Summary

This course presents the principles and methods associated with the petrophysical interpretation of open- and cased-hole wireline and LWD well logs. Open-hole topics covered include the use of log data to determine porosity, mineralogy, hydrocarbon saturation and lithology, as well as interpretation of facies, stratigraphic and structural features, especially the use of imaging logs. Thru-casing topics include measurements for fluid movement monitoring, cement-bond quality, and a discussion of "best-practice" perforation issues.

Learning Outcomes

Participants will learn:

(a) For Log Quality Control, to:

1. Understand the differences between wireline and LWD/driller’s depth and deviation measurements and identify likely sources or error and discrepancies, and the consequent uncertainties in hole navigation.
2. Recognise the importance of the verification of log data before attempting interpretation and how to check log quality by crossplots and quick-look overlays.
3. Understand that large errors are likely to be encountered by using modern iterative interpretation software without preliminary “eyeball” assessment of data inputs, comparison with other data sources such as bit-samples, cores and mud-logs, as well as step-by-step evaluation of intermediate results.

(b) For Open-Hole Measurements, to:

1. Understand and use basic petrophysical and geological models in “clean” formation interpretation.
2. Identify zones of potential interest using SP, GR, Resistivity and Porosity measurements.
3. Use wireline and LWD resistivity measurements to calculate Rt, Rxo and invasion profiles and use density, neutron and sonic measurements to determine porosity and lithology.
4. Apply the basic physical principles of PhotoElectric, Spectral GR and Elemental Capture Spectroscopy measurements and how they can be used to enhance mineralogy determination in complex lithology.
5. Appreciate the concept and shortcomings of Formation Factor as the key link between resistivity and porosity/mineralogy measurements.
6. Use the empirical logic leading to the Archie Water Saturation Equation and be able to determine water saturation in both virgin and flushed zones.
7. Understand the basic functions of Formation Tester hardware and use the resulting pressure measurements to discern formation pressure profiles, fluid contacts and densities and to derive “drawdown” and “buildup” permeabilities.
8. Apply the basic physical principles and tool technologies of NMR measurements to distinguish between electrostatically- and capillary-bound water and free fluids, to derive permeability and water-cut, and to identify hydrocarbon-bearing zones, especially in complex or shaly reservoirs.
9. Interpret dipmeters and imaging logs to assist geological interpretation, together with typical depositional “signatures” gained from porosity and resistivity logs.
10. Use logs, crossplots and overlays to identify probable immature and mature source rocks, and to estimate Total Organic Carbon.

(c) For Cased-Hole Measurements, to:

1. Evaluate the relative worth of various methods of cement-bond evaluation for zone isolation.
2. Use thermal neutron decay and GR spectral measurements, especially in time-lapse overlays, to identify changes in hydrocarbon/water contacts due to production during the life of a reservoir.
3. Appreciate issues related to skin effect and perforator performance, such as near borehole damage due to poor perforation methods and inadequate charge penetration.

(d). For Advanced Topics (time permitting), to:

1. Use multipole sonic measurements for rock-strength, azimuthal and radial stress evaluations.
2. Apply dielectric measurements to determination of saturations in freshwater environments, to texture constants in complex carbonates and to kerogen identification in oil/gas-shales.
3. Acquire a general understanding of the issues and methods involved in advanced log interpretation in thin-beds, shaly-sands, complex carbonates and shale-oil/gas environments.

Duration and Training Method

A five-day classroom course in modular format. Lectures on each topic are supported and illustrated by exercises, and participants build their own interpretations of at least two sets of wireline logs, and are expected to complete several "homework" exercises including a simple interpretation of a third set of (LWD) logs. Computers are provided, but participants should bring scientific calculators with them. This is a challenging course which covers a great deal of ground in only 5 days.

Who Should Attend

The course is intended for entry-level geoscientists and engineers, as well as for more experienced staff and technical assistants needing a better understanding of the principles of log interpretation and/or to update themselves on the range of log measurements and techniques now available to them.

Prerequisites and Linking Courses

N121 has no formal prerequisite, although it may be advantageous to have a basic knowledge of well logs.

Further treatment of petrophysics topics, by the Nautilus Training Alliance, are offered in courses N030 (Rocks and Fluids, Practical Petrophysics), N054 (Intermediate Petrophysics for Conventional Reservoirs), N187 (Low Resistivity Low Contrast Pay), N267 (Petrophysics for Shale Gas Reservoirs), N314 (Advanced Petrophysics for Conventional Reservoirs) and N970 (Cased Hole Logging for Production Monitoring).

