Petrophysics Pty Ltd
www.petrophysics.net

Benchmark Petrophysics Training

Integrated Petrophysics for Reservoir Characterisation - Course Contents

Daily: Recap - Theory - Practical - Lunch - Theory - Practical

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DAY1

INTRODUCTION
Course Overview
Objective of Formation Evaluation
Difficult Conditions for Formation Evaluation
Data Sources
Non-Numerical Information
Limitations of Data Sources - General
Scales of Measurement and Heterogeneity
Increased Heterogeneity Requires Increased Sampling
Micropractical
Fine Scale Data Requires Log Correlation
Inequalities Between Laboratory and Reservoir
Non-Unique Transforms between Measured Parameter and Reservoir Parameter
Lack of Rigid Calibration Grid
Deterministic vs. Probabilistic Petrophysics

QUICK LOOK LOG ANALYSIS
Operations Petrophysics: Chronological Tasks and Responsibilities
Environmentally Correct Logs
Compute Vsh
Compute Ø
Micropractical
Compute Sw
Compute k
Compute Netpay

DATA PREPARATION
Log Data Preparation
Missing Data
Log to Log Depth Matching
Environmental Corrections
Merge LWD and Wireline
Log Normalisation
Seismic Petrophysics Log Editing Process dt, rhob
Core Data Preparation
Core to Log Depth Matching
Vetting Special Core Data
Preliminary Zonation

LITHOLOGY and CLAY CONTENT: Vcl , Vsh
Objective
Distinction Between Clay and Shale
Uses of Vclay , Vshale
Importance
Common Problems
Non-Radioactive Fines and Radioactive Non-fines
Gas and other Non-Shale Influences Vshale Logs
Is Vclay / Vshale Relevant to Reservoir Beds?
Lack of Core Calibration and a Certain Vshale = Zero Reference
Scales of Heterogeneity in Core Calibration
Lithology, Vcl, Vsh Input Data
Bulk Volume Irreducible from Magnetic Resonance Logs, mbvi, bvf
Movie
Vshale, Vclay & Capillarity from Laser Particle Analysis Grain Size Distribution
Clay Volume from Core Plugs or Trims, Vclcore
Clay Volume from Thin Sections, Vcltx
Thin Section Limitations
Core Photographs and Descriptions

X-Ray Diffraction and Scanning Electron Microscope
Mudlogs and Lithlogs
Practical Session
Log Integration
Method
Shale Volume from Gamma Ray: Vshgr
Non-linear Vsh
Shale Volume from Density-neutron: Vshdn
Shale Volume from Density-sonic: Vshds
Shale Volume from Resistivity: Vshres
Vshgr, Vshdn, Vshds or Vshres ?
Thomas-Steiber clay distribution

POROSITY: Ø
Objective
Importance
Common Problems
Badhole Conditions
Minimising Badhole Conditions
Effective Porosity
Shale
Gas
Unknown Grain Density
Lack of Density Tool

DAY2

Morning Daily Recap, Questions, Debate
Non Shale Corrected Density-neutron Total Porosity
Porosity Input Data
Conventional Coring Criteria
Core Porosity and Grain Density, Øcore, rhog
Recommended Routine Core Analysis procedure
Core Porosity Method
Core Overburden Porosities
Log Integration
Total and Effective Porosity: Øt, Øe
Carbonates: Intergranular and Vuggy Porosity, Øv
Fracture Porosity, Øf
Density Total Porosity, Ød
Mean Grain Density Determination
Grain Density in Complex Lithologies
Correct rhog, neutron & sonic matrix in shales
Fluid Density, rhof
Magnetic Resonance Total Porosity, Ømrt
Magnetic Resonance Effective Porosity, Ømre
Shale Corrected Neutron Total Porosity, Øn
Neutron Porosity Method
Shale Corrected Density-Neutron Total Porosity, Ødn
Gas Zones
Micropractical
Shale Corrected Sonic Total Porosity, Øs
Sonic Porosity Method
Limitations of Multiple Linear Regression Porosity, Ømlr
Probabilistic Porosities
Badhole Conditions
Shale Volume Derived Porosity, Øvsh
Water Saturated Resistivity Porosity, Øro
Two Stage Minimum Porosity: Øs, Øvsh
Effective Porosity Equations, Øe
What is Effective Porosity?
Mainstream Petrophysics Effective Porosity
Traditional log analysis Effective Porosity
Magnetic Resonance Porosities, Øe, Øt
Vary rhog with shale
Recap - Summary of Typical Porosity Evaluation

