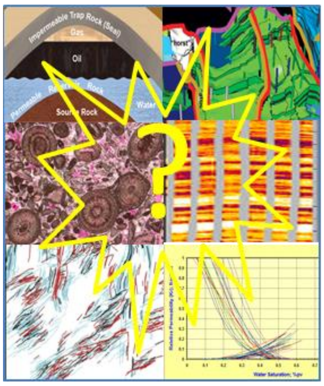


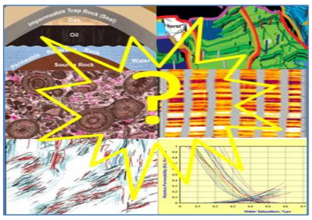
Challenging Reservoirs

LPS

Thursday 21st September 2017

The Geological Society, Burlington House, London

	Start time	End time	Name	Affiliation	Talk Title
	09:00	***09:30***	***Registration***		
	09:30	**09:45**	***Joanne Tudge***	***LPS***	***Welcome & Introduction***
1	**09:45**	**10:05**	Roddy Irwin	*Rockflow Resources LTD.*	Is there such a thing as a "Simple" Reservoir?
2	**10:05**	**10:40**	Mike Millar	*Independent*	North Sea Chalk – A Challenging Reservoir
	10:40	**11:15**	**Break**		
3	11:15	11:50	Iain Whyte	*Tullow Oil*	The added value of multiple data sources in complex lithologies - some practical examples of an operator's perspective
4	11:50	12:25	David Maggs	*Schlumberger*	Laminated Reservoirs - what can you do with pesky LWD Data?
5	12:25	13:00	Paul Worthington	*Park Royd P&P*	Thin bed analysis - calibration of the Thomas-Stieber model
	13:00	**14:00**	**Lunch**		
6	14:00	14:35	Krishnan Raghavan	*Nexen*	Exploration Success in a Low Resistivity Low Permeability Reservoir
7	14:35	15:10	Michel Claverie	*Schlumberger*	Evaluating hydrocarbon volumes and predicting produced fluids in "Challenging Reservoirs"
	15:10	**15:45**	***Break***		
8	15:45	16:20	Stephen Fayers	*Baker Hughes*	Fractured basement evaluation utilizing borehole images and acoustic Deep Shear Wave Imaging
9	16:20	16:55	Adriaan Gisolf	*Schlumberger*	In-situ measurement of low-level H2S in Fluid Sampling
	16:55	17:00	***Joanne Tudge***	***LPS***	***Closing Comments***
17:00 onwards			***Refreshments***		



Challenging Reservoirs

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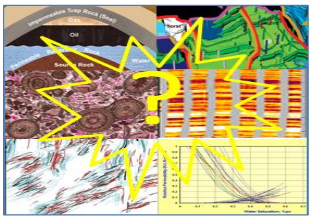
The following pages contain the Abstracts



Challenging Reservoirs

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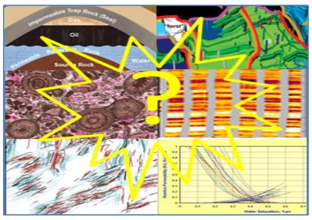
Is there such a thing as a "simple" reservoir? An overview of challenging reservoir types and their petrophysical interpretation

Roddy Irwin, Rockflow Resources Ltd.

The diversity in petrophysical properties of conventional oil and gas reservoirs reflects not only the original depositional environment but also the burial history and subsequent diagenesis of the reservoir rock. Every petroleum reservoir has its unique complexities and challenges in terms of petrophysical evaluation. However, the petrophysical community has attempted to classify reservoirs into broad types, e.g. clastics/carbonates; monomineralic/multimineralic; clean/shaly; massive/laminated etc. This has been done historically to enable the identification of appropriate petrophysical workflows to be applied to specific reservoir types. However, within these broad reservoir types nature has conspired to create some really tricky rock and fluid combinations which require careful application of logging and evaluation techniques: e.g. shaly clastics with freshwater; thin bedded laminated shale/sand; high capillary bound water; carbonates with multiple pore systems and fluid fills to name a few.

