Visual Basics

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You can't depend on your eyes when your imagination is out of focus (Mark Twain).

Today's sophisticated software offers unprecedented formation evaluation capabilities, but just as Mark Twain opined 100 years ago, the full benefit will not be achieved unless we have a clear understanding of the underlying inter-relationships, and a focused vision with which to interpret the results.

Simple visual patterns can signal (and more)

- are (independent) laboratory measurements internally consistent with one another, and the wireline data,
- whether an interval is wet or hydrocarbon bearing,
- locally appropriate values for Rw, 'm' and 'n',
- is there a 'short circuit' risk to Sw(Archie).

In a manner analogous to laboratory bead pack studies, we have used actual carbonate capillary pressure curves from a single rock type, to construct the corresponding Saturation-Height relation. This laboratory-based Sw is then used, as a function of Height Above Free Water Level, to deduce the corresponding (simulated) wireline resistivity across a range of porosities, for specified values of Rw, 'm' and 'n'.

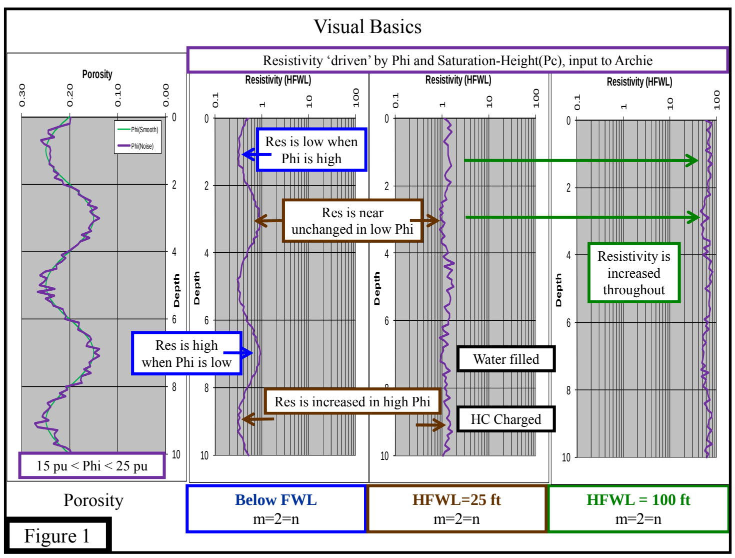


Figure 1

The approach allows us to construct petrophysical responses for a single rock type, across a continuous interval, and thereby makes the visual response more apparent. Different pore systems will exhibit different behavior, and may be similarly investigated via construction of the appropriate Sat-Height relation.

In the case of intergranular – intercrystalline porosity (represented as a sine curve with random noise super-imposed) with Rw=0.02 ohm-m and n=2=n, ***the Pc-based Sat-Height resistivity simulation reveals*** (Figure 1)

- In the water leg, resistivity is low when porosity is high and vice versa.
- In the transition zone, hydrocarbon enters the best porosity while the lower porosity remains water filled, with the combination causing resistivity to remain low in the poor porosity and increase (relative to the water leg) in the better rock (the relative resistivity – porosity pattern inverts, with respect to the water leg).

- The difference in the two resistivity endpoint values, and the physical juxtaposition of the laminations, can give rise to Low Resistivity Pay (Griffiths, et al), which we have personally experienced, just as Griffiths predicts, in the transition zone.

- Higher in the column, hydrocarbon is present across the porosity range.

Among the ***'deliverables' of this visual perspective, are:***

- Quick look identification of where the reservoir is wet versus hydrocarbon charged,
- Quick look identification of where laminations of low quality rock may produce 'short circuits' that would compromise the utility of Archie's Sw equation,
- Graphical determination of Rw, 'm' and potentially 'n' from a Pickett Plot display, if we are fortunate enough to have a range of porosity present for a single rock type,
- A graphical platform within which to integrate RCAL, SCAL, routine wireline and NMR wireline.

Saturation - Height

Saturation-Height

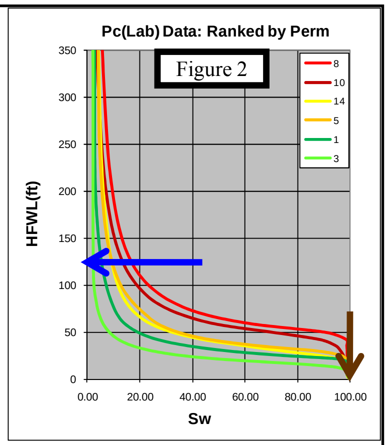
•***An internally consistent (and relatively simple) set of petrophysical relations is developed by*** first ***calibrating a Saturation-Height relation on actual carbonate capillary pressure measurements from a single well/reservoir***.

