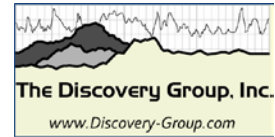


## Beyond Resistivity:

### A gameboard approach to determining petrophysical parameters

Daniel A. Krygowski, Senior Petrophysical Advisor, The Discovery Group



*The Discovery Group offers courses in petrophysics for your people, at your location, at a date convenient to your needs and internal schedules. The courses will benefit geologists, engineers, geophysicists, and geotechs, and can be of benefit to other specialists who routinely work with those geotechnical specialists. The best class size is from about 10 to 25 people from a variety of specialties who can share their professional experiences in the context of a greater understanding of petrophysics.*

#### Synopsis:

While resistivity was the first openhole logging measurement to be invented, the quantitative relationship between resistivity and the presence of hydrocarbons wasn't detailed until 15 years after the first commercial logging job (Archie, 1942). The complexity of the equation which connects resistivity to fluid saturation, discovered in the years before computers and calculators, led to graphical solutions as alternatives to using a slide rule to get answers.

The course illustrates how graphical methods ("pattern recognition techniques") that we once used to quickly determine fluid saturation and moveability (Pickett, Hingle, and Buckles plots) can now be used to determine calculation parameters for the equations, leaving the arithmetic to the hardware while the user concentrates on the interpretation of the data. Exercises provide the means to put the information shared here into practice.

#### *The course:*

- Starts with a review of the inputs and parameters needed to determine water saturation (Sw) from Archie's equation;
- Addresses Bulk Volume Water (BVW) as a quantity related to the production of water;
- Considers how the application of graphical solutions to Archie's equation (Pickett plots and Hingle plots) have changed with changing technology;
- Shows how enhancements to Pickett and Hingle plots, and the addition of Buckles plots, have enhanced the consistency in determining Archie and matrix parameters;
- Illustrates that the graphical methods can provide a quick, qualitative evaluation of the subsurface while easily providing the parameters needed for quantitative calculations.

The course strives to build on the existing understanding of petrophysical interpretation techniques to recognize formation fluid content at a glance, improve the interpretation of fluid content with a minimum of effort, and provide some understanding of what petrophysical software does "under the hood"

#### *Course topics include:*

- A quick review of the physics of the measurements to be discussed;
- Determination of water saturation through the traditional use of Archie's equation;
- Determination of calculation parameters through the graphical solutions to Archie's equation and bulk volume water;
- A methodology to determine those parameters simultaneously;
- Interpretation exercises to reinforce the interpretation methods that are covered.

*Length:* One day

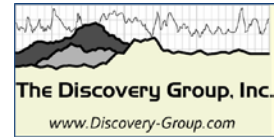
#### *Equipment needed:*

Calculator with exponent function, straightedge, pencil or pen;

A laptop that can be shared among a small group, with Microsoft Excel (a specific spreadsheet will be provided for the last exercise).

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**Agenda:** No specific times are listed, as the times to cover material will depend on the questions and comments of the class. Questions and comments based on the experience of participants are welcomed and encouraged, and often provide insights to local conditions and methods that would otherwise not be presented.

Short breaks will be taken throughout the course, as needed.

### Day 1

Course Logistics, Introduction

Archie's water saturation equation: inputs and parameters

Physics of the measurements

    Sonic traveltime, bulk density and photoelectric effect, neutron porosity

    Resistivity: laterologs and induction logs

Water saturation; a qualitative view

    Invasion profiles

Bulk volume water, BVW

Water saturation, again:

    Pattern recognition (graphical) techniques

        Early wellsite methods: F-overlay, Ro curve

        Apparent water resistivity,  $R_{wa}$

        Pickett plots

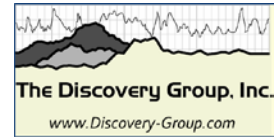
        Hingle plots

        A "gameboard" approach to estimating saturation and porosity parameters

            Pickett, Hingle, and Buckles plots in concert

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### About the instructor:



**Daniel A. Krygowski** is a Senior Petrophysical Advisor at The Discovery Group, in Denver, Colorado, USA. In this role, he has worked petrophysical interpretation projects in a variety of international and US domestic locations. Currently he is spending most his time providing and developing training courses in basic and intermediate openhole petrophysics. The courses include the common instructor-led formats, as well as longer-term, lower intensity formats that allow participants to spend more time with the course material while delving deeper into areas of personal interest.

Since the late Cretaceous, Dan has taught the AAPG Basic Well Log Analysis course with Dr. George Asquith. In recent years, Rick Lewis, with Schlumberger, has joined George and Dan in instruction in the course. In 2004, the AAPG published *Basic Well*

*Log Analysis*, co-authored by Dan and George, with Steve Henderson and Neil Hurley. The book is the second edition of George's similarly-named book which was one of AAPG's all-time best sellers, and the second edition has also become an AAPG best seller.

Dan earned a BA in Physics from the State University of New York at Geneseo. He then earned MS and Ph.D. degrees in Geophysics from the Colorado School of Mines, where he focused on petrophysics under Dr. George R. (Dick) Pickett.

After completing his formal education, Dan worked for Cities Service Company (now part of Occidental Petroleum), Atlantic Richfield (now part of bp), Petrophysical Solutions, Landmark Graphics (a Halliburton company), and Chevron. At several of those companies, he held positions in petrophysics and petrophysical software development, with both technical and management responsibilities. He joined The Discovery Group in late 2006.

Dan has been active in the Denver Well Logging Society, serving two terms as Director, and terms as Vice-President Technology, and Vice-President Membership. Dan is a member of SPWLA, AAPG, SPE, SEG, DWLS, and RMAG.

Dan can be reached at:

DanKrygowski@Discovery-Group.com  
303.831-1515 x207      office  
303.862.0110          cell