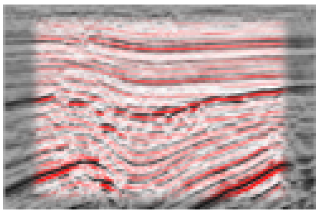


Seismic Rock Physics – One Day Seminar

Thurs 27th September 2018

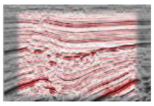
The Geological Society, Burlington House, London

LPS One Day Seminar - Seismic Rock Physics - Thurs 27th Sep - Geological Society					
	Start time	End time	Presenter	Affiliation	Title
	08:45	09:15	**Registration**		
	09:15	09:25	Mike Millar	LPS President	Welcome address
1	09:25	10:00	Jonathan Pye	Rockflow	Introduction
2	10:00	10:35	Grant Affleck	Weatherford	A Geophysical Approach to Detecting Casing Issues
3	10:35	11:10	Nasser Bani Hassan	ERCE	Incorporating FWI velocity in simulated annealing based acoustic impedance inversion – Jansz gas field case study
	11:10	11:40	**Break**		
4	11:40	12:15	Rafael Guerra	Schlumberger	Calibration of anisotropic velocity models using sonic and Walkaway VSP
5	12:15	12:50	Reza Saberi	CGG	Determining Biot Coefficient
	12:50	13:40	**Lunch**		
6	13:40	14:15	Pat Connolly	Patrick Connolly Associates	Probabilistic seismic inversion using pseudo-wells
7	14:15	14:50	Sam Matthews	BP	One Dimensional Stochastic Inversion for Quantitative Seismic Reservoir Characterisation - Case studies
8	14:50	15:25	Rajat Singh Rathore	CGG	Fluid replacement modelling- A key to understand seismic response with fluid content variation
	15:25	15:55	**Break**		
9	15:55	16:30	Åsmund Drottning	Rock Physics Technology AS	Rock Physics modelling and inversion
10	16:30	17:05	Nick Huntbatch	Ikon Science	The role of regional rock physics knowledge in reducing uncertainty
	17:05	17:10	Dawn Houliston	LPS VP Technology	Closing remarks
	17:10	Onwards	**Wine and savouries in the library**		

£150 for delegates (Speakers exempt)
(LPS is not VAT registered)
Students can register for free
Includes lunch and post-seminar wine and savouries.
Doors open at 9am.
For more info or to register for this event please visit ***www.lps.org.uk/events/***

Jonathan Pye – Rockflow

Introduction



Grant Affleck – Weatherford

A Geophysical model to Detecting surface-casing vent flows, leaks, and gas-migration issues at even the lowest frequencies

The new service has been developed that uses a geophysical approach to identify the source of gas migration behind casing by recording sounds transmitted through the casing. Deployed by wireline truck, an advanced VSP type technology uses electromechanical locking arms to press the sensors against the casing. Securing the tool to the casing enables superior sound quality by eliminating reliance on wellbore fluids, which cannot transmit frequencies as high as, or amplitudes as low as, the casing can.

The technology typically includes four geophone sensors spaced at pre-determined interconnect lengths. Three directional components in each sensor detect the noises in the wellbore. By analyzing the data recorded by the sensors, we can distinguish between vertical and horizontal flow. We can also determine move-out along the array in vertical and horizontal tensor directions, which leads to accurate source locations.

A horizontal acoustic signal indicates horizontal inflow of fluid behind the casing or at a leak. A vertical acoustic signal indicates vertical flow. Tube waves, identified at multiple sensors in the tool array, are used to interpret flow direction. Analyzing the frequency spectrum, evaluating flow direction, and integrating open- and cased-hole log data enables us to interpret the fluid flow in and around the wellbore. The resulting plot enables you to recognize areas behind the casing with gas or water movement at very low flow rates. In fact, you can locate the source of surface-casing vent-flow (SCVF) issues and identify gas-migration issues, such as behind casing crossflow between wells.

