8:45 – 9:00

Opening Remarks

Thanks to BP for Hosting & M. Rabinovich for Arrangements

Safety

Emergency Exits

Cafeteria Location

Announcements

Abstracts & Speakers' Bios

9:00 – 9:30 am

Beginnings of Petrophysics at Shell: An Historical Summary with One Man's Recollections, Abridged

E.C. Thomas

You've used the Thomas-Stieber model; you've read the Waxman-Thomas paper. You know that Shell played a leadership role in our craft. E.C. will share some of his stories regarding the Shell pioneers in the first and second generation of petrophysicists. This talk is going to interest you! Guaranteed! dk

For a more complete and most interesting biography, click on the link below:

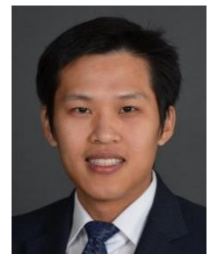
https://1drv.ms/b/s!AhahHCzwL-WGgxWDTNLPVjBhH3T2?e=PoVr0L

9:30-10:00

First Lwd Co-Located Antenna Sensors For Real-Time Anisotropy And Dip Angle Determination, Yielding Better Look-Ahead Detection

Electromagnetic (EM) resistivity tools measure the electrical properties of downhole formations that are critical in determining the hydrocarbon saturation of a reservoir. In complex and heterogeneous reservoirs, both horizontal and vertical formation resistivities are required to obtain an accurate hydrocarbon saturation. For decades, wireline multi-component induction type measurements have provided reliable determination of formation anisotropy, structural dip, and dip azimuth in wells with any orientation relative to the bedding planes. Logging-while-drilling (LWD) multi-array propagation resistivity tools have also demonstrated similar capability in deviated wells where the relative dip angle is between 45 and 90 degrees. However, measuring anisotropy and dip in wells with low relative dip angle still poses difficulties for LWD propagation resistivity systems because of the antenna structures employed.

We discuss the development of a new LWD EM sensor equipped with an innovative, co-located, tilted antenna structure. The tool, along with a unique processing scheme, enables the determination of horizontal and vertical resistivity as well as the dip angle and the azimuth of the formation based on an assumption of transversely isotropic (TI) formation models while drilling in real time. The co-located sensor design is capable of acquiring multi-component signals that are sensitive to formation anisotropy and structural dip in wells at any orientation. Modeling studies and several field trials have proven that the design concept can detect these formation properties at any arbitrary wellbore deviation. We present test results from the new technology, together with reference measurements from azimuthally compensated LWD and fully triaxial wireline resistivity measurements. Good comparison is observed in these trials, providing an independent verification of the tool performance. The azimuthal measurements of the new sensors allows for determining formation anisotropy and dip at any wellbore deviation as well as providing 360-degree azimuthal resistivity and geosignals, and allowing a three-dimensional (3D) resistivity mapping technique for real-time decisions. Integrating the co-located antennas with deep-reading antennas in a near-bit collar further provides both anisotropy measurements and ultra-deep signals very close to the bit and enhances look-ahead detection ranges for LWD applications.



Hsu-Hsiang (Mark) Wu is a senior scientific advisor in the electromagnetic sensor-physics research group in Halliburton in Houston. He joined Halliburton in 2008 and has since improved the LWD resistivity logging tools and developed several new electromagnetic tools. Wu has been working on LWD-related projects for more than 13 years and has helped develop the new ranging system and ultradeep resistivity tool in the last six years. He received his MS and PhD degrees in electrical engineering from the University of Houston in 2007 and in 2017, respectively. Wu has proposed various innovations related to downhole formation evaluation, look-ahead look-around determination, and magnetic ranging detection since 2009.

10:00-10:30 a.m.

Machine Learning (ML)-based Convolution Method for Fast Forward Modeling of Induction Log

Teruhiko (Terry) Hagiwara retired

ABSTRACT: We built a convolution model using Machine Learning to calculate induction log responses for 1D earth models. Compared to analytical forward modeling, the convolution model is extremely fast. The Machine Learning (ML)-based convolution finds the accurate induction tool responses from an earth model with layer resistivity and layer boundaries. For a unit induction tool 2C40, the 101-point 50-ft window convolution model works satisfactorily for a well deviation angle of 60°.

