connectivity and other concerns. This evaluation incorporated charge history, fluid equilibration processes, biodegradation, and gas evolution with integration of thermodynamics and geochemistry. These results were also linked with key structural geodynamic processes confirming the petroleum system context of reservoir charge. Different GOCs are a natural consequence of charge into a connected reservoir. The key conclusion of good connectivity across almost the entire reservoir has been confirmed in two years of production. This textbook reservoir case study is relatively simple to understand and provides a systematic framework for evaluation of any reservoir.

Bin Dai

Digital sampling: An Equation of State, Machine Learning, and Pattern Recognition, a Real Time Approach to Formation Fluid Property Assessment and Use

Acquiring physical samples from an open hole is usually a one opportunity event. That is a formation tester is sent down hole with a limited number of sample chambers, either on an LWD or a Wireline conveyance system. The samples are acquired, retrieved and sent to a laboratory for analysis which then takes place weeks to months later. By the time the laboratory has performed an analysis the section has been cemented, and perhaps the rig has finished operations and moved on. Success of the sampling operation is predicated that the samples be acquired from the right locations (Where to sample?), that the samples be acquired at the right time to minimize drilling fluid filtrate contamination (When to sample?), and in a manner that preserves the integrity of the sample and is representative of the formation fluid (How to sample?). Digital sampling is a technique that that can be used to both optimize the when, where and how of physical samples taken and further augment the information collected with sensor analysis from locations that are not physically sampled. This work shows a new technique that can be used to extrapolate clean fluid properties with moderately high contamination levels in a rapid pumpout. A series of rapid pumpouts can then be used to map a formation for selection of where to sample, to constrain contamination models to match multi-depth equation of state models and determine when to sample, and optimize the pumpout parameters to obtain a representative sample in the shortest period of time.

Mark Proett, MP Consulting

Automated Workflows for Planning Formation Testing & Sampling

A primary source of dynamic data for formation evaluation is available from wireline and LWD formation testing. In a typical exploration or appraisal well, the formation testing can provide definitive data for the identification of flow units, fluid types, contacts, composition and even EOS models. In the process of pressure testing and sampling, the dynamic data also provides a link to the static open hole logging data that can be integrated to enhance the formation evaluation. However, this dynamic data is frequently overlooked due to the uncertainty created by the wide variability of the tool technology, measurement options and interpretation methods available. Most open hole logs produce standardized results that are readily accessible and accepted. In the case of formation testing, the data is normally analyzed and the results are reported by the service provider's analysis which can be subjective. Recently, reporting standards have been instituted enabling the relative quality of the measurements to be assessed objectively and uniformly (Proett, et al, 2015). This has led to the development of automated analysis methods that have progressed to the point where an entire testing run's dynamic data can be analyzed automatically.

While the interpretation of the dynamic data is being addressed, there is still a need to automate the job planning process. The tools and measurement options available are numerous and can be daunting to someone not familiar with the technology. In addition, the formation testing is typically the most expensive portion of the open hole logging program which puts considerable focus on this task with competing objectives by all the parties involved. Current job planning methods do not have a well-defined workflow and typically rely heavily on the availability of highly skilled specialists and, due to time constraints, a detailed job plan is rarely done. However, by implementing a systematic approach, a job planning workflow can be defined that is highly automated, enabling formation testing jobs to be optimized. This presentation provides an overview of the new methods currently being developed and how they can be made accessible to a wide audience.

German Garcia, Schlumberger

Let's Disrupt the Wireline Pressure Testing Practices, Shall We?

A concept platform integrating the precise movement of a linear or azimuthal actuator, such as in instrumented wireline intervention tools (IWIT), with fast pressure measurement is presented. This device is intended to accurately move a measurement probe or sampling assembly either in the longitudinal or azimuthal direction in the wellbore to significantly improve data quality and operational efficiency.