Nasser Bani Hassan – ERCE

Incorporating FWI velocities in Simulated Annealing based acoustic impedance inversion – Jansz gas field case study

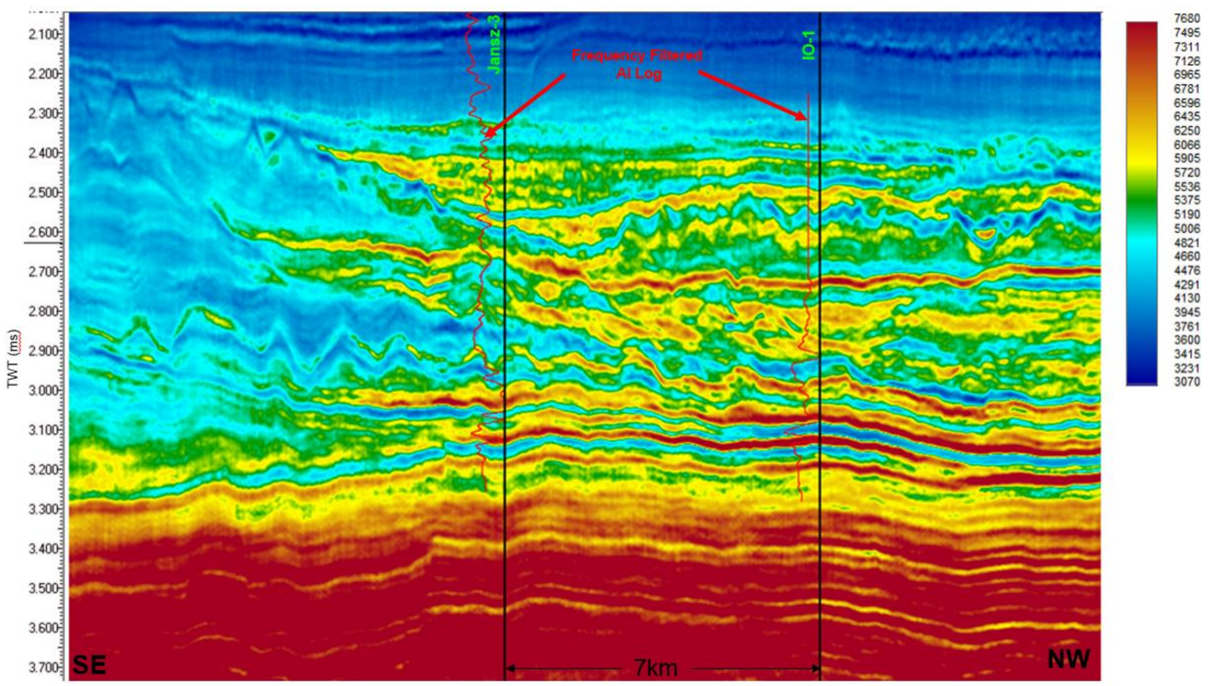
Nasser Bani Hassan[1], Sean McQuaid[1]

1 ERCE Ltd.

The frequency spectrum of seismic data is constrained by its recording capabilities, outside which the seismic are missing information. Construction of the Low Frequency Component (LFC) has always been one of the major challenges of deterministic seismic inversion. Typically, well data are extrapolated and combined with seismic velocities to construct the LFC, but uncertainties increase with distance from well control due to structural and stratigraphic variations. This leads to an increased uncertainty in the reservoir properties obtained from impedance inversion products.

Acoustic Full Waveform Inversion (FWI) is an iterative method for obtaining a high-resolution velocity model of the subsurface by matching the modelled waveforms to the observed data. This modern technique is often used to derive an accurate velocity model in structurally complex areas such as salt diapirs, or areas where conventional imaging is challenging such as gas clouds. These velocities can be directly used for depth conversion and reservoir characterisation.

In this study we use the velocity volume derived from FWI as the low frequency input to Simulated Annealing inversion to construct an absolute acoustic impedance. This case study investigates the results when applied to the 3D seismic survey covering the Jansz-IO gas field, 220km off the northwest coast of Australia. The approach is entirely data driven and the result of the inversion not only honours the well data from two blind (unused) wells, but also reveals variations that are otherwise hidden from conventional seismic data.



Rafael Guerra - Schlumberger

Elastic Seismic Response and Anisotropy from Walkaway VSP and Sonic Data

Rafael Guerra and Erik Wielemaker (Schlumberger Wireline)

We present a few case studies, from North Sea, West Africa and Gulf of Mexico, where borehole geophysics data allowed bridging the gap between the well logs and surface seismic scales. In some projects the seismic resolution was relatively poor due to absorption in the overburden, multiples and distortion from complex structures. Some of the seismic challenges included reducing the velocity anisotropy uncertainty and/or to independently measure the true AVA response of the reservoirs, complementing logs and surface seismic.