Affiliation: Terry R&D

Teruhiko (Terry) Hagiwara retired from Sr. Consultant, Upstream Group of Aramco Services Company, Houston, TX in December 2021. He was Research Consultant for Shell International E&P, Houston; Technology Advisor for Halliburton Energy Services, Houston; and Research Physicist for Shell Development Co. at Bellaire Research Center, Houston. His main research interests are borehole geophysics and petrophysics. He holds a BS in physics from the U. of Tokyo, Japan, and a Ph.D. in theoretical physics from the SUNY at Stony Brook. He is a recipient of Distinguished Technical Achievement award from SPWLA in 2007.

10:30 – 11:00 a.m.

Deep Learning Enhanced Multiphysics Joint Inversion

Jiefu Chen

Abstract: : In this talk we will discuss a deep learning enhanced multi-geophysics joint inversion for subsurface characterization. A key issue of joint inversion is to develop effective strategies to link

different geophysical data in a unified mathematical framework. In our work, we enforce the constraint of structural similarity by a deep neural network (DNN) during the learning process. The framework is designed to combine the DNN and the traditional separate inversion workflow together and improve the joint inversion results iteratively. The network can be easily extended to incorporate multi-physics without structural changes. In addition, this learning-based framework demonstrates excellent flexibility when the sensing configuration changes or different discretization is used for different models. Numerical experiments show that our deep learning enhanced joint inversion framework can reconstruct more accurate both physical property values and structures of subsurface features than separate inversions and traditional cross-gradient based joint inversion.

Jiefu Chen is an Associated Professor with the Department of Electrical and Computer Engineering, University of Houston. He received the Ph.D. degree in electrical engineering from Duke University in 2010. From 2011 to 2015, he was a Staff Scientist with Weatherford International. Dr. Chen has published more than 100 technical papers in computational electromagnetics, inverse problems, machine learning for scientific computing, oilfield data analytics, seismic data processing, subsurface wireless communication, and well logging. He is a Full Member of USNC-URSI Commission F, National Academies of Sciences, Engineering, and Medicine, and a Senior Member of the Institute of Electrical and Electronics Engineers (IEEE). He has been serving as an associate editor for IEEE Journal on Multiscale and Multiphysics Computational Techniques since 2018, and for IEEE Transactions on Geoscience and Remote Sensing since 2020.

11:00-11:30 a.m.

Petrophysical Applications for the Quadrature Induction Conductivity

John C. Rasmus

The induction quadrature conductivity is a function of the skin effect and dielectric constant of the formation. Low frequency dielectric constants are associated with interfacial polarization effects and not primarily water volumes as they are for 1.1 GHz measurements. Recently, an inversion was built to simultaneously determine both the formation conductivity and dielectric constant using the in-phase and quadrature induction conductivity measurements. We will review the theory behind the inversion and show that the real part of the dielectric constant perturbs both the in-phase and quadrature induction measurement, while the imaginary part perturbs only the in-phase induction measurement. This part is called the “dielectric loss” factor. It appears that both graphitic kerogen and to a much lesser extent pyrite create dielectric losses while clays do not. We will show how other measurements can be used to calculate the dielectric loss factor and correct the inverted formation conductivity. This correction must be applied before using the inverted conductivity for petrophysics.

The real part of the dielectric constant contributed by clays has been modeled using Revil’s formulations and shown to fit the Vinegar quadrature conductivity database remarkably well. The quadrature conductivity is a function of the counterion mobility and conductivity of the Stern layer, Qv, salinity and the saturation. We will show how we can use both the in-phase conductivity and real part of the dielectric constant in shaly sands to determine more than just water saturation.

John C. Rasmus retired from Schlumberger in 2018. While at Schlumberger he was an Advisor-Reservoir Characterization in the Schlumberger logging-while-drilling (LWD) product line based in Sugar Land, TX. Duties included LWD interpretation field and client support, resistivity and nuclear interpretation support and special projects. Previously he held various interpretation positions developing new and innovative interpretation techniques for secondary porosity in carbonates, geo-steering of horizontal wells, geo-pressure quantification in under-compacted shales, downhole motor optimization and high-angle horizontal (HAHZ) well petrophysics. John holds a BS degree in mechanical engineering from Iowa State University in Ames Iowa and an MS degree in petroleum engineering from the University of Houston. John is a member of SPWLA, SPE, AAPG and is a registered professional petroleum engineer in Texas as well as a registered professional geoscientist. John recently started Interfacial Polarization Dielectric Petrophysics LLC to develop and market the interpretation methodology. John can be contacted at 281-678-9325 or at jrrasmus.tfs@gmail.com

11:30 a.m. 12:30 p.m. Lunch: BP Cafeteria

12:30 – 1:00 p.m.

