Advanced Well Log Interpretation

Course Price

£3050

Course Description

A five-day classroom course, which introduces advanced petrophysical concepts and their use in difficult lithology environments such as complex carbonates, shaly sands and thin-bed evaluation. An overview is also presented of problems encountered in using well-logs for shale-oil/shale-gas evaluation.

The first two days cover all standard and modern open-hole well-logging measurements, both Wireline and LWD, and the remaining days cover more advanced topics including NMR, Multipole Acoustic and Dielectric measurements, dipmeter/imaging logs and their use in correlation, mineralogy and saturation determination.

The principal cased-hole measurements are also presented, including reservoir fluid-level monitoring, corrosion, recent developments in cement-bond evaluation, and the issues concerning optimal perforation procedures are discussed

Course Objectives

Successful completion of the course will give participants a good understanding of the basic logging measurements and interpretation methods, the ability to assess log quality and to identify and correct data acquisition problems. The more complex topics covered towards the end of the course will give insights into the use of new measurements and will discuss the issues involved in making interpretations in complex geological environments.

Great emphasis is placed on the fact that log interpretation is still largely based on empirical relationships, the applicability of which may depend on local factors, and course participants are constantly reminded that reliance on “black box” interpretation methods can lead to serious misinterpretations. Thus, the computers used in the course are largely there to enhance the speed of computation of the data points manually chosen by the participants, using simple Excel spreadsheet programs implementing standard relationships, rather than for pushing un-screened log data through a pre-set interpretation package.

Efforts are also made broadly to cover the technologies offered by the various different service vendors, rather than only those from a single supplier, in order to present an up-to-date “shop window” of the wireline & LWD tools & techniques now available to the industry.
Who Should Attend

The course is intended for engineers and geo-scientists and technical assistants needing to understand better, the principles of log interpretation and/or to update themselves on the range of log measurements and techniques now available to them, and to appreciate the complexities of interpretation in more complex reservoirs.

Although the course is appropriate for both engineers and geologists/geophysicists, the emphasis and level can be changed depending upon the participants’ requirements and backgrounds.

Course Content

This course presentation is modular and covers the topics listed below, using many generic examples for the participants to work on themselves as each topic is covered. As the course progresses, participants develop their own interpretation of 2 sets of logs (one wireline, one LWD), as well as examples of complex lithology identification, source rock evaluation, etc. and (most of) the last two days is taken by discussing and working through examples in more complex environments.

Documentation

The course handouts include a hardcopy manual, exercises and a CD with the worked course examples and a selection of standard texts on log interpretation:

- Log Interpretation Charts (Halliburton)
- NMR Logging Principles & Applications (Halliburton)
- Log Interpretation Openhole & Cased Hole Principles (Schlumberger)
- Log Interpretation Chartbook (Schlumberger)
- Introduction to Wireline Log Analysis (Baker Atlas)

Day 1: General Topics and Resistivity Measurements

1. Overview of Basic Petrophysical Models & Relationships Used in “Clean” formation interpretation for determination of Porosity & Water Saturation using Archie relationship
2. Depth Measurements & Control

Unfortunately, depth measurements are still a major source of error, so this topic is thoroughly discussed to include: Wireline depth control, LWD depth control, depth measurement problems in deviated holes, perforating depth control precautions

3. Conductivity in Electrolytes: Derivation of Rmf at Formation Temperature
4. Use of SP for Geological Interpretation and to determine Rw
5. Resistivity Measurements to Determine Rt, Rxo and invasion profile:
1. Deep-reading Resistivity Measurements (Induction, Laterolog, Propagation Resistivity) to determine $R_t$
2. Pad-type Resistivity Measurements to determine $Rx_o$ (Microlog, Microlaterolog/Proximity Log, MicroSpherically- & MicroCylindrically-focused logs)

(iii) Mandrel-type Resistivity Measurements to determine $R_i$ (Early Electric logs, Spherically-focused logs)

3. Tornado chart corrections & implications of the “step-profile” and other invasion profile assumptions
6. Gamma Ray: Th, U, K main components, API Calibration, relationship with grain size & shaliness
7. Caliper Measurements: mechanical calipers and their use in log quality control, acoustic calipers, present-day Stress Azimuth determination

**Day 2: Porosity and Mineralogy/Lithology Measurements, Linking Resistivity with Porosity/Mineralogy Measurements**

8. Measurements for Determination of Porosity & Mineralogy/Lithology:

1. Density Measurements: measurement principle & tool technology evolution (W/L & LWD), Density/porosity/mineralogy relationship
2. Neutron Measurements: measurement principle, fluid & mineralogy effects, porosity determination, effect of gas, shale, mud constituents
3. Acoustic Measurements: measurement principle $\tau_p$, $\tau_{shear}$, $\tau_{stoneley}$, porosity/mineralogy determination (Wyllie, Raymer-Hunt), use of $\tau_p$/?ts for gas detection, lithology, rock strength prediction, fracture identification, permeability from Stoneley attenuation

(Azimuthal/radial stress analysis is discussed in a separate advanced module)