To measure the elastic response in-situ, reduce the velocity model uncertainties and allow improvements in anisotropic surface seismic processing, comprehensive Walkaway VSP and modern wireline sonic logging surveys were planned in new appraisal and production wells.

The borehole measurements represent a first step in the velocity model calibration workflow and highlight the importance of integrating data taken at different scales: cores, sonic, borehole and surface seismic, in order to understand the elastic properties and seismic response of the rocks drilled.

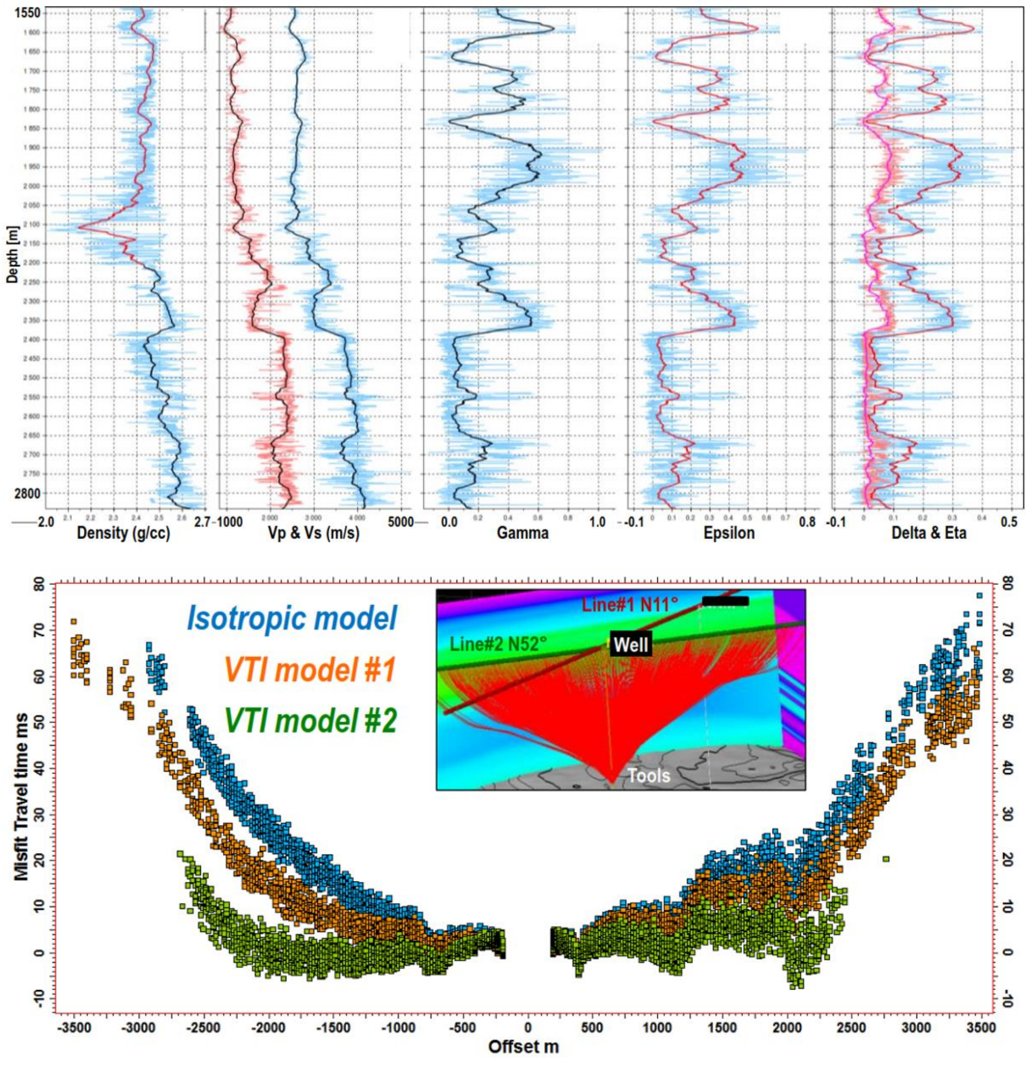


Fig.1 Elastic VTI-anisotropy logs from sonic-walkaway integration with Backus upscaling (top) and ray-tracing walkaway time residuals for different velocity models (bottom)