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. Participants develop their own interpretation of at least one set of logs as the course progresses, and (part of) the last day is taken by working on another set. If possible, the latter example will be chosen from an area relevant to the course location.

The course concentrates specifically on the petrophysical side of the interpretation of well logs. Although focused mainly on wireline measurements, equivalent LWD measurements are also covered, remarking upon the differences and their advantages/disadvantages, with examples. The range of measurements discussed is comprehensive, so participants are also presented with an up-to-date "shop window" of the wireline and LWD tools and techniques currently available to the industry.

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 participants are constantly reminded that reliance on black-box interpretation methods can lead to serious mis-interpretations. Thus, the computers used on the course are largely there to enhance the speed of computation of the data points manually chosen by the participants, rather than for pushing un-screened log data through a pre-set interpretation package.

Topics Covered

Day 1: Introduction, Resistivity Measurements

- Introductions: Lecturer, Course Participants
- What is required of Wireline and LWD Measurements?
- Basic Petrophysical Models and Relationships Used in "Clean" formation interpretation:
  - Basic Geological Models and Signatures obtainable from well logs
  - Basic Reservoir Engineering data obtainable from well logs
- Depth Measurements and Control
- Conductivity in Electrolytes and Derivation of Rmf at Formation Temperature
- Use of SP for Geological Interpretation and to determine Rw
- Resistivity Measurements to Determine Rt, Rox and invasion profile
- Simple Gamma Ray Measurements
- Caliper Measurements
- Identification of Potential Zones of Interest using SP, GR and Resistivity

Day 2: Porosity and Mineralogy/Lithology Measurements

- Density, Neutron and Sonic Measurements for Determination of Porosity and Mineralogy/Lithology
- Gamma Ray Spectrometry and Core Sampling for Enhanced Mineralogy Determination
- Other Geological Applications of Porosity and GR Spectrum Measurements, including source rock identification and evaluation

Day 3: Linking Resistivity with Porosity/Mineralogy Measurements

- Linking Porosity, Formation Factor and Water Saturation
- Determination of Water Saturations in Virgin and Flushed Zones
• Completion and review of first example set of logs which the participants have been working on over the first 3 days

Day 4: NMR and Topics for Geological and Petroleum Engineering Applications

• Nuclear Magnetic Resonance T1 and T2 measurements to determine total, bound-water and free-fluid porosities, fluid types, kerogen identification
• Formation Testers for Pressure Measurements, Fluid Sampling and Analysis
• Permeability Determination from Logs and Pressure Measurements
• Geological Interpretation topics, including:
  ○ Dipmeters, Imaging Logs and Paleomagnetic Logs
  ○ Using logs for inter-well correlation
• Petroleum- and Reservoir-Engineering topics, including:
  ○ Cement-bond logs (CBL/VDL, CET, Segmented-bond, Isolation Scanner, Temperature and Noise)
• Thru-casing measurements to determine porosity, water saturation and changes in fluid levels during production by time-lapse monitoring:
  ○ Porosity logs
  ○ TDT logs
  ○ Carbon/Oxygen and GR spectroscopy logs
  ○ Borehole gravity for gas-cap monitoring
  ○ Thru-casing resistivity
• Skin-effect and Perforation issues
  ○ Overview of skin-effect, damaged zone
  ○ Implications for perforator performance and API RP19 sections 1-4 criteria
  ○ Perforation design alternatives and recommended procedures to enhance productivity index

Day 5: Log Quality Control, Interpretation of Final Example

• Overview of Some Important Log Quality Control Issues
• Recap of Uncertainties and Assumptions in Log Measurements, and Suggested Procedures to "Eye-ball" Data for Problem Identification and Preliminary Interpretation
• Overview of Computer Log Interpretation Methods
• Participants work on second example set of logs, preferably from general area of course
• Review of interpretation of second set of logs, final summary and prize-giving, award of certificates

Topics of Special Request (if time permits):

Advanced Logging Measurements

• Multifrequency acoustic logging for investigation of azimuthal and radial changes in rock-strength properties
• Modern dielectric log measurements and interpretation applications
• Logs for casing-corrosion identification and monitoring
• Production logs for flow analysis in highly deviated holes
Advanced Interpretation Overviews

- Thin-bed problems
- Shaly-sands
- Shale-oil/gas
- Complex carbonates

At the beginning of days 2-5, the previous day's activity and any overnight "homework" will be briefly reviewed.