Bayesian inversion of well logs and core data for improved petrophysical interpretation

Check the Resistivity SIG page on SPWLA.org website for an update to this Announcement that includes Abstract for this talk.

Carlos Torres-Verdín received a B.Sc. degree in Engineering Geophysics from the National Polytechnic Institute of Mexico, a M.Sc. degree in Electrical Engineering from the University of Texas at Austin, and a Ph.D. degree in Engineering Geoscience from the University of California at Berkeley in 1991. During 1991-1997, he held the position of Research Scientist with Schlumberger-Doll Research. From 1997-1999, he was Reservoir Specialist and Technology Champion with YPF (Buenos Aires, Argentina). Since 1999, he has been affiliated with the Department of Petroleum and Geosystems Engineering of the University of Texas at Austin, where he is currently Full Professor, holds the Brian James Jennings Memorial Endowed Chair in Petroleum and Geosystems Engineering, and conducts research on borehole geophysics, formation evaluation, petrophysics, well logging, and integrated reservoir description. Dr. Torres-Verdín is the founder and director of the Research Consortium on Formation Evaluation at the University of Texas at Austin, which has been in operation for 21 years and is currently sponsored by 20 companies. He has published over 230 refereed journal papers and over 250 conference papers, two book chapters, co-authored one book, is co-inventor of 6 U.S. patents, has served as Guest Editor for Radio Science, invited Associate Editor for *Interpretation* (Society of Exploration Geophysicists, SEG), Associate Editor for the *Journal of Electromagnetic Waves and Applications*, *SPE Journal* (Society of Petroleum Engineers, SPE), and *Petrophysics* (Society of Petrophysicists and Well Log Analysts, SPWLA), chair of the editorial board of *The Leading Edge* (SEG), Editor of *Petrophysics* (SPWLA) and Assistant Editor for *Geophysics* (SEG). He is a member of the research committee of the SEG, was a member of the technical committee of the SPWLA during two 3-year terms, was VP of Publications of the SPWLA during two one-year terms, and currently serves as VP Technology of the SPWLA. Dr. Torres-Verdín is recipient of the 2020 Virgil Kauffman Gold Medal from the SEG, 2019 Anthony Lucas Gold Medal from the SPE, 2017 Conrad Schlumberger Award from the EAGE (European Association of Geoscientists and Engineers), 2014 Gold Medal for Technical Achievement from the SPWLA, 2008 Formation

Evaluation Award from the SPE, 2006 Distinguished Technical Achievement Award from the SPWLA, Distinguished Member of the SPE, and Honorary Member of the SEG. He also received the 2003, 2004, 2006, and 2007 Best Paper Awards in *Petrophysics* (SPWLA), Honorable Mention for the 2015 Best Paper published in *Geophysics*, 2020 Best Paper Award published in *Geophysics*, 2006 and 2014 Best Presentation Awards and the 2007 Best Poster Award by the SPWLA, and was designated Distinguished Technical Speaker during 2006-2007 and 2013-2014 by the SPWLA. Dr. Torres-Verdín has supervised 34 PhD and 47 Master's students, conducted numerous industry training courses, co-chaired several technical workshops and conference sessions, and has served as member of multiple SPE, SPWLA, and SEG committees in the past. The internet link http://sites.utexas.edu/carlostorresverdin/ provides a historical and detailed record of the publication, technical projects, training courses, and research projects undertaken by Dr. Torres-Verdín.

1:00 – 1:30 p.m.

