Double Time ….. *March*
R. E. (Gene) Ballay, PhD
www.GeoNeurale.com

It's said that the senses of smell and sound are best at resurrecting long forgotten memories. Who, for example, can smell wood smoke without recalling an evening camp fire with their family, many years ago? And the sound of crickets chirping in the night will reinforce that same recollection.

Fast forward a few years, to a horribly hot and humid day, when physical exertion has left us weary and drenched in sweat. Just as we think the situation could not be any worse, the Platoon Sergeant bellows: **Double Time …… *March***. "Worse" has happened.

Fast forward a few more years. After hours spent wrestling with unreliable fax machine reception or digital transmission irregularities, we finally have the wireline data in hand, only to hear "we need that Quick Look within the hour….and the graphics must be in color"….. Double Time …. *March*. "Worse" has happened again, but there is another side to this particular coin.

Quick-look evaluations serve a number of useful purposes. Firstly, for those in an operations environment, they provide a fast, integrated evaluation of the recently acquired data. That is, while the porosity and resistivity ***logs appear to be valid individually, one must also ensure that the integrated result is reasonable***. We furthermore need quick, ***first-pass reservoir attributes for Management***: Double Time …. *March*.

Later in time, the QL results continue to serve a purpose as a reference against which to compare the more sophisticated, final interpretation. As an example application, probabilistic evaluations of LWD data (with generally larger light hydrocarbon effects) can be vastly superior to deterministic options, but care (with local experience) must be exercised in setting up that probabilistic Model. In the past ***we have identified faulty (improperly specified) probabilistic results by comparison to QL results.***

It was not that many years ago that petrophysical calculations were done via pencil / paper / overlays / crossplots: there was not even a computer in the office, let alone in the field. And so simple ***Quick Look algorithms were developed for the routine deliverable***. Yes, this was admittedly a limitation, but how well I remember being so impressed by Old Timers who could simply "look" at the logs, do a quick mental calculation and then give an interpretation.

Today these ***QL interpretations, compared to the final, sophisticated evaluation, also provide a valuable QC check going forward.***
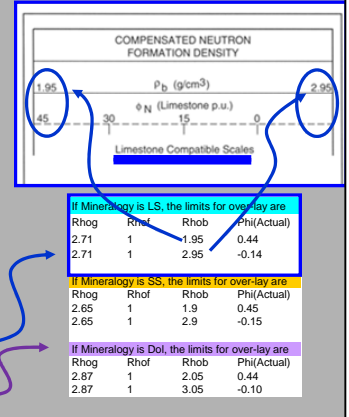
"Quick Look" Porosity Model

The choice of display scale for the porosity logs is an important issue. Because environmental corrections for the neutron log typically require limestone units for input, ***there is merit is having the neutron porosities delivered in LS units even if the reservoir is clastic***. And the attraction of working in LS units actually goes well beyond this.

If the bulk density measurement is converted to equivalent limestone porosity *(or better yet, displayed in gm/cc across appropriate limits, Figure 1)*, **the simple arithmetic average of Phi(Neutron/LS) and Phi(Rhob/LS) is often a reasonable first-pass porosity estimate in both sandstone and dolostone** (and of course limestone): ***Figure 2.***

Porosity Log Display Scales

Figure 1

• *Choice of scale for the Density-Neutron display* is an *important issue*

• *Neutron environmental corrections typically require the input to be in LS units*

  • There is merit is using the limestone scale, even if the mineralogy is sand or dolomite

• The *bulk density gm/cc scale can then be adjusted to yield porosity* in the *dominant mineralogy*

  • Typical NPhi display range is -0.15 → 0.45

  • *1.95 → 2.95 for limestone*

  • *2.05 → 3.05 for dolostone*

If Mineralogy is LS, the limits for over-lay are			
Rhog	Rhof	Rhob	Phi(Actual)
2.71	1	1.95	0.44
2.71	1	2.95	-0.14

If Mineralogy is SS, the limits for over-lay are			
Rhog	Rhof	Rhob	Phi(Actual)
2.65	1	1.9	0.45
2.65	1	2.9	-0.15

If Mineralogy is Dol, the limits for over-lay are			
Rhog	Rhof	Rhob	Phi(Actual)
2.87	1	2.05	0.44
2.87	1	3.05	-0.10

The validity of this simplistic success can be exhibited (and tested) with the appropriate basic porosity crossplot. Enter the crossplot with locally representative values across a sand, and compare that xplot result to the numerical average: ***Figure 3***.