•***Potential samples are selected to span the range of permeabilities***, expected in the reservoir.

•***Pc(Lab) is converted to HFWL*** (per light oil in this example) to allow a more direct (ie absent intermediate calculations) application to the reservoir.

•***The Pc curves stack, as expected***.

Smpl	Phi	Perm
#	%	md
8	17.3	0.5
10	15.8	1.2
14	17.7	1.3
5	23.8	1.9
1	25.5	3.0
3	26.7	4.0



•Pc curves 'stack', right to left (decreasing Sw), according to Perm

•Pc curves 'stack', top to bottom (decreasing displacement pressure, or HFWL), according to Perm

Modern spreadsheets offer analytical power that is often not generally recognized. Statistical summaries are simple, residuals may be explicitly defined in various orientations and minimized in mathematical formulations that are non-linear, Monte Carlo simulations can be performed, and much more. Calibration of a Saturation–Height relation, to laboratory measured Pc curves, is another application (Ballay, Statistics Are Pliable, 2010).

In the case at hand, ***actual carbonate capillary pressure curves have been converted to reservoir conditions, and displayed as Height Above Free Water Level*** (for a light oil): Figure 2.

$$P_c(1) / \{ \sigma(1) * \mathrm{Cos}[\theta(1)] \} = P_c(2) / \{ \sigma(2) * \mathrm{Cos}[\theta(2)] \}$$

$$\mathrm{HFWL(TVD)} = P_c(\mathrm{Reservoir}) / [\, 0.433 * (\rho_w - \rho_{nw}) \,]$$

The various Pc curves 'stack' in the sense that the displacement pressure increases as permeability decreases, and at a specific HFWL the higher displacement curve exhibits a lower non-wetting phase saturation (***Brooks and Purcell for a bead pack study illustration***).

This behavior is ***consistent with Lucia's Petrophysical Classification methodology***. Based upon a large laboratory database of Pc(Hg Inj) measurements and visual descriptions, Jerry found (as physically expected) a correlation between the average particle size, and displacement pressure.

Based upon the inflection points in this relation, he identified two boundaries (three domains) across which the Porosity ⇔ Permeability relation changed, which then allowed him to develop three generic Phi ⇔ Perm, and Saturation ⇔ Height, relations.

In the case at hand, we have locally specific Pc curves, and so are able ***to develop the local Sat ⇔ Height relation.*** Mitchell's formulation is utilized,

$$S_w = a*Pc^b*Prm^c \text{ with } Pc \rightarrow HFWL$$

but before establishing the actual, locally specific parameters (a, b and c), we must address the issue or Petrophysical Rock Quality categories.

Porosity ⇔ Permeability and Rock Quality

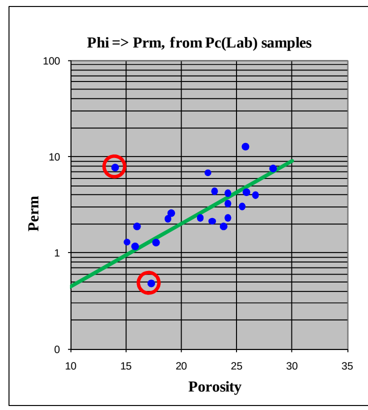
There are a number of mathematical formulations for Sat⇔ Height relations, with ***the general underlying principle being to estimate Sw as a function of Height (TVD) and some indicator of rock quality.***

Porosity by itself is not necessarily a representative indicator of quality (Brooks and Purcell bead pack study, for an illustration) and so one typically examines the core Phi ⇔ Perm crossplot early on, in the construction of the Sat ⇔ Height relation: Figure 3.

Saturation-Height and Porosity ⇔ Permeability

- ***As formulated, the Sat-Height model will be driven by HFWL and Perm***
- ***Application requires a mathematical representation of the Phi ⇔ Perm relation,*** with ***one option being exponential in nature.***
- ***The Phi ⇔ Perm relation is an integral part of any evaluation and deserves careful consideration, with regard to 'grouping' similar pore systems***
- ***Calibration samples which fall off-tend*** should be ***omitted from the calibration.***
- Note that in the case of a well-defined Phi⇔ Perm relation, it may be possible to formulate the Sat-Height model direct on porosity

$$S_w = a*HFWL^b*Prm^c \rightarrow a*HFWL^b*Phi^c$$



Prm=a*exp(b*Phi).	
a	0.1
b	0.15

Figure 3

When core Phi – Perm relations yield a well-defined trend, it is tempting to represent that correlation with any convenient mathematical relation (often semi-Log or exponential), and proceed from there. There are two ***pitfalls in this approach.***

- Minimizing the residuals of logarithms is not the same as minimizing the residuals of the actual values; Woodhouse for an illustration.
- There is no guarantee that the 'trend' displayed on the Phi – Perm crossplot corresponds to a single rock quality; Hartmann for a detailed discussion with illustrations.