Reza Saberi – CGG

A Rock Physics Strategy to Model Dynamic Biot's Coefficient

Mohammad Reza Saberi and Fred Jenson CGG GeoSoftware

The Biot-Willis coefficient, which defines the relationship between confining stress and induced pore pressure, is an important parameter needed to define effective stress. Effective stress is utilized in many geomechanical applications from drilling to hydraulic fracturing and Biot's coefficient is a key component in such workflows. It can be calculated either through dynamic or static approaches. This study uses three wells with high-quality compressional sonic, shear sonic and density logs to demonstrate a rock physics workflow to determine dynamic Biot's coefficient. The workflow includes interpretation of detailed petrophysics, determination of rock elastic properties from measured curves and creation of synthetic curves incorporating information obtained from analysis of measured logs. Both measured and synthetic data are used in analyzing the elastic properties and physical characteristics of the Barnett formation, but the workflow is applicable to any type of reservoir. The lithological description of the formation is determined using stochastic methods and the mineral volumes are used to compute the bulk modulus of the solid rock matrix (Ko) using the Voigt-Reuss-Hill average value. Kdry is generated using two methods (a generic method based on Mavko and Mukerji) and a more rigorous computation using DEM theory. After Ko and Kdry are determined, the vertical dynamic Biot's Coefficient is generated from both measured and modeled log data.

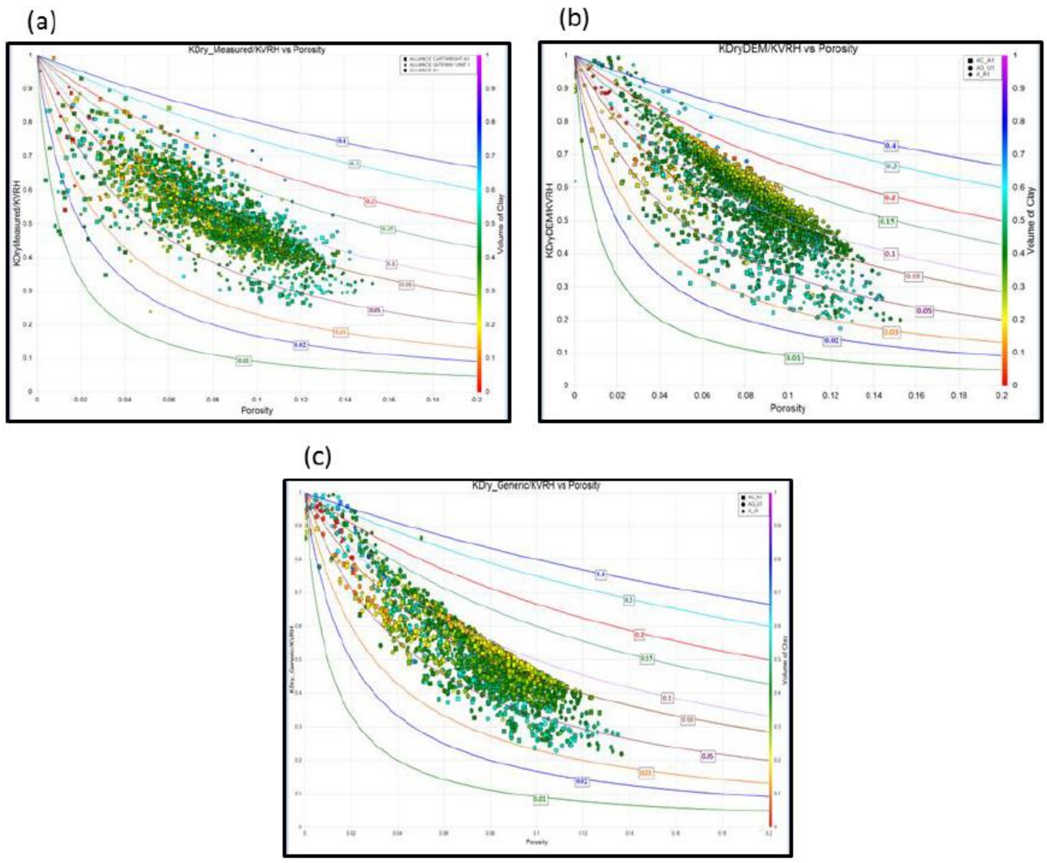


Figure 1: Kdry/K0 vs porosity crossplots using three different approaches for calculating Kdry: (a) using measured sonic and density logs with Gassmann (1951), (b) using DEM rock physics, and c) using a rock physics-modeling of logs and assuming that the Kdry value is similar to the Ksat value. The rock physics template for Biot's coefficient is overlaid on the crossplots.

