<table>
<thead>
<tr>
<th>Start</th>
<th>End</th>
<th>Speaker</th>
<th>Company</th>
<th>Talk Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>09:00</td>
<td>09:30</td>
<td></td>
<td>Registration</td>
<td></td>
</tr>
<tr>
<td>09:30</td>
<td>10:15</td>
<td>Michael O’Keefe</td>
<td>LPS</td>
<td>Welcome &amp; Introduction</td>
</tr>
<tr>
<td>10:15</td>
<td>11:15</td>
<td>Kevin Corrigan</td>
<td>Independent Consultant</td>
<td>What is Advanced Formation Evaluation?</td>
</tr>
<tr>
<td>11:15</td>
<td>12:15</td>
<td>Roddy Irwin</td>
<td>Rockflow Resources LTD</td>
<td>Shaly sand evaluation in the total &amp; effective porosity systems: Know the difference!</td>
</tr>
<tr>
<td>10:45</td>
<td>11:15</td>
<td></td>
<td>Break</td>
<td></td>
</tr>
<tr>
<td>11:15</td>
<td>12:15</td>
<td>Iain Whyte</td>
<td>Tullow Oil</td>
<td>Resistivity in thin beds...some case studies</td>
</tr>
<tr>
<td>11:45</td>
<td>12:15</td>
<td>Michel Claverie</td>
<td>Schlumberger</td>
<td>A review of low-resistivity &amp; low-resistivity contrast pay with focus on Africa</td>
</tr>
<tr>
<td>12:15</td>
<td>12:45</td>
<td>Steve Cuddy</td>
<td>Baker Hughes/SPE</td>
<td>Using fractals to determine a reservoir’s hydrocarbon distribution</td>
</tr>
<tr>
<td>15:00</td>
<td>15:30</td>
<td>Richard Dawe</td>
<td>Retired Consultant</td>
<td>The problem of the high permeability streak</td>
</tr>
<tr>
<td>15:30</td>
<td>16:00</td>
<td>Mike Lovell</td>
<td>Leicester University</td>
<td>Shale gas petrophysics; key parameters, assumptions, and uncertainties</td>
</tr>
<tr>
<td>16:00</td>
<td>16:30</td>
<td>Chiara Cavelleri</td>
<td>Schlumberger</td>
<td>Improved cased-hole formation evaluation: the value of new fast neutron cross-section measurements &amp; high definition spectroscopy</td>
</tr>
<tr>
<td>16:30</td>
<td>17:00</td>
<td>TBA</td>
<td>Independent Consultant</td>
<td>Getting More from Less - Using legacy data and sparse data sets</td>
</tr>
<tr>
<td>17:00</td>
<td>17:10</td>
<td>Michael O’Keefe</td>
<td>LPS</td>
<td>Closing Comments</td>
</tr>
<tr>
<td>17:10 onwards</td>
<td></td>
<td></td>
<td>Refreshments</td>
<td></td>
</tr>
</tbody>
</table>
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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.

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The following pages contain the Abstracts
What is Advanced Formation Evaluation?

Kevin Corrigan, Independent Consultant

You’ve been on the courses, read the books, are proficient at making the calculations and doing what you’ve been asked to do, and now it’s time to step up to the plate as your mentors move on. This is a scenario that will be new to many as they find themselves in an industry that is down-sizing and the responsibilities fall to them to make, not only the necessary calculations, but key judgments and analyses for the all-important investment decisions.

The end of “easy oil” is upon us and no longer can we rely upon conventional reservoirs and standard analytical techniques to deliver the necessary supplies. We have to look toward advances in our understanding, which can be delivered or supported by academia, software houses, service companies and consultancies. We should no longer be afraid to say “I don’t know” or “I need some guidance”, particularly as our sphere of influence grows and our results greatly impact associated disciplines. Today’s seminar is a part of that learning experience as we go forward in this new era and take on the challenges of: shale gas, thinly-bedded reservoirs, carbonate plays, low resistivity pay and complex reservoir solutions, to name a few.

Examples will be shown where, by no longer taking a Petrophysics 101 view of the data but approaching it from an integrated and Advanced Petrophysical viewpoint, we can obtain totally unexpected results.

Kevin Corrigan has over 40 years of Petrophysics experience in the industry and has been a member of the SPWLA (London Chapter) and LPS during that time. He entered the industry with Schlumberger in Paris, as it developed its Computerized Processed Interpretation software. He was a wireline Field Engineer in North Africa and the Middle East, before becoming a Petrophysicist with BP in the North Sea. He has worked on numerous international projects as a consultant and has recently left Anadarko Petroleum where he was a Petrophysics Manager for the Gulf of Mexico and International New Ventures. Kevin is a Chartered Engineer and member of the SPWLA, SPE, PESGB and IMMM.
Shaly Sand Evaluation in the Total & Effective Porosity Systems: Know the Difference!