There are a variety of Petrophysical Rock Quality characterization protocols, with five common methodologies being: Lucia, Lønøy, Winland, Sqrt (Perm/Phi) and Amaefule. ***These options share some common objectives:***

- Recognition of rock quality categories so as to ensure that SCAL measurements include samples from all categories.
- Quantification of quality to allow comparison of SCAL measurements within a single category for quality control purposes and development of locally specific correlations (Sat-Height, for example).
- Identification of Phi ⇔ Perm boundaries, supported by SCAL measurements if possible, to thereby leverage the value of the routine core Rhog, Phi, Perm measurements. That is, we realize that that the routine Phi – Perm crossplot likely spans a range of quality categories, but it is not necessarily clear exactly where the boundaries are; if the boundaries can be identified then the routine core analyses, which may be ten times or more the size of the SCAL database, can be used for wireline rock quality calibration and the value of that routine data has been greatly leveraged.

Without meaning to minimize the value of any of the options, the practical approach may very well depend upon what one has to work with (Ballay, Coffee or Tea).

The ***Lucia*** method, which is carbonate focused and well documented, has as its basis a large routine core analyses database, mercury injection capillary measurements, and thin section descriptions. It is ***formulated in a manner that allows visual implementation, at the well site or in the core shed***.

Lønøy's method builds upon the combination of Choquette & Pray (geologically focused) and Lucia (petrophysically focused) to identify 20 pore types.

On the other hand, it's common for field studies to be done years after the wells have been drilled / cored, and for one to find that not only are there ***no quantitative petrophysical core descriptions*** (ie Lucia type) to reference, but there may in fact not be a significant amount of core even available to examine. ***If the SCAL included capillary pressure*** though, ***those curves can serve as a quality indicator: Winland.***

Regardless of which protocol is used, it's a good idea to cross-check if at all possible. In the case at hand, with Pc(Hg Inj) available and no quantitative rock description, Winland is an obvious consideration, and the cross-check is to compare the R35 that one would calculate per Winland's generic correlation, against that measured with the actual capillary pressure curves. In Figure 4 we observe R35(calculated) ~ R35(measured), thereby validating the protocol on this dataset.

Saturation-Height and Porosity ⇔ Permeability

•In addition to the (perhaps) routine Exponential and/or Semi-Log Phi⇔ Perm relations, there are ***alternative, physically based Rock Quality characterization protocols.***

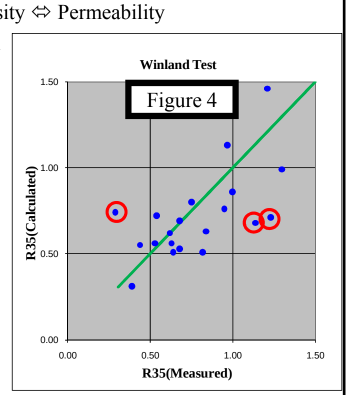
- ***Lucia***
- ***Winland***
- ***Others***

•The suitability of a particular framework should be 'tested' for each application.

•In the graphic at right, ***R35 has been determined from the measured Pc curves, and compared to the calculated result per Phi and Perm measured on the same plug***

•Anomalous samples should be reviewed, and potentially discarded from the calibration

•The Phi ⇔ Perm relation is an integral part of any evaluation and deserves careful consideration, with regard to 'grouping' similar pore systems



$$\text{Log } R35 = 0.732 + 0.588 \text{ Log } Ka - 0.864 \text{ Log } \Phi$$

Winland R35 compares favorably with the independently measured pore throat radii

Saturation-Height and Porosity ⬄ Permeability

•***In a practical sense, the choice of a Rock Quality Classification system hinges upon what one has to work with***.

•***Visual rock descriptions*** lend themselves to a ***Lucia*** framework.

•***SCAL data***, examined perhaps years after the well was drilled and cored (and in the absence of detailed visual descriptions), may be addressed with a ***Winland*** approach.

•***Regardless of which protocol is used, it's a good idea to cross-check***.