FORMATION WATER RESISTIVITY: Rw

Rw Input Data
Recovered Formation Water
Well Tests
Reservoir Temperature, Tres
Wireline Formation Tester Water Samples
Archie Apparent Water Resistivity, Rwa
Certain water zones, Sw100
Micropractical
Archie Apparent Flushed Zone Water Resistivity, Rmfa
Resistivity Ratio Apparent Water Resistivity, Rwrr
SP Logs
Origin of SP
Determining Rwsp
Rwsp Recipe
Rw Catalogues
Wireline Formation Tester Water Gradients
Integration of Rw Values
Practical Session

WATER SATURATED RESISTIVITY: Ro
Summary of Common Problems
Special Core Analysis 'm' Not Equal To In-situ 'm'
Invalid Ø, a, or m or Rw and Sw100 zones
Øsca ^{1} Ørca ^{1} Ølog
Ro Equation Inputs
Total Porosity, Øt
Formation Water Resistivity, Rw
Cementation Exponent 'm'
'm' Objective
Pickett Plot
'm' Importance
'm' Input Data
Electrical Special Core Analysis Laboratory 'a' and 'm'
Problems with Laboratory 'm' values
Log Analysis Water Zone 'm'
Carbonates: Øv and Water Zone 'm'
Problems with Log Analysis 'm' values
'm' Log Integration

DAY3

Morning Daily Recap, Questions, Debate
RESISTIVITY SATURATION: Swrt
Summary of Common Problems
Absence of Conventional Core Calibration
Core Analysis 'n' Not Equal To In-situ 'n'
Freshwater Shaly Sands
Formation Heterogeneity Un-Resolved by Rt
Sw Equation Inputs
Formation True Resistivity, Rt
Which Logging Tool?
Rt Problems
Inadequate or Inappropriate Rock Volume Resolution
Deep Invasion
Shoulder Beds
Horizontal and Vertically Resistivity in Laminated Beds (3DEX)
Groningen and Delaware Effects
Cased Hole Resistivity Tool (CHFR) xx
Saturation Exponent, 'n'
'n' Objective
'n' Importance
Laboratory 'n' Problems
Wettability - Containing the Problem
Laboratory 'n' Input Data
Electrical Special Core Analysis Laboratory 'n'
Guidelines for Improved Laboratory 'n'
Micropractical

SHALY SAND Swrt

Waxman Smits Equation Inputs
Cation Exchange Capacity (CEC) and Qv
Qv from Magnetic Resonance Logs, Qvmr
Qv from Archie apparent water zone 'm'
Equivalent Conductivity of Exchange Cations, B
Waxman & Smits Cementation Exponent, mws (m*)
Waxman & Smits Saturation Exponent, nws (n*)
ImageLog Facies as Classes of Clay Distribution and B
Shaly Sand Swrt Log Integration
Is a Shaly Sand Equation Required ?
Log Data
Laboratory Electrical Data
Selecting a Suitably Structured Resistivity Swrt Equation
Core Sw Equation Inputs Do Not Guarantee Sw Output

CORE SATURATIONS
Oil Base Mud Core Sw and 'n' Calibration (Swobm)
Low Invasion Water Base Mud Core Sw and 'n' Calibration
Conventional Core Porosity and Permeability Sw and 'n' Calibration
Minimum Fluids Exchange
Conventional Core Fluid Saturations as Sw Constraints
1 Limitations of Conventional Core Fluid Saturations
Restored State Core
Well Tests as Sw Constraints
Reservoir Saturation Tool, RST