Pat Connolly – Patrick Connolly Associates

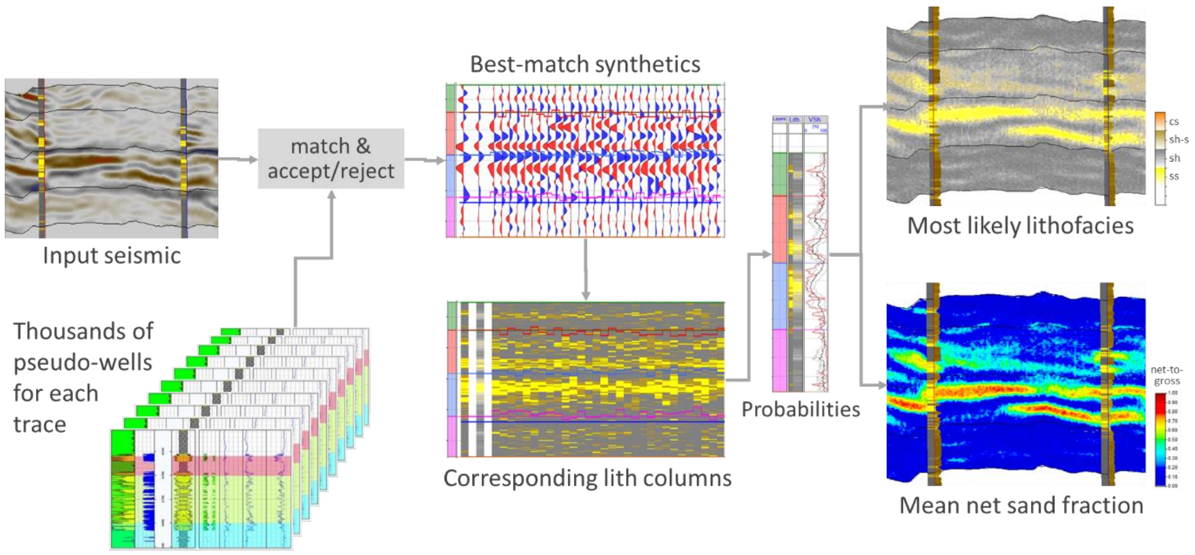
Probabilistic seismic inversion using pseudo-wells

Patrick Connolly, PCA Ltd

The quantitative estimation of reservoir parameters requires the integration of many types of data. These data will be uncertain to varying degrees. If the uncertainty is ignored by effectively pretending all data is accurate as is done with deterministic inversions then we risk giving undue weight to some data which will bias the results. Bayesian methods provide a framework to account for the uncertainty of the prior knowledge to give appropriate weighting to each datatype and provide a probabilistic parameter estimate. Probabilistic inversions are not just about putting errors bars on results; they reduce bias to give better answers.

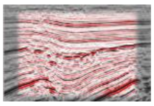
Bayesian problems can be solved in a number of ways, one of which is called Monte Carlo rejection sampling. This method has the advantage of being conceptually simple and can be implemented in a highly transparent manner; there is no 'black box' element. It works by randomly selecting a large number of possible solutions from the prior then each candidate solution is compared with the seismic data. Solutions with a high probability of being consistent with the seismic are selected, the rest are rejected. The selected solutions, consistent with both the prior and the seismic data, form the posterior probability distribution.

BP developed an application based on this approach called ODiSI; One Dimensional Stochastic Inversion (Connolly & Hughes, 2016). The prior samples, referred to as pseudo-wells, are 1D geological profiles containing lithofacies and associated reservoir and elastic properties. In this talk I will describe the principles and practical implementation details of ODiSI.



Reference

Connolly, P. A., and M. J. Hughes, 2016, Stochastic inversion by matching to large numbers of pseudo-wells: Geophysics, 81.