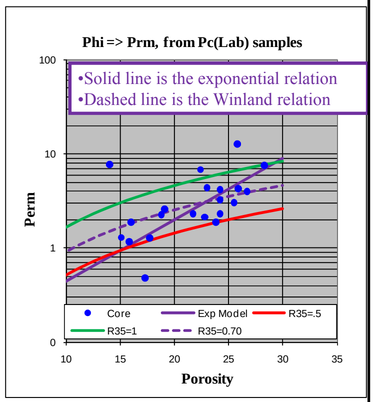


Figure 5

Kair = 10 ^ [(logR35 + 0.864 logPhi - 0.732)/0.588]

•In the case at hand, the ***potential Sat-Height calibration points are bounded by 0.50 < R35 < 1.0, and the Phi ⬄ Perm relation may be described by R35 ~ 0.70***

•***The choice of a Phi ⬄ Perm relation, and Quality Categories, is a Key Issue***

Be aware that it is fairly easy to find examples of reservoir rocks that are not properly described by routine generic protocols, Lucia, Winland or the other options. Due diligence requires a cross-check at the earliest opportunity.

With the suitability of Winland established by comparison of measured and calculated R35 (Figure 4), ***one is now presented with an enhanced view of the Phi ⬄ Perm crossplot***: Figure 5.

In the case at hand, actual ***Phi and Perm measurements on the mercury injection samples are observed to yield:***

- ***0.5 um .LE. R35 .LE. 1 um categorizes the locally specific rock quality***.
- ***Perm as a function of Phi, corresponds to Winland's relation for R35 ~ 0.70 um, which yields a Phi ➔ Perm relation*** (that is observed to be different from the exponential correlation that might otherwise have been used).

Our mental vision of the Phi ⬄ Perm crossplot now has an additional dimension, that of pore throat size, for the Winland grids superimposed upon the crossplot generically reveal:

- Decreasing porosity at constant perm, infers pore throats are getting larger, as the trend crosses Winland grids in the direction of increasing R35.
- Increasing perm at constant porosity, infers pore throats are getting larger, as the trend crosses Winland grids in the direction of increasing R35.

For those who are perhaps more familiar with the Sqrt(Perm/Phi) approach, Hartmann points out (and illustrates) that:

- Winland's R35 boundaries are very similar what one would arrive at with the Sqrt(Perm/Phi) approach.
- Winland's R35 has the advantage of representing a physically meaningful attribute, the pore throat radii being penetrated at Sat(Non-wetting) = 35%, whereas Sqrt(Perm/Phi) is simply a number.

Saturation – Height Calibration

Implementation of the Sat-Height concept requires a choice of the mathematical formulation to be used, and again one is presented with a number of issues and options; Hirasaki has kindly posted his course notes to the WWW and additional material may be found in Wiltgen et al, Ding et al, Negahban et al, Gunter et al, Harrison et al.

Specific mathematical models require specific Pc curve behavior, and so one can ***screen the suitability of the various models by displaying the data in an appropriate fashion.*** In the case of Mitchell (S_w=a*Pc^b*Prm^c), for example, the individual Pc curves should appear linear, when displayed in a Log-Log format: Figure 6.

Saturation-Height

•The ***mathematical formulation of the Saturation-Height model is that of Mitchell***, et al. ***S_w=a*Pc^b*Prm^c with Pc → HFWL***

•Prediction of Formation Water Saturation from Routine Core Data Populations,

•P. Mitchell, D. Walder & A. M. Brown

•Mitchell points out that if this formulation is to be valid, the data must appear linear on a log-log display, and that ***non-linear behavior may be an indication of some kind of physically-based discrepancy***

•Mitchell suggests that ***data not appearing linear on the log-log display may be reasonably considered for editing***

•The ***calibration is done with Excel's Solver***, ***by minimizing the sum of DeltaSw^2 across all the acceptable sample measurements*** at the various HFWL's, where

DeltaSw = Sw(Solver) – Sw(Lab)

S_w= 100*a*HFWL^b*Prm^c	
a	135.21
b	-1.42
c	-0.87

Figure 6

Figure 6

With the mathematical model identified and the data appropriately screened, ***calibration is accomplished with Excel's Solver***: Figure 7. At this point ***one should QC the calibration*** by comparison of the Solver solution against the individual input Pc curves, one by one.

Also, ***if the calibration has been against centrifuge, rather than mercury injection***, there will typically be far fewer actual lab measurements, and the pressures achieved will be substantially less. In the case of a reservoir with large structural relief, one must ensure that if the crest of the reservoir is beyond the highest pressures achieved in the lab, the mathematical representation (extrapolation) is reasonable.