In the case of dolostone (***Figure 4***), a similar test will document the applicability in that mineralogy.

***Is the method "perfect"? Of course not. But in many cases it is a reasonable first estimate***.

QL(Porosity) is more accurate with some tools, than others, which is why ***there must be a local validation***.

Additionally, ***light hydrocarbon effects***

Porosity Log Display Scales

• An *attraction of the limestone scale for both clastic and dolostone reservoirs*, is that a *Quick Look porosity and mineralogy can be estimated by simply averaging Φ(Rhob_LS) & Φ(NPhi_LS)*

• *Φ(Formation)* ~ [Φ(NPhi_LS) + Φ(Rhob_LS)] / 2

• *ρ_g (Formation)* ~ $(\rho_b - \rho_f \phi)/(1 - \phi)$

• When display scales are in limestone units, *one need only "draw a line down the middle" to achieve a QL porosity evaluation*

• If local porosities are lower, select a different (locally appropriate) set of scales to accomplish a similar result

• *Be aware of limitations* (see text)

Figure 2
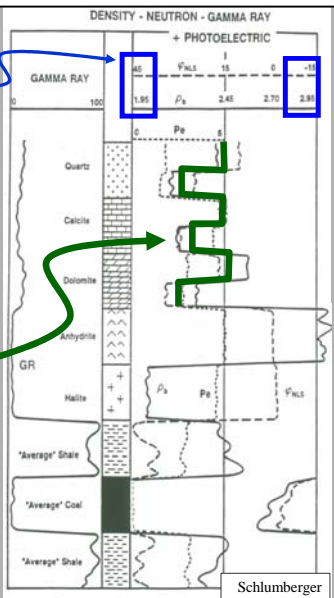
and / or clay (anything that affects one of the two tools, more than the other, will upset the balance) ***will invalidate the technique.***

Not only do we get a porosity estimate, but also a mineralogy indication (both visual and digital).

Visually, with appropriate display scales, "high neutron porosity" tells us we are dealing with dolostone while "low neutron porosity" says sandstone.

Quick Look Porosity

• Display *Density and Neutron Logs in Limestone Units* and calculate the *average*

  Φ(Formation) ~ [Φ(CNL/LS) + Φ(Rhob/LS)] / 2

  Reasonably Accurate in both Sand and Dolomite (Φ > 5 pu)

• *20 pu Sand*

  • Φ(CNL) ~ *16 Lpu*

  • Rhob ~ *2.32 gm/cc* => Φ(LS) ~ *23 pu*

  • *Φ(Average) ~ 20 pu*

• *The accuracy of this short-cut varies from one Rhob-NPhi tool combination to the next*, and should be tested

Figure 3
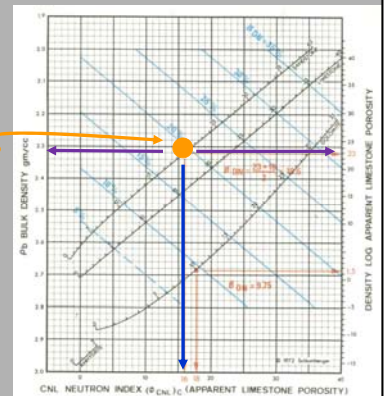
Schlumberger Arabian Well Evaluation Conference - 1975