This talk will give a high level overview of the main "conventional" reservoir types, highlighting where special circumstances make these a challenge to evaluate and where inappropriate application of "standard" evaluation techniques could put an unwary interpreter onto the road to perdition. The art of petrophysics is essentially applied problem solving and the key enabling techniques and technologies will be discussed to initiate further debate during the course of the day….and possibly into the evening too.

Roddy Irwin: *Partner & Principal Petrophysicist at Rockflow Resources Ltd., 27 years' petrophysical evaluation experience gained during an international career with major oil companies and consultancies.*



North Sea Chalk – A Challenging Reservoir

Mike Millar

This presentation will show some of the techniques and pitfalls involved in the formation evaluation of Chalk reservoirs using North Sea examples. It will show how petrophysical evaluations can be used as inputs to Geological and Engineering models to determine the in-place volumes and the potential reserves. Petrophysics also works with Production Engineering to help design well placement and completions to effectively exploit the resource. Saturation monitoring during the life of the field also plays an important role in ensuring maximum economic recovery.

Late Cretaceous Chalk is generally an autochthonous micritic carbonate rock made from the tests of coccolithophores. It is very fine grained with generally good to excellent matrix porosity, but generally poor matrix permeability. Chalk is generally very clean (low clay content) with a narrow range of grain density. The Chalk's original structure may have been altered in a number of ways, by re-sedimentation, diagenesis and fracturing. The re-sedimentation can occur by slumping, mass flow and turbidity currents. Diagenesis takes many forms including bioturbation, cementation and compaction. Hydrocarbon production frequently relies on natural fractures.

At a superficial level Chalk is a simple rock type to analyse, and it can be easy to determine porosity and saturation. However, permeability can be dependent on matrix and / or fractures, making permeability prediction and modelling difficult. There are generally long transition zones in the hydrocarbon columns of Chalk fields, but oil can be produced from fractures which are not reflected in the responses of resistivity logs. These fractures can be below the resolution of images logs. Also, pervasive fractures can make core recovery poor, so the better reservoir may not be represented in core analysis.

Some North Sea Chalk oil fields have been shown to have tilted free-water levels, which together with the long transition zones, further complicate prospect evaluations and reserves assessments.

Harris, R. G., And Goldsmith, P. J. 2001. Water Saturation Analysis And Interpretation Of A Tilted Free-water Level In The Joanne Chalk Field, U.K. North Sea. SPWLA 42nd Annual Logging Symposium, paper EEE.

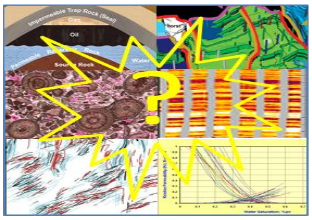
Dennis, H. et al, 2005. Tilted Oil-water Contacts: Modelling The Effects Of Aquifer Heterogeneity. Petroleum Geology: North-west Europe And Global Perspectives - 6th Geological Society Of London Petroleum Geology Conference Proceedings.

The added value of multiple data sources in complex lithologies – some practical examples of an operator's perspective

Iain Whyte & Oliver Tallon, Tullow Oil

Hydrocarbons reside in many different environments and are not exclusively confined to Archie type rocks. When these situations occur, the petrophysicist needs to be able to adjust their approach in analysing these reservoirs if we want to understand the true volumetrics within our reservoirs. Relying on one approach, tool or interpretation more often than not leads to an inaccurate answer. In the current low oil price environment, there is immense pressure on subsurface teams to find the right balance between spending less money evaluating the reservoirs, whilst also reducing uncertainty on the oil in place in order to make projects economically viable.

The author will show extracts from an operator's perspective on how Tullow Oil approaches these uncertainties and quantify the impacts of the "wrong answer". A mixture of environments will be looked at with particular focus on fresh water reservoirs, shale rich reservoirs, and reservoirs in imbibition.