4. Pe Measurements: additional lithology identification from Pe & Density
5. Crossplot methods for porosity & lithology determination: compatible log scaling for quicklook overlays, 2-D crossplots, M-N crossplots, MID plots (#1 & #2)
9. Gamma Ray Spectrometry and Core Sampling for Enhanced Mineralogy Determination
10. Spectral Gamma Ray: use of Th, U, K components for clay mineralogy
11. Elemental Capture Spectrometry: use of Capture GR emission analysis for complex mineralogy
12. Percussion & Mechanical Sidewall Coring: as alternative to fullsize cores for fluid/porosity/permeability and mineralogy analysis
10. Linking Porosity, Formation Factor and Water Saturation

1. The link between Porosity & Formation Factor, and derivation of “m”
2. The link between Formation Factor and Water Saturation
3. Verification of simple Archie formula, and derivation of “n”
4. Effect of clay minerals conductivity in shaly formations

**Determination of Water Saturations in Virgin and Flushed Zones**
1. Archie formula
2. Crossplots (Pickett, Hingle)
3. Quicklook Rwa, F-Ratio methods
4. Quicklook logarithmic overlays
5. Moveable Oil Plot
12. Completion & review of 1st example set of logs ("Clean Sand" example) which the group has been working on in teams over the first 2 days.

Day 3:

Review of GoM LWD set of logs ("Homework" example) given to participants for their study after course hours.

1. Advanced Measurements & Topics for Complex Geological Applications:
   13. Nuclear Magnetic Resonance Measurements:
   14. Overview of NMR principles, definition of T1, T2 relaxations
   15. Overview of NMR tool technology (W/L & LWD)
   17. NMR as supplement/alternative to resistivity/porosity measurements in shaly sands
   18. T2 – permeability relationships
   19. NMR & produceability
   20. NMR diffusion for fluid-type discrimination using T1, T2 relaxations
   14. Permeability Determination from Logs & Pressure Measurements:
   15. Permeability, relative permeability, core measurements
   16. Derivation from irreducible water saturation
   17. Derivation from pressure drawdown, buildup
   18. Derivation from NMR measurements
   15. Dipmeters, Imaging Logs & Paleomagnetic Logs; using logs for Geological Interpretation
   16. Overview of electrical, acoustic and nuclear tool technologies for imaging
   17. Recent developments in imaging from W/L & LWD measurements
   18. Paleomagnetic logging
   19. “Squaring” of logs for geological & thin-bed interpretation, sand count issues
20. Lithofacies zonation of logs using histograms, principal component analysis, paleoflow energy, wavelet spectrogram
21. Discussion of examples & applications
16. Overview of Computer Log Interpretation Methods
17. Underdetermined, uniquely determined and iterative solutions
   2. Iteration and error minimization, neural networks
17. Other Geological Applications of Resistivity, Porosity & GR Spectrum Measurements
18. Source Rock Evaluation
19. Sequence Evaluation
20. Using log measurements for geological applications (texture, overpressures, anisotropy)
21. Combination of Electrical Log & Other Data for Lithological Interpretation

2. Additional Topics for Petroleum Engineering Applications:
18. Pressure Measurements, Fluid Sampling & Analysis using Formation Testers: Overview of formation tester tool technology, pressure sampling, fluid analysis, permeability/mobility measurements
19. Cased-Hole Logging Measurements:
20. Thru-Casing Logging for Porosity and Resistivity, monitoring Fluid-level Changes using
Pulsed-Neutron decay, Carbon/Oxygen & Gravity Methods
21. Cement Bond Evaluation, including recent developments
22. Corrosion Prediction, Detection and Monitoring
23. Perforation, Skin and Productivity Index Enhancement

Days 4 & 5:

a. Log Quality Control and Interpretation in Complex Environments

20. Overview of Some Log Quality Control Issues

Unfortunately, poor log quality remains one of the major problems in well-log interpretation, so a detailed overview is presented of typical problems encountered, how they can be identified and (possibly) corrected before data is entered into an automated interpretation programme

b. Recent Developments in Measurement Technologies:

21. Dipole Sonic Measurements: measurement principle & tool technology evolution (W/L & LWD), azimuthal and radial stress relief, use of tp, tshear, tstoneley to analyse stress fields around borehole and estimate rock strength
22. Electromagnetic Propagation Measurements: measurement principle & tool technology evolution, use of dielectric permittivity to evaluate complex saturation environments, determination of “w” textural exponent

c. Log Interpretation in Complex Environments:

These topics take the form of Overviews of some of the issues and difficulties of making log interpretations in more complex geological & completion environments, accompanied by a “Walk-through” of a typical example of the environment discussed

23. Overview of Shaly Sand Interpretation: Clay properties & identification, laminated vs. dispersed clays using Thomas/Stieber method, Vsh determination, clay double layer & excess conductivity, different resistivity models/approaches for saturation determination

25. Overview of Log Applications in Shale – Oil/Gas Formations: Well-navigation issues, source rock identification/kerogen/TOC/adsorbed gas estimation, use of sonic and imaging logs to identify brittleness and select zones for frack design
26. Overview of Log Interpretation in Complex Carbonate Reservoirs: Macro-, meso- & micro-porosity issues, porosity determination in multiple lithologies, determination of Rw & saturations, permeability in tight/fractured carbonates, “walk-through” interpretation of complex carbonate example
27. Overview of Different Approaches to Cement Bond Evaluation: CBL/VDL, azimuthal bond, modern flexural attenuation/acoustic impedance measurements, “walk-through” comparison of older and newer evaluations
CPD Unit

Continuing Professional Development

35 HOURS CPD