Sam Matthews – BP

One Dimensional Stochastic Inversion for Quantitative Seismic Reservoir Characterisation - Case studies

BP has developed a one-dimensional stochastic inversion method (ODiSI) for jointly estimating reservoir properties and facies, and also, importantly, the associated uncertainties. ODiSI generates a large number of pseudo-wells consistent with the input prior information (well data and seismic horizons) at each trace location. It then generates a synthetic seismic trace for each pseudo-well, compares these traces to one or more colour-inverted seismic angle stacks and selects the ones that give the best match. These best match pseudo-wells are then analysed to provide estimates of the reservoir properties and associated uncertainty. No low-frequency model is required, and no lateral constraints imposed.

This talk presents case studies demonstrating application of ODiSI to understand net-to-gross distribution in a clastic reservoir, and estimate porosity in a carbonate reservoir. These studies show that a thorough understanding of all input well data, and detailed validation of the parameters input to the inversion process is crucial to obtaining a good result. We also illustrate some of the various products that can be output from such an inversion process to help constrain subsequent geostatistical reservoir modelling.

Rajat Rathore – CGG

Fluid replacement modelling- A key to understand seismic response with fluid content variation

Rajat Rathore (Regional Senior Petrophysicist, CGG)

Fluid replacement modelling plays an important role in any seismic rock physics study. Its results help to understand the link between seismic responses and various fluid scenarios. The underlying principle is the variation of pore space compressibility which acts as direct physical link between dry and fluid saturated moduli from in-situ fluid to modelled fluid condition and form the basis of Biot Gassmann's equation. One of the main challenges for any rock physics study is to constrain dry frame rock properties e.g. dry frame bulk modulus (Kdry). A combination of empirical, heuristic and theoretical models can be used to estimate Kdry. It has also been observed that Kdry decreases as porosity increases.

Biot Gassmann's equation is commonly used to perform fluid substitution. However there are certain assumptions to be considered before applying this equation to the well data. The uncertainty in the modelling is mainly driven by input fluid properties, initial water saturation, porosity, matrix and frame properties of the rock. Complete process of fluid substitution can be broken down to few key steps as described below.

1. Log editing and interpretation (mineral fraction volume, porosity and water saturation)
2. Shear velocity estimation (if missing or not acquired at the first place)
3. K and G calculation for in-situ conditions
4. K0 calculation based on mineral fractions (mixing laws)
5. Fluid properties derivation at reservoir P/T (from PVT, water sample reports)
6. Fluid mixing for in-situ case using SW/SXO
7. Kdry (K*) calculation
8. New fluid properties (bulk modulus and density) calculation at desired new SW
9. New saturated bulk modulus calculation using Gassmann
10. New bulk density calculation
11. New compressional velocity calculation
12. New shear velocity calculation

Fluid replacement modelling can be used as prediction or validation tool for AVO/AVA analysis both at the well or undrilled location. This would eventually help in de-risking a potential play and avoid drilling dry wells.