Laminated reservoirs, what can you do with pesky LWD data?

David Maggs, Schlumberger

Laminated or thin bed reservoirs provide multiple challenges for petrophysical evaluation. By definition the beds are thinner than the resolution of the logging tools and therefore their properties are not fully resolved by the measurements. The situation is further complicated when the measurements (especially resistivity) do not return the correct average value of the multiple beds they are investigating.

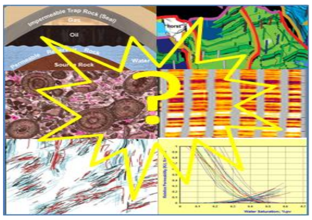
There are two main approaches to determine the correct petrophysical answers in these reservoirs, which I will label “sharpening” and “the big picture”. In the sharpening approach a high resolution log, normally a borehole imager, is used to define the bed boundaries and then the lower resolution logs are sharpened to match. Log convolution is used to ensure the log bed boundary responses are respected when sharpened. After sharpening standard petrophysical algorithms are used to solve for porosity, saturation etc. The big picture approach makes no attempt to define the formation properties in individual layers, but focuses on ensuring that the correct average properties are obtained in an interval. An example would be the use of tri-axial induction tools to determine the horizontal and vertical resistivity of the formation, and then used to determine hydrocarbon volumes and saturations.

The approaches mentioned above have been available for some time and are regularly applied to wireline data in vertical wells. But in these days of tight budgets and high angle and horizontal wells such data is not always available. The talk attempts to demonstrate how the sharpening and big picture approaches can be modified and applied to use LWD data in vertical, high angle and horizontal wells through a series of case studies and examples.

Quality Assuring the Petrophysical Evaluation of Thin Beds

Paul F. Worthington, Park Royd P&P (England) Ltd

Failure to identify thin hydrocarbon-bearing layers has led to the loss of much potential pay over many years. Although the resolution of logging tools has sharpened considerably, many practitioners are using uncalibrated log-analysis protocols because the available petrophysical datasets are not commensurate with reservoir complexity. This presentation looks at ways in which a more definitive evaluation of thin beds can be secured. In particular, the petrophysical evaluation of thinly-bedded sand-shale sequences requires that proper volumetric account is taken of layered and dispersed shales. There are two key issues; the identification of the geometry of thin beds, and the estimation of dispersed shale content within the sand layers. These two issues are addressed with a view to providing an enhanced quality assurance through defined interpretative workflows using petrophysical datasets that are fit for purpose. The benefits are illustrated through case histories that demonstrate a securable hydrocarbon upside.



Challenging Reservoirs

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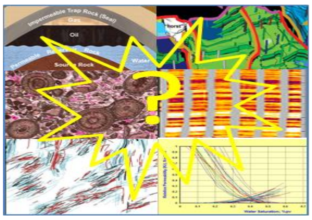
Exploration Success in a Low Resistivity Low Permeability Reservoir – a case study