Roddy Irwin, Rockflow Resources Ltd.

Every profession has its enduring debates and differences of opinion. Petrophysics has, for decades, been divided into the Total Porosity and Effective Porosity camps in terms of Shaly Sand evaluation approaches. Petrophysicists even argue over the precise definition of Effective Porosity and serious disputes arise concerning the use of either a Volume of Shale or Volume of Clay term in the analysis. Tempers have been lost and some petrophysicists no longer send each other Christmas cards as a result.

Essentially Total Porosity is the entire pore space which may contain fluids, regardless of whether they are mobile or bound. Effective Porosity evaluation approaches attempt to distinguish the free fluid porosity portion from bound fluids.

Calibration of the petrophysical log evaluation to core analysis data requires a working understanding of the core analysis process to determine the extent that either porosity system is represented by the core data. Controlled humidity drying of the core plugs is designed to preserve the intra porosity clay structure, but this is not always the case in practice.

In principle, hydrocarbon volumes estimated from either system should be equal, as the porosity decrease resulting from moving from a Total Porosity to an Effective Porosity must be compensated by an increase in the hydrocarbon saturation since the same hydrocarbon amount is present in nature. However this only works if the Total and Effective evaluation protocols are followed rigorously and the appropriate saturation equations are applied: Total and Effective porosity systems require distinctly different types of Water Saturation equations, as the conductivity property of clay is treated differently in each system.

With the widespread use of multimineral probabilistic interpretation modules in modern petrophysical software it is all too easy to run a “black box” evaluation without due consideration to the reasons why specific algorithms or routines should be adopted or avoided. The risk is that an inappropriate evaluation could be performed without due consideration of the formation lithology, the porosity systems, the hydrocarbon phases and the available core analysis data.

The talk builds upon concepts introduced in the LPS 2016 Petrophysics 101 Seminar and will cover the appropriate methods for the determination of Porosity and Water Saturation in Shaly Sandstone reservoirs. The key differences and potential pitfalls of the Total and Effective Porosity System evaluation protocols will be highlighted. The special case of laminated thin bedded Shaly Sands will also be addressed.

Roddy Irwin: Partner & Principal Petrophysicist at Rockflow Resources Ltd., 26 years’ petrophysical evaluation experience gained during an international career with major oil companies and consultancies.
Resistivity in Thin-Bed... some case studies

Iain Whyte, Tullow Oil

This presentation will open with some basics of resistivity measurement principles and then move on to look at some field examples where oft time very large financial decisions were required to be made near real time based on available data. We will look at some tool measurement phenomenon and what to watch out for including how to model or correct for those effects.

Iain Whyte has worked for Tullow Oil for past 6 years in the role of Group Operations Petrophysics Lead supporting data acquisition of all types for Tullow Oil globally. Prior to this he worked as a Petrophysicist and Operations Petrophysicist for BP between 2004 and 2010 in locations including Turkey, Norway, Azerbaijan and Angola. Iain’s background prior to moving to work for Operators was as a Wireline Logging Engineer, working 1 year for Weatherford and 7 years for Baker Hughes. In his spare time he is the current President of London Petrophysical Society. He received his honours degree in Applied Physics from Robert Gordon University in 1995.
A review of low-resistivity and low-resistivity-contrast pay with focus on Africa

Michel Claverie, Schlumberger

We will review the rocks and fluids characteristics that cause hydrocarbon reservoirs to exhibit either low formation resistivity or low resistivity contrast with water-bearing zones. Together with the evaluation of accurate hydrocarbon volumes in these reservoirs, we will look at methods to estimate their flow properties and predict their produced fluids fractions.

Africa offshore and land reservoirs display a wide variety of complex formation resistivity patterns from thin sand and shale laminations, porous and silty sandstones, lithic or homogeneous fresh water sands, and conductive grain-coating minerals. As we go through several case studies, we will comment on the limitations of the porosity-resistivity saturation methods for shaly sands, and describe simple and robust alternative methods for the estimation of hydrocarbon volumes and predicted produced fluids fractions.

Fig. 1: Very fresh water reservoirs, onshore Africa. The oil volumes calculated from porosity-resistivity (Archie) are highly dependent on the selected formation water salinity FSAL.