Åsmund Drottning – Rock Physics Technology

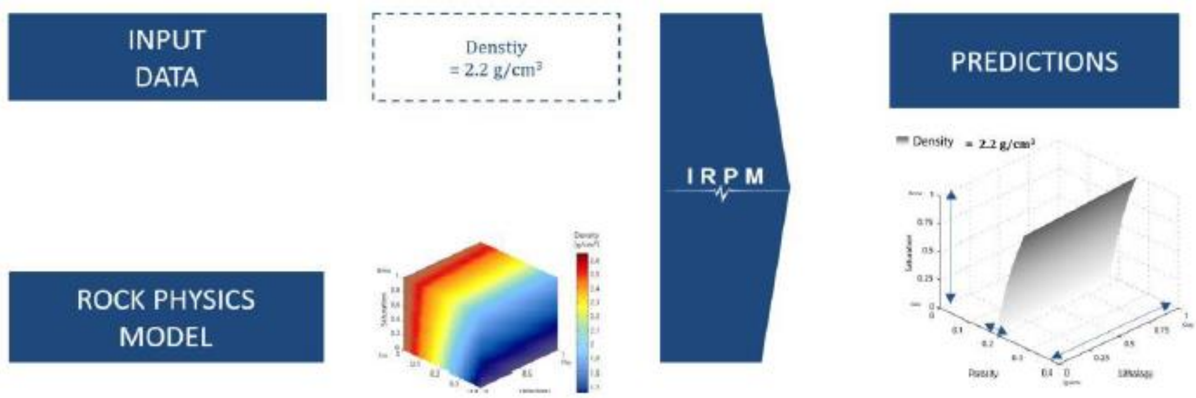
Rock Physics modelling and inversion

Åsmund Drottning and Erling H. Jensen, Rock Physics Technology, Bergen, Norway

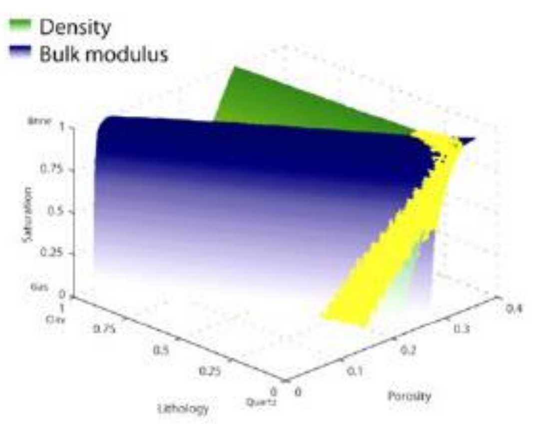
A key challenge in geophysics is the prediction of reservoir properties, such as porosity, lithology and saturation (so-called PLF properties), from geophysical data. This paper will address this challenge by the use of the Inverse Rock Physics Modelling (IRPM) method that was introduced by Johansen et al. (2013).
Rock physics is a key element of the link between micro-scale rock properties and geophysical data. The choice of a rock physics model (RPM) will depend on factors such as depositional environment, mineral composition, rock texture, burial history, temperature, pressure, etc. In other words, the RPM should reflect the geological characteristics and the geological history.

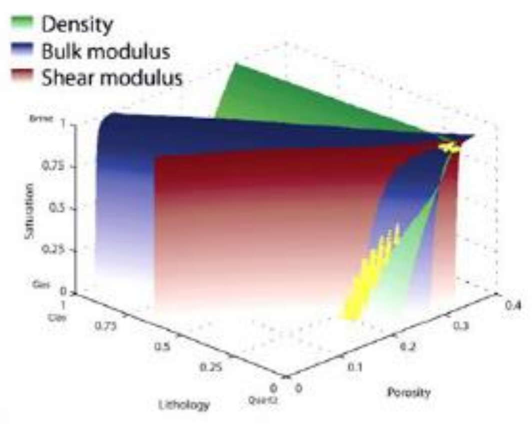
Inverse rock physics modelling (IRPM) is a method for predicting reservoir properties from geophysical data. A common application is the prediction of PLF properties from P-wave impedance, Vp/Vs-ratio and density data. The relationship can be non-linear and have non-unique solutions.

IRPM is based on an exhaustive search for consistent solutions of PLF parameters in a solution space spanned by the calibrated RPM at hand. As an example, an observed density value can be caused by different combinations of PLF values. The solutions will plot as an isosurface in the PLF domain such that any point on the surface has the same density.