Krishnan Raghavan – Nexen Petroleum UK Ltd

Contemporary commercial focus on gas raised the significance of a deep gas-bearing sequence which was first identified in 1983 but termed as water-wet. After about 24 years the Upper Miocene sequence became apparent as part of the evaluation of a deep high-pressure (HP) play. The Beta prospect is a simple 3-way fault/dip closed structure with the prospective reservoir section consisting of multiple stacked reservoir-seal pairs. The reservoir architecture is made up of thin interbedded sandstones and shales of inner neritic origin and outer shelfal facies. Expected to have a large lateral extent, the reservoirs were deposited in a lower shore-face environment and thinly bedded, very fine grained sands, which are interpreted as storm events. The general reservoir quality degrades with depth due to compaction. Permeability ranges from 0.01mD to 1mD in reservoirs with 8% to 12% porosity with rare occurrences of thin interbedded high permeability sands. Generating pseudo log to model poor-quality and missing log intervals in well B-1 and the "Back-to-Basics" way of working, resulted in an exploration success story. Well Beta-2(B-2) subsequently discovered significant gas volume in the deep stacked pay sequence. B-2, a vertical well located 7 km offshore in a water depth of 17.4 m, encountered gas in the above-mentioned objectives and a total of some 215m net pay was logged. Although the sands showed relatively low average porosities of only 5 to 10%, the NMR signature, as well as the formation pressures and successful recovery of 3 gas samples, all indicated the likely mobility of gas. After a couple of appraisal wells, the field is currently put on production with an estimated recoverable volume of 450-500BCF. To successfully develop such tight gas sands often requires more reservoir data than conventional reservoirs. The key to improved understanding of in-place volumes is extensive logging, formation pressure tests and samples, coring, and subsequent well testing. Nonetheless, significant uncertainty can be addressed through phased field development which will accommodate future outcomes. In this presentation, it is explained as to how exploration success could be tasted through creative and innovative formation evaluation methods using limited data. The art of discovering oil and gas very much depends on successfully reducing the uncertainties one by one and through application of simple techniques.



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Evaluating hydrocarbon volumes and predicting produced fluids in "Challenging Reservoirs"

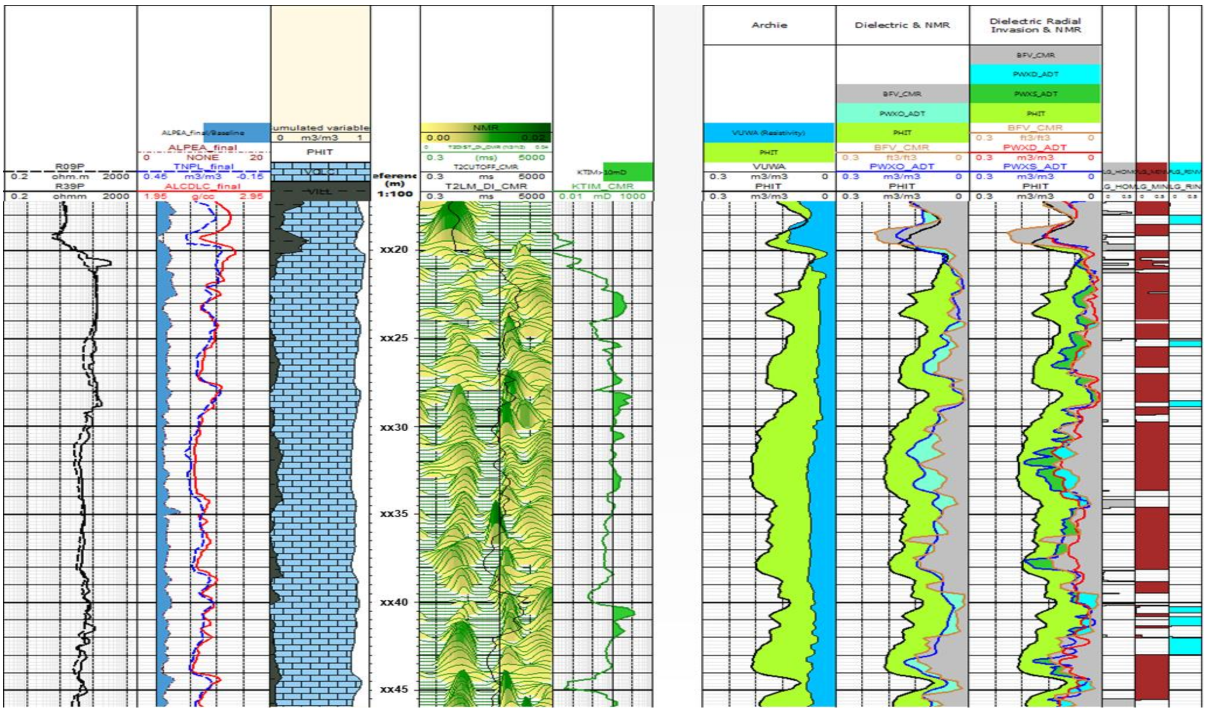
Michel Claverie – Technical Director Wireline Petrophysics, Schlumberger

