

Contents

1. Electrical Resistivity of Rocks.	1
1.1 Introduction.	1
1.2 Definition of Electrical Resistivity.	1
1.3 Nature of Electrical Resistivity of Reservoir Rocks.	2
1.4 Formation Resistivity Factor.	2
1.5 Effect of Formation-Water Salinity and Temperature on Rock Resistivity.	3
1.6 Rock Resistivity/Porosity Relationship.	6
1.7 Relationship Between Formation Resistivity Factor and Permeability.	10
1.8 Relationship Between Rock Resistivity and Fluid Saturation.	11
1.9 Electrical Properties of Shaly Sands.	13
2. Radioactive Properties of Rocks.	25
2.1 Structure of the Atom.	25
2.2 Energy States and Radioactivity.	25
2.3 Nature and Type of Natural Radiation.	26
2.4 Rate of Radioactive Decay.	28
2.5 Natural Gamma Ray and Gamma Ray Logging.	31
2.6 Gamma Ray Interactions.	32
2.7 Absorption of Gamma Rays.	33
2.8 Gamma Ray Absorption Logging.	36
2.9 The Neutron.	37
2.10 Neutron Interactions.	38
2.11 Neutron Diffusion.	39
2.12 Neutron Logging Methods.	41
3. Acoustic Properties of Rocks.	45
3.1 Introduction.	45
3.2 Basic Concepts of Elasticity.	45
3.3 Acoustic-Wave Propagation in Fluid-Filled Borehole.	48
3.4 Acoustic-Wave Propagation in Rocks.	53
3.5 Porosity/Transit-Time Relationships.	54
4. Measurement Environment.	60
4.1 Measurement Environment Effects.	60
4.2 Borehole Diameter and Shape.	60
4.3 Mud, Mud-Filtrate, and Mudcake Properties.	64
4.4 Invasion Profile.	71
4.5 Formation Temperature.	73
4.6 Record of Measurement Environment.	79
5. Resistivity Logs.	92
5.1 Introduction.	92
5.2 Apparent Resistivity.	92
5.3 Conventional Electrode Tools.	95
5.4 Focused Current Devices.	101
5.5 Induction Devices.	103
5.6 True Resistivity Determination.	106
5.7 Determination of R_{xo} From Microresistivity Tool Readings.	123
5.8 Summary.....	125
6. The Spontaneous Potential Log.	129
6.1 Naturally Occurring Electrical Potentials.	129
6.2 The SP Log.	129
6.3 Origin of the SP	130
6.4 Theoretical E_{sp} vs. Measured SP	132
6.5 Determination of Formation Water Resistivity.	133
6.6 Character and Shape of the SP Deflection.	141

7. Gamma Ray Log.	146
7.1 Introduction.	146
7.2 Detection and Measurement of Nuclear Radiation.	146
7.3 Unit of Measurement.	147
7.4 Statistical Variations.	147
7.5 Logging Speed.	149
7.6 Tool Response.	151
7.7 Applications of the Gamma Ray Log.	153
7.8 Gamma Ray Spectrometry Log.	153
8. Gamma Ray Absorption Logs.	159
8.1 Introduction.	159
8.2 Single-Detector Formation Density Tool.	159
8.3 Dual-Detector Density Tool.	159
8.4 Tool Calibration.	164
8.5 Porosity From Density Log Response.	165
8.6 Litho-Density Tool.	167
9. Neutron Logs.	172
9.1 Introduction.	172
9.2 Types of Detectors.	172
9.3 N-G Tool.	173
9.4 Sidewall Neutron Log.	174
9.5 Dual-Detector Neutron Tool.	176
9.6 Pulsed Neutron Tools.	180
10. Sonic Porosity Log	189
10.1 Introduction	189
10.2 Single-Receiver System.	189
10.3 Dual-Receiver System.	190
10.4 Borehole-Compensated Dual-Transmitter System.	195
10.5 Long-Spacing System.	199
10.6 Amplitude and Waveform Sonic Systems.	202
11. Conventional Interpretation Techniques.	206
11.1 Introduction	206
11.2 Acquiring Raw Data From Logs.	206
11.3 Basic Concepts of Conventional Interpretation Technique.	209
11.4 Calculation of Recoverable Hydrocarbons.	218
11.5 Concept of Critical or Cutoff Saturation.	218
11.6 Concept of Critical or Cutoff Porosity.	221
11.7 Concept of Movable Oil Saturation.	222
11.8 Advantages and Limitations of Conventional Interpretation Techniques.	224
12. Reconnaissance Interpretation Techniques.	241
12.1 Introduction	241
12.2 R_{wa} Technique.	241
12.3 The R_o Log.	249
12.4 The F_{xo}/F_s Approach.	250
12.5 The R_{xo}/R_t Method.	252
12.6 MOP's	254
13. Pattern-Recognition Interpretation Techniques (Crossplotting)	268
13.1 Introduction	268
13.2 Nonlinear-Resistivity/Linear-Porosity (Hingle) Crossplot	268
13.3 Log R_t vs. Log ρ_p Pickett Crossplot	276
13.4 Flushed-Zone Resistivity/Porosity Crossplots	283
13.5 Interplay of Hingle and Pickett Crossplots	284
13.6 Summary	284

14. Interpretation in Complex Lithologies.	292
14.1 Introduction	292
14.2 Lithology/Porosity Interpretation With Two Porosity Tools.	292
14.3 Lithology/Porosity Interpretation With Three Porosity Tools.	296
14.4 Lithology/Porosity Interpretation With the Litho-Density Tool.	304
15. Log Interpretation of Shaly Formations.	312
15.1 Introduction	312
15.2 Shale Content From the SP Log.	312
15.3 Shale Content From the Gamma Ray Log.	312
15.4 Porosity Logs in Shaly Formations.	314
15.5 Effective Porosity and Shale Content From Porosity Logs.	317
15.6 Density/Neutron Crossplot for Shaly Formation.	319
15.7 Water Saturation Determination in Shaly Formations.	322
16. Evaluation of Gas-Bearing Formations.	329
16.1 Introduction	329
16.2 Effect of Gas on the Neutron Log Response.	329
16.3 Effect of Gas on the Density Log Response.	329
16.4 Effect of Gas on Sonic Log Response.	330
16.5 Visual Gas Detection With Porosity Overlays.	330
16.6 Porosity Determination in Gas-Bearing Formations.	330
16.7 Saturation Determination in Gas-Bearing Formations.	338
16.8 Gas Effect on Lithology/Porosity Crossplots	338
16.9 Shaly Gas-Bearing Formations.	339
Appendix A SI Metric Conversion Table.	354
Appendix B Answers to Selected Problems.	355
Appendix C Abbreviations.....	359
Author Index.	361
Subject Index.	363