CAPILLARY PRESSURE SATURATION, Swpc
Capillary Pressure Derived Sw and 'n' Calibration
What Is Capillary Pressure?
Capillary Pressure Data Acquisition
Identifying Bad Capillary Pressure Data
Capillary Pressure Data Interpretation
The Reservoir Master Equation, [Sw-Ø-k-Height]
The J Function Method
The Regression Method
Individual Plug Curve Fit Methods, Skelt etc
Log Integration of Swpc
Problems with Capillary Pressure Derived Sw and 'n'

DAY4

Morning Daily Recap, Questions, Debate
MAGNETIC RESONANCE SATURATION, Swmr
Magnetic Resonance Tool's Swi

RECONCILLIATION OF Swrt via n
'n' Log Integration
Implied Sw Constraint from Electrical versus Capillary Pressure 'n' values ?
Field Example of Data Integration Constraining 'n'
Earth Tide Downhole Pressure Variations and Netgas Porosity xx
Sw Logical Constraints
Resistivity Ratio, Swrr
Log(Rt/Rxo) v SP Movable Hydrocarbon Indicator

BASE CASE SATURATION - THE Sw DECISION TREE

SATURATION DERIVATIVES
Movable Oil Saturation, Som
Residual Oil Saturation, Sor
Log / Core Minimum Rt for Maximum Water Cut - Netpay
Micropractical

CONTACTS, FLUID ZONES AND CAPILLARY PRESSURE
Objective
Hydrocarbon Types
Reservoir Capillary Pressure: Pc
Importance
Summary of Common Problems

Core Ø - k plots
Log Pore Typing Parameters
Is Facies Based Zonation Useful?
Borehole Image-log Facies Zonation
Other Log Permeability Predictors
Sonic Responses
Specific Surface Area
Log Integration
Timur-Coates Permeability Equation
Components of Bound Fluid Volume and their Log Prediction
Fitting Timur-Coates constants a, b and c
Summary of Conventional Log Permeability Evaluation
Effective Porosity, kpor
Saturation, ksw
Reservoir Master Equation Enables k from Sw as well as Swi
Clay / Shale Volume, kvsh
Multiple k Inputs: Accuracy versus Stability
Estimated Production Rates

DAY5

Morning Daily Recap, Questions, Debate
NETPAY and NETROCK: N:G
Objective
Importance
Common Problems
Relevant Hard Data Usually Not Available
Different Understanding of Meaning and Function
Violating the integrity of the petrophysical results table
Impact of Marginal Bed's Thickness and Location
Use Core-log Data not stand-alone Core data
Reservoir Geometry May Isolate Rock Volumes
N:G Input Data
N:G Non-Log-Inputs
Water Encroachment
Depletion
Permeability at Zero Movable Oil from Relative Permeability Data
Core Fluorescence
Capillary Threshold Height and Closure
Borehole Image Logs
Conventional Core Porosity Permeability Data
Well Tests and Production Data
Micropractical
WFTs
Hydrocarbon Pore Volume from Material Balance
N:G Log Inputs
Magnetic Resonance Logs
Invasion Profiles
0.5 Micron Mean Pore Throat Radius
Mudcake Build-up - Microlog
Mudcake Build-up - Caliper
Borehole Image-logs in heterolithic beds
Evaluated Saturation, Porosity and Clay / Shale Volume
Micro Spherically Focused and Microlateral Logs
Log Integration
Criteria: Why Permeability?
Determine Netpay first then Netrock
Determine the Cut-off from Direct Reservoir Observations If Possible
Netpay and Fluid Zones

SENSITIVITIES & UNCERTAINTY
Importance
Cutoff Sensitivities
XLS or Batch Recalculation Sensitivity Studies
P10 P50 P90 Geo.Model Uncertainties
Reducing Sensitivities & Uncertainties Cost-Effectively

SEISMIC - PETROPHYSICAL INTEGRATION
Depth-Time Conversion

Maximum understanding, minimum time: 420 message driven slides

This course for benchmark, mainstream petrophysics training