"As-Received" Core Electrical Properties

Authors: Kent Newsham, Ragheb (Ray) Hanna, Robert Lee, Craig Whitney, Roland Chemali

Objective: To provide a superior workflow that circumvents wettability alteration & retain fresh clay structure while establishing Archie's Parameters "m" & "n"

Methods, Procedures, Process: When cores are received. Formation water resistivity (Rw) is measured using a patented resistivity dispersion method (RwCore Patented). Bulk resistivity (Rt) is measured using a two-electrode system. Initial porosity and water saturation (Sw%) are measured using high frequency nuclear magnetic resonance (NMR). The sample is de-saturated by centrifuge, applying a series of drawdown pressures with Sw and Rt measured at each de-saturation state. Ro, the resistivity of a 100% water-saturated sample, is derived from an Rt versus Sw regression analysis. FF, RI and the Archie parameters of 'm' and 'n' are calculated using traditional methods.

Results, Observations, Conclusions: Test samples used in this study include Bone Spring silts, and Wolfcamp and Avalon organic mudstones. All tests were successfully completed on each sample at each step in the process. Calculation of Ro was best determined from results measured at the "as-received" state and after the first desaturation step. For each sample, the graphical solution of the porosity exponent, 'm', was determined from the cross-plot of FF and porosity, while the solution of the saturation exponent, 'n', was determined from the cross-plot of Sw and RI. These results were crosschecked against the measured Sw using a numerical solution and graphical solution of the Archie equation. All tests were found to be consistent with the measured Sw. Results ranged from 1.9 to 2.2 for 'm' and 1.7 to 2.6 for 'n'.

Relevance: This method provides an accurate and relatively fast measurement of FF and RI on "as-received" samples, resulting in the determination of the Archie parameters 'm' and 'n'. These parameters play an essential role in estimating hydrocarbon in place using Archie's equation and provide insight into partial oil-wetting conditions. Cleaning, drying, and resaturating the sample is not required, minimizing the risk of altering the initial wetting state of the sample.

R. Ray Hanna, Sr. Technical Advisor _ Petrophysics (SCAL) & SME-Electrical Properties at Core Laboratories'. Ray holds a BSc. in Geology minor Physics and Math from Cairo University - Egypt.

Ray has worked in Core Analysis for 33+ years and has played a leading role in the development of the Core Laboratories RwCoreTM Patented technology, as well as introducing the core-based Dielectric response measurements technology in the servicing sector; Ray has co-authored SPE-191746-MS paper, in addition to several internal proprietary publications to Core Laboratories. Ray is a member of SPWLA, SPE, and Rt-Sig. Ray works on the research and development of new improved workflows that can improve technical results dealing with the ultra-tight formations, using new venues that were not conventionally been used.

1:30 – 2:00 p.m.

Diffusional and Electrical Tortuosity of Unconventional Shale Reservoirs

Ali Tinni

Abstract: Tortuosity is a property that measures the interconnectedness and sinuosity of the pore space. It plays a critical role during electrical conduction and fluid flow, particularly in low porosity low permeability reservoirs such as unconventional shales. Despite their importance, experimental values of diffusional and electrical tortuosities of shales are scarce. To improve the understanding of diffusive transport and electrical conductivity in unconventional shale reservoirs, we have measured and compared the diffusional and electrical tortuosities of shale samples from the Utica, Bakken, Wolfcamp and Eagle Ford formations.

To measure the diffusional tortuosities, the samples were saturated with 2.5% KCl brine and immersed into D_2O in order to allow the diffusion of D_2O into the samples. The rates at which D_2O diffused into the samples were obtained with 12 MHz NMR measurements. The combinations of the effective diffusion coefficients of D_2O and the bulk diffusion coefficient of D_2O were used to compute the diffusional tortuosities.

To obtain the electrical tortuosities, the samples were resaturated with 2.5% KCl brine prior to immersion into 6% KCl brine. The measurements of the samples' resistivities as function of time after immersion into the 6% KCl brine were used to compute the effective ionic diffusion coefficients. These effective ionic diffusion coefficients were used to compute the electrical tortuosities. The electrical tortuosities of the samples were also computed using the formation factors obtained at the end of the ionic diffusions.

Our measurements show that the diffusional and electrical tortuosities have similar values. These tortuosities vary between 1.4 and 5.8 for the unconventional shale samples studied. We also observed that TOC exerts a primary control on the tortuosity of unconventional shale reservoirs.

The observations made during this study also show that electrical and diffusive flows are controlled by the same flow path. Therefore, electrical properties can be predicted from diffusion measurements.