Quick Look _Porosity_ **Figure 4**

• Display Density and Neutron Logs in Limestone Units

$$\Phi(Formation) \sim [\ \Phi(CNL/LS) + \Phi(Rhob/LS)\ ]\ /\ 2$$

Reasonably Accurate in both Sand and Dolomite ($\Phi > 5$ pu)

• _20 pu Sand_

   • $\Phi(CNL) \sim 16$ Lpu

   • Rhob ~ 2.32 gm/cc => $\Phi(LS) \sim 23$ pu

   • $\Phi(Average) \sim 20$ pu

• _10 pu Dolomite_

   • **$\Phi(CNL) \sim 18$ Lpu**

   • **Rhob ~ 2.68 gm/cc => $\Phi(LS) \sim 1.5$ pu**

   • _$\Phi(Average) \sim 9.8$ pu_

• _More / Less Valid **with Specific Crossplots**_

• _Exercise Caution with LHC & Clay_

Schlumberger Arabian Well Evaluation Conference - 1975
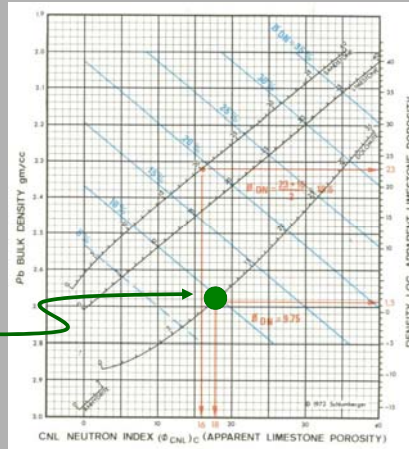
Numerically, the simple equations in **Figure 5** yield a digital mineralogy (in fact, it is usually equations such as these that yield mineralogy in the more sophisticated deterministic models) that can be used to drive a graphical display.

If one thus chooses the display scales appropriately, a reasonable Phi(QL) / Rhog(QL) estimate can deduced by _simply drawing a line down the middle_ of Phi(Neutron/LS) and

Phi(Rhob/LS) and observing if Phi(Neutron) is "High" or "Low". Double Time ….. _March._

And if we later display the final (sophisticated) porosity interpretation along with the properly scaled raw (NPhi & Rhob) data on the appropriate scale (as in Figure 2), we then expect that 'final' porosity value to roughly "go down the middle of the basic raw measurements".

Deviations are normal in shaly and gas intervals, but if observed in clean oil- and/or water-filled rock, should be investigated. Remember, there are assumptions in what we are doing.

The accuracy of this short-cut varies from one Rhob-NPhi tool combination to the next, and can (_should_) be tested for a specific situation by cross-plotting Phi(QL) (ie the simple average) against Phi(Final - the sophisticated estimate) across the non-shaly, non-gas intervals of an accepted interpretation.

Once validated locally, we have a quick and useful reference against which to quickly compare Phi(Best Estimate) and Rhog(Best Estimate).

Quick Look _Mineralogy_ **Figure 5**

• _20 pu Sand_

   • $\Phi(CNL) \sim 16$ Lpu

   • Rhob ~ 2.32 gm/cc => $\Phi(LS) \sim 23$ pu

   • _$\Phi(Average) \sim 20$ pu_

   • $\rho_g = (\rho_b - \rho_f\ \phi)/(1 - \phi) \sim (\rho_b - \Phi)/(1 - \Phi)$

      $= (\ 2.32 - 0.20\ )\ /\ (\ 1 - 0.20\ ) = 2.65$ gm/cc

Same intervals as preceding exhibit

• _10 pu Dolomite_

   • $\Phi(CNL) \sim 18$ Lpu

   • Rhob ~ 2.68 gm/cc => $\Phi(LS) \sim 1.5$ pu

   • _$\Phi(Average) \sim 9.8$ pu_

   • $\rho_g \sim (\ \rho_b - \Phi\ )\ /\ (\ 1 - \Phi\ ) = (\ 2.68 - 0.10\ )\ /\ (\ 1 - 0.10\ ) = 2.87$ gm/cc