Saturation-Height

•As formulated, ***the Sat-Height model is driven by HFWL and Perm***

•It is also (sometimes) possible to formulate the Sat-Height model direct on porosity

S_w=a*HFWL^b*Prm^c → a*HFWL^b*Phi^c

•We typically do both calibrations and compare Sw(Solver) back to Sw(Pc) to identify the best formulation

•For a specific selection of Phi, Rw, 'm' and 'n', this Sat-Height model specifies a simulated set of wireline resistivities, which will be internally consistent with the independent Pc(Lab) data.

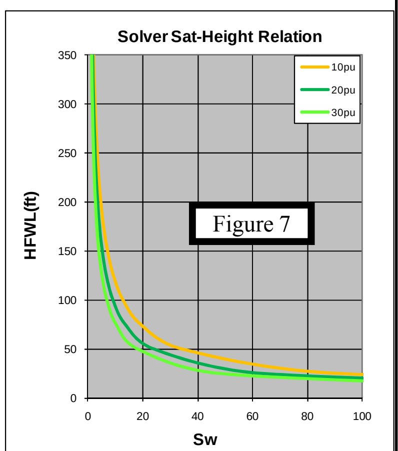


Figure 7

S_w= 100*a*HFWL^b*Prm^c	
a	135.21
b	-1.42
c	-0.87

Resistivity = R_w / [Phi^m * S_w(Sat-Height)^n]

This Saturation-Height model, in conjunction with assigned values of porosity (the sine wave) and consistent Rw, 'm' and 'n' can ***now be used to establish the corresponding resistivity, for a specific petrophysical rock quality. The approach allows one to illustrate the behavior of a single rock type, in depth or any other graphical format,*** independent of the mixing of rock quality categories that so often happens in an actual reservoir: Figure 7.

The Pickett Plot

Although ***Bulk Volume Water*** and ***Pickett Plots*** are less commonly seen today, than in years past, they remain powerful, quantitative pattern recognition tools. Furthermore, ***as pointed out by Aguilera, it's possible to combine the two concepts*** into a single graphic, thereby compounding the utility of the graphic and achieving ***Double Duty***.

At the simplest level, that of water saturated rock, Archie's equation reduces to

$$m*\text{Log}(\phi) = \text{Log}(Rw) - n*\text{Log}(\boldsymbol{Sw \rightarrow 1}) - \text{Log}(Rt)$$

$$m*\text{Log}(\phi) = \text{Log}(Rw) - \text{Log}(Rt)$$

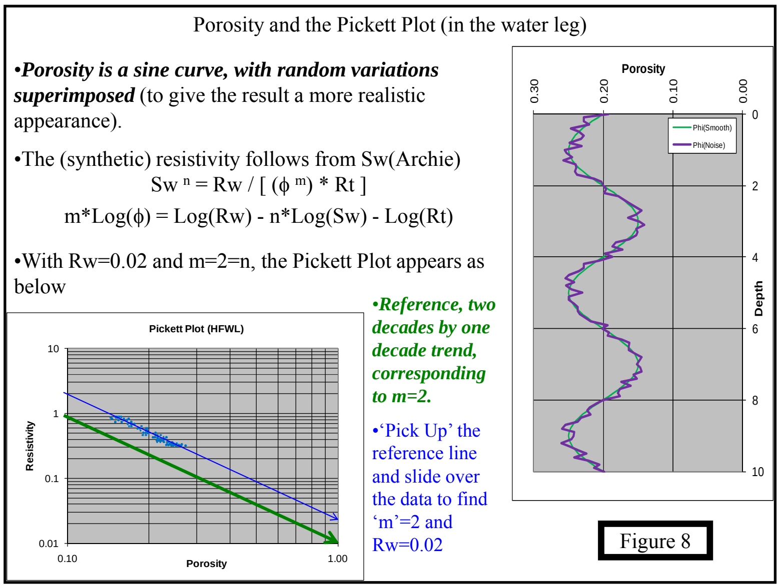


Figure 8

Displaying measured porosity and resistivity, in a Log-Log format, has the visual effect of taking the logarithm, which results in a linear trend with slope of 'm' (or 1/m, depending upon the choice of vertical and horizontal axes) and the intercept being Rw: Figure 8.

Given that the conventional mathematical slope – intercept nomenclature is y = m*x + b, one immediately wonders if our petrophysical use of 'm' for the cementation exponent has its roots in the mathematician's vocabulary. And 'n' of course, simply follows 'm' in the alphabet.