Precise movement control enables acquiring data at exact intervals to eliminate errors induced by cable stretching, overpulls, or variable cable creep. Simulations with current IWIT capabilities shows significantly reduced pressure gradient uncertainty over common wireline protocols. The operational procedure includes correlation using standard wireline gamma ray logs, anchoring of the platform at the top of the interval to be tested and performing the distributed survey using a linear actuator for every probe displacement. Removing cable movement significantly reduces an important source of error in distributed pressure measurements. These acquisition errors induce interpretation uncertainties like position of contacts and connectivity between flow units. These have profound impacts in exploration and appraisal decisions and field development plans.

This concept platform would enable reducing the time spent on pressure surveys if similar accuracy to current standard practices is acceptable. Because the remaining source of error is mostly due to gauge accuracy, results show that fewer stations are necessary to replicate standard wireline results. Where accuracy is important, as with distributed pressure measurements to quantify reserves using gradient intersection to define fluid contacts or determine compositional gradients, the proposed approach is shown to significantly reduce gradient error using the same number of stations. We use synthetic data sets built from previous work to show the impact of the error reduction in the position of the fluid contact.

IWITs currently used in cased hole employ active anchoring to perform intervention tasks. The controlled downhole force available for these operations goes up to 40,000 lbf while the anchoring force could be up to 150,000 lbf. In the proposed concept platform, this pulling force could be instrumental where there is high risk of differential sticking. By anchoring the upper part of the platform in overlying impermeable intervals, the probe could be lowered into the permeable interval to conduct the pressure survey without exposing the full length of the platform to the pressure differential forces for significant risk mitigation. The high pulling capacity of the anchoring module can be used to apply up/down force on the probe in case of differential sticking without applying high tensions to the wireline cable.

The proposed architecture for the concept platform innovatively combines several operational concepts used today as separate entities in wireline operations. Their integration, however, generates important efficiency gains, reduces the risk in stationary measurements and operations, improves accuracy, and enables the implementation of unprecedent distributed pressure measurements with azimuthal rotational capabilities using wireline. Azimuthal movements can be used to align the measurement probe away from breakouts, drilling induced fractures, debris or geological features like vugs or fractures that may compromise the sealing ability of the probe.

Asif Amin, Baker Hughes

Estimation of Typical Total Dissolved Solids in Water from Downhole Ultrasonic Sound Speed Formation Tester Survey

Surface laboratory analyses of downhole water samples can typically introduce a significant delaybetween the sampling and reporting of fluid properties. The work described in this paper aims to quantify downhole formation water property measurements, and derivations from the high frequency acoustic sensor data

acquired in water-based mud settings. The methodology is implemented by a careful estimation of the Total Dissolved Solids (TDS) typically found in formation waters.

Wireline formation testing and sampling tools are used to collect downhole samples, and to monitor cleanup from mud filtrate to collect a representative formation fluid sample with the aid of different downhole sensors, particularly optical spectrometers. In case of water-based mud (WBM) and water cleanup, the optical spectrometer does not distinguish between filtrate and formation water due to the very low optical spectrum contrast. Oftentimes, non-calibrated resistivity sensors are used to differentiate filtrate from formation or injection water, when there is a detectable salinity contrast. Resistivity and density trends are successfully utilized for cleanup monitoring, however the measured values could lack accuracy to be reliably used as the input parameters in petrophysical evaluation, particularly in the cases of transition zones characterization.

The objective of this work is to verify estimation of the common TDS from downhole ultrasonic sound speed sensor data, acquired by wireline formation tester at in-situ conditions, with the laboratory reported values, and to demonstrate its applicability for transition zones testing. Comparison of laboratory reported TDS was made for water samples collected from various reservoirs, borehole conditions, and a high range of water composition. Considering the different methodologies and consistent trends observed, the new real-time monitoring solution adds a confident tool for quantitative fluid properties assessment, and particularly in a challenging transition intervals. Based on different methodologies, the relationship between salinity, concentration of solids and density was evaluated.

The work provides the methodology to estimate TDS of water in-situ to characterize and differentiate water types. In combination with real-time density measurement, confidence in fluids properties assessment is increased, assisting in swift reservoir evaluation and decision making for prospecting and operational purposes.