Dr. Ali Tinni is a faculty in the Petroleum Engineering Department of the University of Oklahoma. Dr. Tinni's research interests revolve around reservoir characterization and enhanced oil recovery. Dr. Tinni has developed several workflows involving the use of analytical tools such as NMR to evaluate unconventional reservoirs. He holds Master's and PhD degree in Petroleum Engineering from the University of Oklahoma.

2:00 – 2:30 p.m.

Title: Enhanced Assessment of Fluid Saturation in the Wolfcamp Formation of the Permian Basin

Authors: Sabyasachi Dash and Zoya Heidari (UT Austin)

Abstract: Conventional resistivity models often overestimate water saturation in organic-rich mudrocks and require extensive calibration efforts. Conventional resistivity-porosity-saturation models assume brine in the formation as the only conductive component contributing to resistivity measurements. Enhanced resistivity models for shaly-sand analysis include clay concentration and clay-bound water as contributors to electrical conductivity. These shaly-sand models, however, consider the existing clay in the rock as dispersed, laminated, or structural, which does not reliably describe the distribution of clay network in organic-rich mudrocks. They also do not incorporate other conductive minerals and organic matter, which can significantly impact the resistivity measurements and lead to uncertainty in water saturation assessment. We recently introduced a method that quantitatively assimilates the type and spatial distribution of all conductive components to improve reserves evaluation in organic-rich mudrocks using electrical resistivity measurements. This paper aims to verify the reliability of the introduced method for the assessment of water/hydrocarbon saturation in the Wolfcamp formation of the Permian Basin.

Our recently introduced resistivity model uses pore combination modeling to incorporate conductive (clay, pyrite, kerogen, brine) and non-conductive (grains, hydrocarbon) components in estimating effective resistivity. The inputs to the model are volumetric concentrations of minerals, the conductivity of rock components, and porosity obtained from laboratory measurements or interpretation of well logs. Geometric model parameters are also critical inputs to the model. To simultaneously estimate the geometric model parameters and water saturation, we develop two inversion algorithms (a) to estimate the geometric model parameters as inputs to the new resistivity model and (b) to estimate the water saturation. Rock type, pore structure, and spatial distribution of rock components affect geometric model parameters. Therefore, dividing the formation into reliable petrophysical zones is an essential step in this method. The geometric model parameters are determined for each rock type by minimizing the difference between the measured resistivity and the resistivity, estimated from Pore Combination Modeling.

We applied the new rock physics model to two wells drilled in the Permian Basin. The depth interval of interest was located in the Wolfcamp formation. The rock-class-based inversion showed variation in geometric model parameters, which improved the assessment of water saturation. Results demonstrated that the new method improved water saturation estimates by 32.1% and 36.2% compared to Waxman-Smits and Archie's models, respectively, in the Wolfcamp formation. The most considerable improvement was observed in the Middle and Lower Wolfcamp formation, where the average clay concentration was relatively higher than the other zones. Results demonstrated that the proposed method was shown to improve the estimates of hydrocarbon reserves in the Permian Basin by 33%. The hydrocarbon reserves were underestimated by an average of 70000 bbl/acre when water saturation was quantified using Archie's model in the Permian Basin. It should be highlighted that the new method did not require any calibration effort to obtain model parameters for estimating water saturation. This method minimizes the need for extensive calibration efforts for the assessment of hydrocarbon/water saturation in organic-rich mudrocks. By minimizing the need for extensive calibration work, we can reduce the number of core samples acquired. This is the unique contribution of this rock-physics-based workflow.

Sabyasachi Dash is a PhD student under the supervision of Dr. Zoya Heidari in the Department of Petroleum and Geosystems Engineering at The University of Texas at Austin. He holds a master's degree in geophysical technology from the Indian Institute of Technology, Roorkee. Sabyasachi has 6 years of experience as an exploration geophysicist working for Cairn India Ltd in fluvial rift systems and the thrust belt area. He is one of the recipients of the 2021 SPWLA Distinguished Speaker Award. His current research interests include formation evaluation, multiscale petrophysics, rock physics, and mathematical modeling.

2:30 -2:45

SDAR Report

Hui Xie, Michael Rabiovich, Jimmy Dai, Alban Duriez, Frank Antonsen

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2:45 -3:00 Business Meeting

Agenda

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