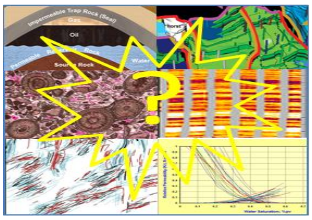
The oil industry is prone to using optimistic euphemisms to describe situations of doubt. The title of this seminar illustrates the point; the expression *challenging reservoir* is often used to describe a reservoir where we don't quite know how to calculate reliable hydrocarbon volumes and predict if a test will produce with water-cut. However, rather than acknowledging these uncertainties, we challenge the petrophysicist to prove that the hydrocarbon volumes are larger than indicated by a conventional analysis and that water is at irreducible saturation. In fact, a *challenging reservoir* is often thought to be a temporary condition on the way to commercial hydrocarbon production without water-cut.

Happily, this is often the case, but we must use all the appropriate technologies and evaluation methods at our disposal to prove it convincingly and without bias.

We present a series of examples where the evaluation of hydrocarbons and moveable water volumes is difficult because of rock mineralogy and texture, and fluids properties. We describe various technologies and interpretation methods that enable a reliable and accurate evaluation of *challenging reservoirs*.

For example, what are the actual oil and free water volume profiles in this carbonate reservoir?





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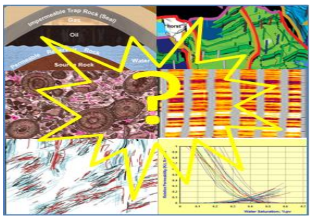
Fractured basement evaluation utilising borehole images and acoustic Deep Shear Wave Imaging

Stephen Fayers, Stephen Morris, Marc Holland, Laura Hynes and Lene Hauge Solberg, Baker Hughes a GE Company

Applications for the characterisation of fractured basement hydrocarbon plays are shown for a North Sea well, utilising the integration of several different types of well dataset. This focuses on LWD high-resolution borehole image data and wireline acoustic Deep Shear Wave Imaging (DSWI).

The exploration of fractured basement plays is becoming an increasingly important subject because natural fractures can play a significant role in hydrocarbon migration and storage. Therefore an understanding of the fracture network and geomechanical properties of the well is of great importance for field development.



In-Situ measurement of low-level H2S in Fluid Sampling

Adriaan Gisolf, Schlumberger

Early quantification of H2S in reservoir fluids is important for many reasons: it is, for example, critical to ensure the safety of people involved in wellsite operations but it is also a determining factor in project economics. Detecting H2S has been challenging because H2S is scavenged by many materials that a reservoir fluid is exposed to during formation testing or well testing operations. The amount of H2S scavenged is determined by the type of material, the quantity of material and the exposure time of reservoir fluid during its path from the reservoir to the H2S measurement. One solution available to operators is to do an extended well test. By producing the reservoir for an extended time, the produced fluid saturates the flow path to the surface and a measurement can be made on surface. Alternatively, a formation tester can be used to capture fluid samples, but this requires the tool to be configured to minimise scavenging materials en-route to the bottle and to ensure that no scavenging mud filtrate is captured with the formation fluid sample. Although both these methods have been used successfully in the past there can be many pitfalls that prevent accurate detection, particularly when low levels of H2S are present.

A new sensor has been developed that can quantify H2S levels during formation tester sampling operations. The sensor measurement methodology and workflow will be presented together with a recent example. Because the sensor is placed close to the Formation tester probe, virtually no H2S is scavenged before the measurement is made. The measurement can be made in all reservoir fluid types and mud systems. Since H2S is quantified as a function of time on station it is possible to visualize the effects of mud filtrate contamination while pumping fluids from formation.