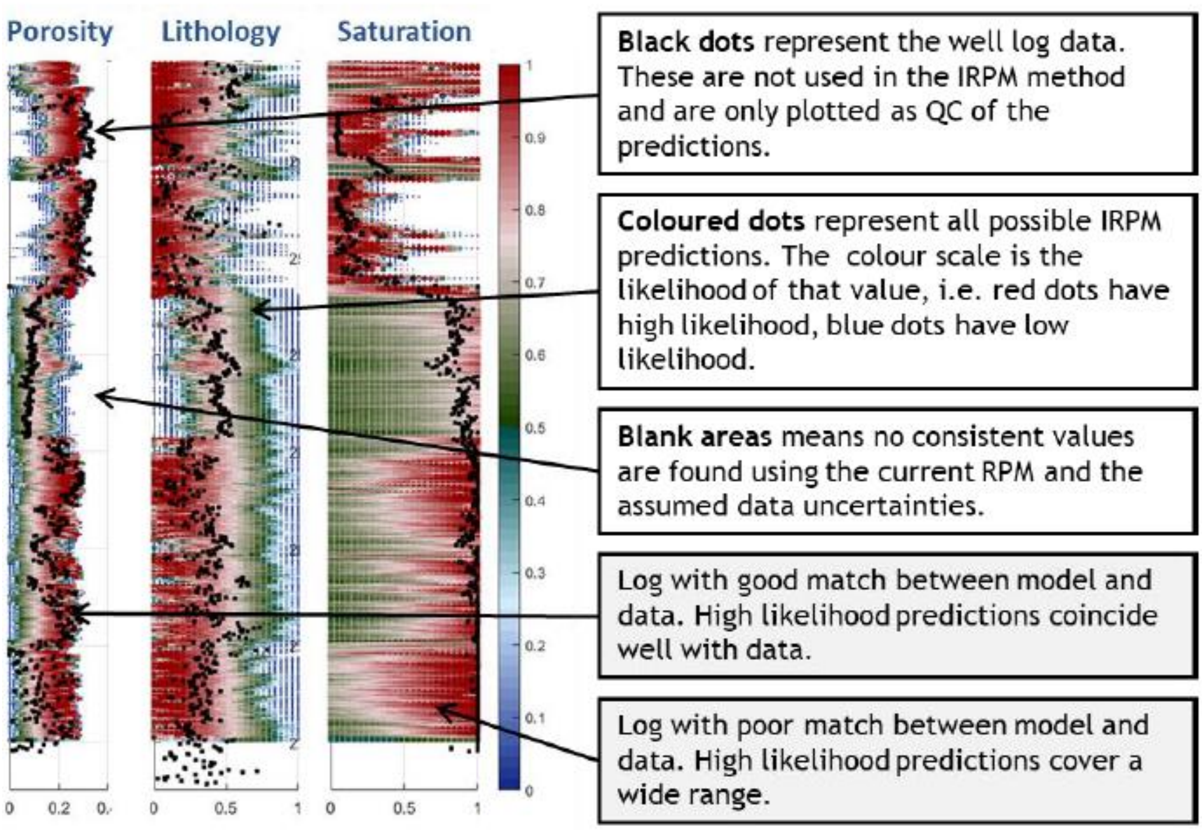


The effect of including more data points is generating more planes and consistent solutions are found where these planes intersect. Adding uncertainties to the measurements will create a point cloud of solutions (yellow points).





The IRPM approach goes beyond the more common Rock Physics Templates approach due to its ability to provide quantitative predictions that accounts for uncertainties in both the RPM parameters and the data. Further, it will identify multiple consistent solutions, i.e. different combinations of PLF parameters with the same elastic properties.
The method will be applied on datasets from the North Sea and the Norwegian Sea to explore the reservoir information that can be extracted from the geophysical measurements, and the accuracy requirements of the different data types.



References

Johansen, T.A., Jensen, E.H., Mavko, G. & Dvorkin, J. 2013. Inverse rock physics modeling for reservoir quality prediction. Geophysics, 78 (2), M1-M18.

Nick Huntbatch – Ikon Science

The role of regional rock physics knowledge in reducing uncertainty

In the current climate, quantitative interpretation (QI) geoscientists are faced with many challenges; complex stratigraphic targets, subtle rock property variations, frontier or unexplored settings with unknown rock types and often only limited seismic and well data that are typically old legacy data and of variable quality. At the same time prospects need to be evaluated in a robust and consistent manner within quick cycle-times due to commercial and governmental (e.g. license round) constraints. The consequences of not getting it right are obvious, leading to a poor understanding of risk, overstated reserves and/or expensive dry-holes.

When evaluating drilling targets, the interpreter can often become too focussed on a particular subset of data local to the lead or prospect, and ignore information from the wider area. At the same time many of the geological properties and processes that drive the seismic response occur on a basin-wide scale such as depositional environment, diagenesis, mineralogy, hydrocarbon type, burial history, compaction state, stress variabilities and pressure variations to name a few. There is also the potential for the unexpected, and if the analysis is too focussed on 'near-field' data the chances of missing a key factor when interpreting the seismic response is often increased.

It is therefore important to include a basin-wide view in rock physics models when interpreting seismic responses, and regional data and/or analogues data are key data in achieving this and reducing the uncertainty, by capturing all relevant scenarios in the rock physics analysis and seismic modelling phase. Regional knowledge, as well as integration between different disciplines, is therefore key to developing and deploying meaningful and robust predictive rock physics models.

Three aspects of a regional rock-physics approach are presented here:

- An integrated workflow for regional rock property analysis
- A method of capturing and interrogating the results of this analysis
- An approach to seismic inversion where regional rock physics knowledge can be included in the inversion scheme