While less intuitive than linear displays, Semi-Log and Log-Log formats are a routine part of petrophysics (Phi ⇔ Perm, Formation Factor, Resistivity Index, etc) ***and straight-forward to work if one remembers the following simple guidelines.***

- A logarithmic axis display has the effect of taking the visual logarithm.
- Think (visualize) in terms of decades. A slope of 2.0, for example, corresponds to a slope of two decades by one decade.
- To quickly estimate a slope, draw any convenient two decade by one decade line, and then 'pick up and move' that trend line to the data cloud.
- When quantifying numerical slopes from a logarithm display, read the actual number from the graphic and then take the logarithm when calculating the slope.

As expected in the case at hand, there is a well-defined trend corresponding to a slope of 2.0 with an intercept of 0.02 ohm-m.

The same concept can be applied in the Rxo – Rmf domain, as a quality control cross-check, plus potentially serving as a Quick Look discrimination between vuggy vs IG/IX porosity (Ballay, Two for One).

Introduction of the Bulk Volume Water concept, within the context of the Pickett Plot, brings forward the possibility of determining not only Rw and 'm', but 'n' as well: Aguilera.

BVW, the product of Porosity and Water saturation, has been referenced by many (Archie, Lucia, multiple NMR applications, etc) as a Rock Quality indicator. Above the transition zone, BVW for a single rock type will often take on a constant value irrespective of porosity, and this behavior can be used to judge whether a relatively high Sw interval is likely to make water, or is simply reflecting a decreased porosity within a constant rock type.

That is, high Sw above the transition zone and within a specific rock type may in fact be still be at Swirr, and one application of the NMR measurement is to compare Phi*Sw from the routine wireline measurements against Bulk Volume Irreducible from the NMR.

The two concepts, Pickett and BVW, are linked by Aguilera via Archie's equation.

At some specific value of BWV, the Archie equation becomes

$$m*\mathrm{Log}(\phi) = \mathrm{Log}(Rw) - n*\mathrm{Log}(\boldsymbol{Sw}) - \mathrm{Log}(Rt)$$

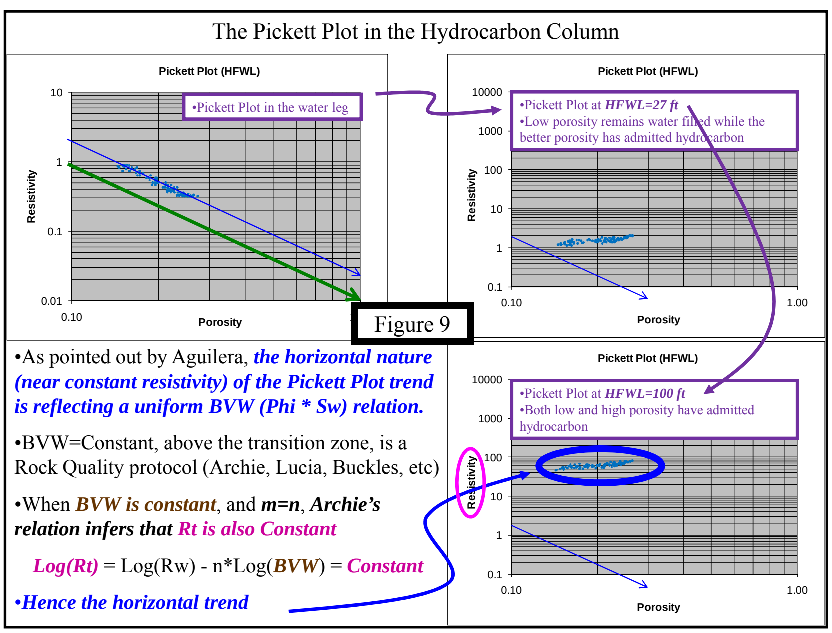
$$m*\mathrm{Log}(\phi) = \mathrm{Log}(Rw) - n*\mathrm{Log}(\mathbf{BVW}/\phi) - \mathrm{Log}(Rt)$$

$$(\mathbf{m - n})*\mathrm{Log}(\phi) = \mathrm{Log}(Rw) - n*\mathrm{Log}(\mathbf{BVW}) - \mathrm{Log}(Rt)$$

In the case of m = n, the ***porosity term drops out*** leaving

$$(\mathbf{m - n})*\mathrm{Log}(\phi) = \mathrm{Log}(Rw) - n*\mathrm{Log}(\mathbf{BVW}) - \mathrm{Log}(Rt)$$

$$\mathrm{Log}(Rt) = \mathrm{Log}(Rw) - n*\mathrm{Log}(\mathbf{BVW}) = \mathrm{Constant}$$