Schlumberger Arabian Well Evaluation Conference - 1975

"Quick Look" R_w

Resistivity measurements are also amenable to quick look interpretations. *Applying Archie to both the Flushed and Unflushed domains, and then taking the ratio of those two equations in the water leg, yields the apparent formation water resistivity as a function of R_{deep} / R_{xo} : Figure 6.*

Resistivity Ratios for R_w

Figure 6

• *Archie's equation applies in each domain*

• **Flushed Zone**

• **Un-invaded Zone**

$$S_{xo}{}^n = R_{mf} / (\Phi^m * R_{xo})$$

$$S_w{}^n = R_w / (\Phi^m * R_{deep})$$

• *R_w in a <u>Water-bearing Zone</u>*

$$S_w{}^n / S_{xo}{}^n = 1 = (R_w / R_{mf}) * (R_{xo} / R_{deep})$$

$$R_w = R_{mf} * (R_{deep} / R_{xo})$$

Schlumberger 1979 Chart Book

This simple equation may be coded into the flow chart that we follow in setting up the digital database. That is, *following trace depth-shifting and splicing, execute this simple algorithm to provide an estimate of R_w well-by-well, thereby jump-starting the interpretation* (we then have a reasonable idea of R_w just as soon as the basic data has been assimilated).

It is *for this reason that we typically start a field study with wells on the flank of the field, for which a water leg will be found. The approach will provide an R_w estimate "right up front"*: indeed we cannot even reasonably evaluate the hydrocarbon column until we have an R_w estimate…so do it first. Double Time ….. *March.*

When the calculation is performed in the hydrocarbon column, an artificially high R_{wa} will result, and we *eliminate this visually by scaling the display appropriately, and disallowing trace wrap-around on the graphics*.

In general, even in a new area, we will have some idea of the brine salinity: fresh, moderate, salty. When combined with the formation temperature this gives an R_w estimate, and *the display scales are then chosen so that only the expected range of R_w values are actually displayed* (the hydrocarbon column wrapping around, without display).

If additional data, such as the SP, PNLs, pressure profile gradients and/or brine samples, are available then that information should be factored into the analyses.

In working with resistivity ratios, we must bear in mind that one is essentially assuming a step invasion profile. Mother Nature is not always so kind, and if for example R_{xo} is seeing mostly R_{mf} but some R_w, then the assumptions will begin to break down, more or less. See, for example, Good News and Bad News (Ballay 2009) and Invasion Revisited (Allen et al 1991).
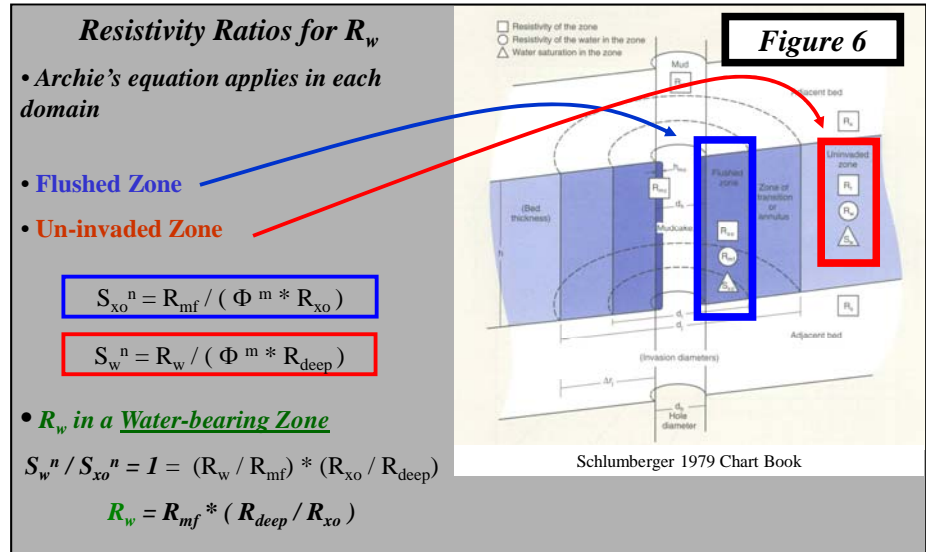
"Quick Look" S_w

The resistivity ratio concept also has application in the hydrocarbon column: Figure 7. Now we make two additional (first pass, adjust as appropriate) assumptions: "n" = 2 and $S_{xo} = S_w{}^{1/5}$.