Fig. 1: Very fresh water reservoirs, onshore Africa. The oil volumes calculated from porosity-resistivity (Archie) are highly dependent on the selected formation water salinity FSAL.

Michel Claverie is the Petrophysics Technical Director for Schlumberger Wireline. Based in London, he also provides technical support to operators in the Europe-Africa region.
Using fractals to determine a reservoir’s hydrocarbon distribution

Dr Steve Cuddy, Baker Hughes / SPE

In order to determine a field’s hydrocarbon in place it is necessary to model the distribution of fluids throughout the reservoir. A water saturation vs. height (Swh) function provides this for the reservoir model. A good Swh function ensures the three independent sources of fluid distribution data are consistent. These being the core, formation pressure and electrical log data. The Swh function must be simple to apply, especially in reservoirs where it is difficult to map permeability or where there appears to be multiple contacts. It must accurately upscale the log and core derived water saturations to the reservoir model cell sizes.

This presentation clarifies the often misunderstood definitions for the free-water-level, transition zone and irreducible water saturation. Using capillary pressure theory and the concept of fractals, a practical Swh function is derived. Logs and core data from eleven fields, with very different porosity and permeability characteristics, depositional environments and geological age are compared. This study demonstrated how this Swh function is independent of permeability and litho-facies type and accurately describes the reservoir fluid distribution.

Also how the shape of the transition zone is related more to pore geometry rather than porosity or permeability alone. Consequently, this Swh function gives insights into a reservoir’s quality as determined by its pore architecture. A number of case studies are presented showing the excellent match between the function and well data. The function makes an accurate prediction of water saturations even in wells where the resistivity log was not run due to well conditions. The fractal derived function justifies using core plug sized samples to model water saturations on the reservoir scale.

Steve Cuddy is an Honorary Research Fellow at Aberdeen University where he holds a doctorate in petrophysics. He also holds BSc (Hons.) in physics and a BSc in astrophysics and philosophy. He has 40 Years industry experience in formation evaluation and reservoir description. He is a distinguished lecturer for the SPE and has been awarded the best SPWLA symposium paper award. He was the General Chairman with overall responsibility for the Annual Logging Symposium of SPWLA in Edinburgh. He has authored a number of SPWLA and SPE papers and carried out more than 200 reservoir studies.
Joint Interpretation of Magnetic Resonance - and Resistivity-Based Fluid Volumetrics – A Framework for petrophysical evaluation

Holger Thern, Geoffrey Page, Baker Hughes Inc.

The accurate quantification of fluid volumes is one of the most important tasks for determining the economic value of hydrocarbon reservoirs. Fluid saturation calculation from resistivity logging data has been established for many decades with known benefits and challenges. More recently, the nuclear magnetic resonance (NMR) logging technology has developed as an alternative, robust method for direct fluid volume estimation by separating movable from bound fluids. As today’s reservoirs are becoming more challenging, conventional resistivity logging data evaluation involves increasing difficulties and ambiguities, for instance in complex lithology due to the presence of conductive minerals, low formation water salinity, fractures and vugs, or local variations in water resistivity. NMR logging data processing and interpretation are also not straight-forward in complex carbonates and heavy oil reservoirs, as well as in case of wettability alteration and due to the presence of magnetic minerals. Ambiguities in either of the measurements can be efficaciously addressed by combining data from both logging services.

We present a systematic compilation and discussion of main properties affecting resistivity and NMR fluid volume estimations such as Archie parameters and $T_2$ cutoffs. Several log examples illustrate a wide range of reservoir scenarios. In addition to the log interpretation aspect, we also relate the results to their applications ranging from real-time drilling optimization through hydrocarbon-in-place estimates and reservoir modeling input to production and completion decisions.

ABOUT THE AUTHORS

Holger Thern is a Technical Lead for NMR research at the Celle Technology Center at Baker Hughes in Germany working with NMR technology for 18 years. Holger earned a B.A. in Physics from the University of Constance and an M.Sc. in Geophysics from the University of Cologne. His work experience includes data interpretation development and technical support for NMR wireline logging applications with Western Atlas in Houston, Texas, and the development of the MagTrak NMR LWD tool in Celle, Germany. Currently he is working on new NMR applications and interpretation methods for both wireline and LWD NMR applications.