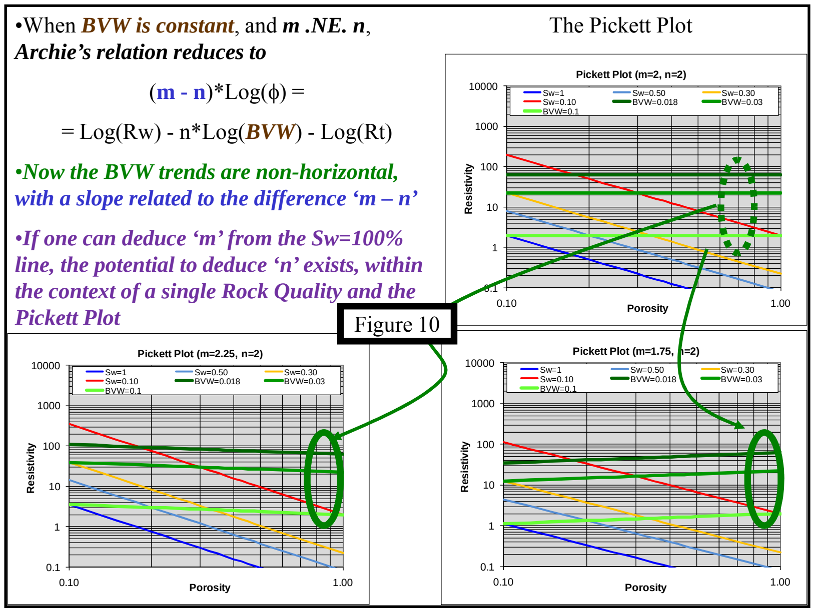


The ***BVW = Constant*** (single pore size) ***grids are straight lines, on the Pickett Plot***: Figure 9.

If "m" and "n" are not equal, the BVW grids are no longer linear, as the porosity dependence in the above relation does not drop out, but there remains a constraint, and a pattern that will appear on the Pickett Plot: Figure 10.

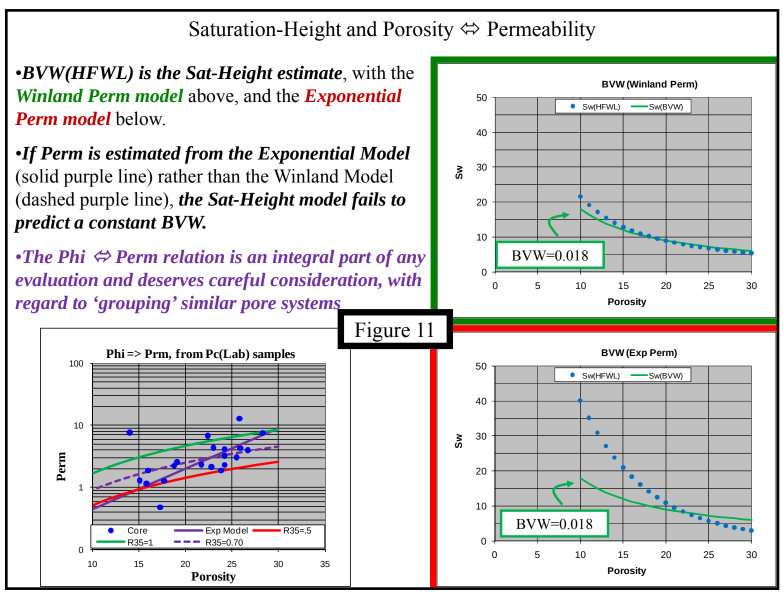
In a favorable situation this Double Duty concept could allow one to deduce "m" from a water leg analysis, and "n" from the hydrocarbon zone response (actually "m – n", but with "m" known from the water leg, it will be possible to deduce "n").

As discussed in detail by Aguilera, ***the same concept can be used to link permeability estimates, Winland R35 boundaries, and other attributes which we often deal with on a stand-alone basis.***



There is ***a final visual comparison to be made,*** that of ***BVW(Pc) and BVW(Wireline).*** The capillary pressure curves and the corresponding Saturation ⬄ Height relation are regarded as the benchmark. In the case at hand that Sat-Height(HFWL) is used to calculate the corresponding resistivity as a function of HFWL and Permeability. The Perm estimate comes from the Phi ➔ Perm relation (as will often be the case), and so an obvious QC point is to compare BVW(Pc) and BVW(Wireline).

If Permeability is estimated via the Winland protocol, agreement is found: Figure 11. On the other hand, if one were to perform the evaluation based upon a simple (ie no rock quality model) exponential relation between porosity and permeability, it's found that BVW(Wireline) does not match BVW(Pc). That is, at HFWL ~ 100 ft, the Sat-Height relation yields a near constant (ie single rock quality) Phi * Sw ~ 0.018 if the Winland Phi ⬄ Perm estimation is used, but not when the exponential Phi ⬄ Perm estimate is used.



Since the Sat-Height(HFWL) calibration was based upon the individual sample measured permeability, this is not a 'Phi ➔ Perm force fit' constraint, but rather reflects the fact that the Winland model is better reflecting the actual inter-relationship between the various petrophysical attributes (ie the Winland Phi ⇔ Perm relation is middle of the road for the single rock quality, while the exponential relation is biased low at low porosity and high at high porosity).

Summary

Visual patterns in wireline signatures are valuable at two end point levels:

- recognition of qualitative (large scale) depositional / diagenetic environment changes,
- characterization of rock quality attributes at the foot-by-foot level.

As discussed in detail by Aguilera, ***many of the ideas which we often draw upon individually can be linked mathematically and visually***; the Pickett Plot, Bulk Volume Water, Winland, Permeability.

Independent SCAL, particularly capillary pressure with thin section descriptions, provide an important and independent perspective.

The concepts and patterns which are useful on a stand-alone basis ***can perhaps yield yet an additional dimension when combined:***

- Laminations which may be water filled in the transition zone, and hence a ***potential 'short circuit' to Archie's equation,***
- Rw, 'm' and ***an estimate of 'n'*** from the Pickett Plot.
- Aguilera for additional benefits.

In practice, the single rock quality population that has been addressed here is likely to be one of several qualities present, each of which may span a range of porosities.

Focke and Munn demonstrated that:

- small (chalk) pores and large (IG/IX) pores can have similar 'm' exponents,
- a decrease in porosity can correspond (perhaps counter-intuitively) to a decrease in 'm', and vice versa.

The 'n' exponent is a function of:

- wettability (Sweeny and Jennings), which may change within the hydrocarbon column,
- surface roughness (Diederix).

These complications do not diminish the importance of visual basics and pattern recognition, but rather bring to focus:

- the importance of a complete wireline, RCA and SCAL dataset,
- the fact that a skilled and inquisitive petrophysicist is unlikely to be replaced by a computer program, regardless of how sophisticated the software might be.

Acknowledgement

As a young man just home from the Army, and attending Missouri State University, three men sparked my interest in physics, and the mathematical tools with which physical models could be constructed: Dr Larry Banks, Dr Bruno Schmidt and Dr Woodrow Sun.

Like the sine wave cycles used to simulate variations in porosity herein, life is also cyclic: birth, ascent to maturity, the golden years and death. In recent months we have lost Dr Banks, but just as the sine wave reappears, his memory keeps returning to those who knew and respected him.

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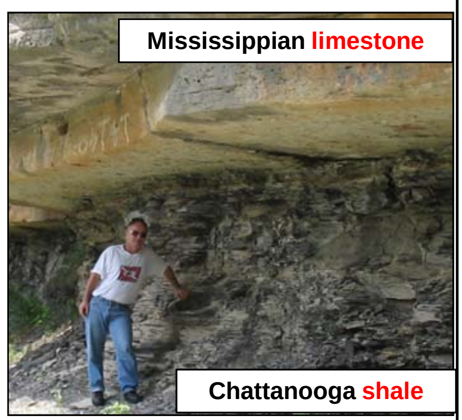
Biography

R. E. (Gene) Ballay's ***34 years in petrophysics*** include ***research and operations*** assignments in Houston (Shell Research), Texas; Anchorage (ARCO), Alaska; Dallas (Arco Research), Texas; Jakarta (Huffco), Indonesia; Bakersfield (ARCO), California; and Dhahran, Saudi Arabia. His carbonate experience ranges from individual Niagaran reefs in Michigan to the Lisburne in Alaska to Ghawar, Saudi Arabia (the largest oilfield in the world).

He holds a ***PhD*** in ***Theoretical Physics*** with ***double minors in Electrical Engineering & Mathematics***, has ***taught physics in two universities***, ***mentored Nationals*** in Indonesia and Saudi Arabia, published ***numerous technical articles*** and been designated ***co-inventor on both American and European patents***.

At retirement from the Saudi Arabian Oil Company he was the senior technical petrophysicist in the Reservoir Description Division and had represented petrophysics in three multi-discipline teams bringing on-line three (one clastic, two carbonate) multi-billion barrel increments. Subsequent to retirement from Saudi Aramco he established Robert E Ballay LLC, which ***provides physics - petrophysics consulting services.***



He served in the US Army as a Microwave Repairman and in the US Navy as an Electronics Technician, and he is a USPA Parachutist and a PADI Dive Master.