Geoffrey Page studied physics at the Royal College of Science in London. He began his oilfield career as a Dresser Atlas field engineer 36 years ago, moved into Petrophysics in Aberdeen 28 years ago, and is now Region Petrophysical Advisor for Baker Hughes based in Aberdeen. He is a former President of the Aberdeen chapter of the SPWLA (AFES) and was honoured with a “life membership.” He has written and presented many papers over the years, helped organise many of the conferences including SPWLA 2008 in Edinburgh, and in his spare time teaches the Petrophysics course of Aberdeen University’s “Integrated Petroleum Geoscience” MSc course.
The Problem of the High Permeability Streak

Prof Richard Dawe - Emeritus Professor in Petroleum Studies, UWI

When the Ninian field was brought on-stream in December 1978 water broke through in 94 days, when it was predicted to be no less than 2 years! Why? Answer - a high permeability streak.

This talk will discuss why - why it happened and why it is bad news for the producer.

We then explore the problems of averaging permeability when it ranges over a number of orders of magnitude.

We will then briefly discuss how the high permeability can be modelled in reservoir engineering - Stiles, Buckley Leverett, when there is gravity crossflow and reservoir simulation.

We finish with some pragmatic thoughts on how to handle a reservoir with a high permeability streak.
In estimating the gas initially in place and determining some simple geomechanical attributes, the petrophysicist starts with well-established techniques and methods that we have successfully applied over many decades to conventional reservoirs. Some of these approaches work, at least in part, on some occasions, but equally we must adapt and modify what we do to take account of the complexity of the different “shale” formations we are trying to evaluate. The petrophysical evaluation of a shale presents significant challenges, not least because the gas has generally not been concentrated through the normal buoyancy processes we encounter in conventional reservoirs, and consequently is dispersed throughout the rock.

Furthermore, shales, or more strictly organic-rich mudstones, have a comparatively varied mineralogy, significant organic matter, two separate gas components (adsorbed and free), are characterized by exceptionally low permeability’s, and can vary both laterally and vertically over short distances. Building on groundbreaking work in the 1980s by the Gas Research Institute, our understanding of shales has improved substantially in recent years. While there is no single correct approach, there are various appropriate routes through the shale gas petrophysics maze, and an awareness of the key parameters, assumptions, and uncertainties can help constrain and improve our petrophysical interpretation and understanding.
Improved Cased-hole Formation Evaluation: The Value of New Fast Neutron Cross-Section Measurement and High Definition Spectroscopy

Chiara Cavalleri, Schlumberger, Petrophysics Domain Champion

Cased-hole formation evaluation has a primary role on proper description of existing reservoir systems and definition of additional productive sand units to assist improved reservoir description and completion optimization, as well as guiding intervention programs or plug and abandonment operations. The log examples we present demonstrate the applicability of a new pulse neutron wireline service to deliver critical evaluation outputs behind casing and within completion.

Additionally to more traditional pulse neutron logging and spectroscopy output, we will show a new formation nuclear property also measured by this service, the fast neutron cross section (FNXS). Being sensitive to the formation’s atom density, with no dependency on formation elements and hydrogen index, the FNXS measurement makes it possible to differentiating gas-filled porosity and low porosity formation. It enable a quantitative gas volumes estimate and provides a standalone cased hole formation evaluation when combined with sigma and spectroscopy outputs, which are also available with the new pulse neutron tool.
Getting More for Less: Using legacy data and sparse data sets

An Independent Consultant

The Electric Logging Industry has a proud record of technological innovation, with new tools and new interpretation techniques constantly improving our ability to understand the subsurface. Unfortunately not all the wells you need to analyse will have a full set of these modern logs.

Sitting on the shelves in store-rooms all over the world are thousands of 'legacy' logs. And even if these borehole data have been acquired with older technology, they still have value and can provide useful information about the reservoir potential in the basin. This is particularly relevant to frontier areas which have experienced some limited hydrocarbon exploration activity in the past and are due a re-evaluation.

Sometimes safety or other well operations can prevent the acquisition of a full suite of electric logs in current wells. In this case it is still the role of the Petrophysicist to evaluate the borehole data that is acquired to guide further operations, whether these be to plug and abandon the well, run completions, plan a side-track or a new well, or to update the hydrocarbon volumes or the geological model.

Examples will be used to show how limited electric log data-sets can be used to illuminate the subsurface and to form the basis of meaningful decision making. But it has to be remembered that limited data will probably lead to limited answers, and it is also the role of the Petrophysicist to highlight the uncertainty resulting from the limited data acquisition.

Useful Reading:
The Art of Ancient Log Analysis, 1979; SPWLA Reprint
Tittman, J. 1986, Geophysical Well Logging

Useful links;
http://petrowiki.org/PetroWiki
http://www.fesaus.org/glossary/doku.php
http://www.glossary.oilfield.slb.com/