The S_{xo} vs S_w assumption in particular might appear to be shaky, but is in fact fairly robust and in use worldwide. And with experience in a specific locale, *one may fine-tune this exponent*.

As was the case with the R_w(QL) calculation discussed above, we must **bear in mind the assumption of a step profile for invasion**: Invasion Revisited (Allen et al 1991).

The utility of simple calculations can be illustrated in the Kansas City – Lansing formation: **Figures 8 & 9**.

Quick Look: Kansas City - Lansing   **Figure 8**

• Take *"n" = 2*, and define the *Moveable Hydrocarbon Index* as

$$S_w / S_{xo} = [(R_w / R_{mf}) * (R_{xo} / R_{deep})]^{(1/2)}$$

• Schlumberger (1972) guidelines are that if the ratio *$S_w / S_{xo} > 1.0$ no hydrocarbons were moved* during invasion.

• True *regardless of whether the zone contains hydrocarbons*.

Quick Look: Kansas City - Lansing   **Figure 9**

• Take *"n" = 2*, and define the *Moveable Hydrocarbon Index* as

$$S_w / S_{xo} = [(R_w / R_{mf}) * (R_{xo} / R_{deep})]^{(1/2)}$$

• *Whenever* $S_w / S_{xo} < 0.7$ for sandstones or *$S_w / S_{xo} < 0.6$ for limestone, moveable hydrocarbons are indicated.*

• *$S_{xo} > S_w / 0.6$ ➔ $S_{xo} > 1.67 * S_w$*

• If a *carbonate reservoir* has a *Moveable Hydrocarbon Index < 0.6*, you can conclude

• *hydrocarbons are present* (not necessarily in commercial quantities)

• *the reservoir has enough permeability so that hydrocarbons have been moved* during the invasion process by mud filtrate.

Generic (get started) guidelines suggest that for water base mud

Define Moveable Hydrocarbon Index = S_w / S_{xo}

$S_w / S_{xo} >= 1.0$ ➜ no hydrocarbons have moved

$S_w / S_{xo} < 0.6$ for limestone ➜ moveable hydrocarbon is present

The generic moveable hydrocarbon ratio of $S_w / S_{xo} < 0.6$ ➜ $S_{xo} > 1.67$ S_w takes us to **Figure 10**, which is yet another (*independent*) carbonate reservoir in which we need to segregate the heavy oil / tar from the light oil.

In this example we had **independent laboratory estimates of oil viscosity** and used that information to color

Lack of Invasion & *Immobile Oil*

Independent validation

•The *generic guideline almost exactly over-lays this locally determined relation*

• *When* $S_w / S_{xo} < 0.7$ for sandstones or $S_w / S_{xo} < 0.6$ for limestone, moveable hydrocarbons are indicated.

$S_{xo} > S_w / 0.6 \sim 1.67 * S_w$

•*Locally specific calibration will enhance the utility of the concept*: G.M. Hamada. Hydrocarbon Moveability Factor: New Approach to Identify Hydrocarbon Moveability and Type from Resistivity Logs. Emirates Journal for Engineering Research (2004).

Figure 10

Sxo vs Sw, color coded per core analyses

•'Hot' color ➜ mobile oil

•'Cool' color ➜ heavy oil

Identification of tar with ratios

code the "z" axis: the "x" and "y" axes are S_{xo} and S_w. **Note how the generic 1.67 ratio value very accurately identifies the tar interval, as compared with the independent data.**
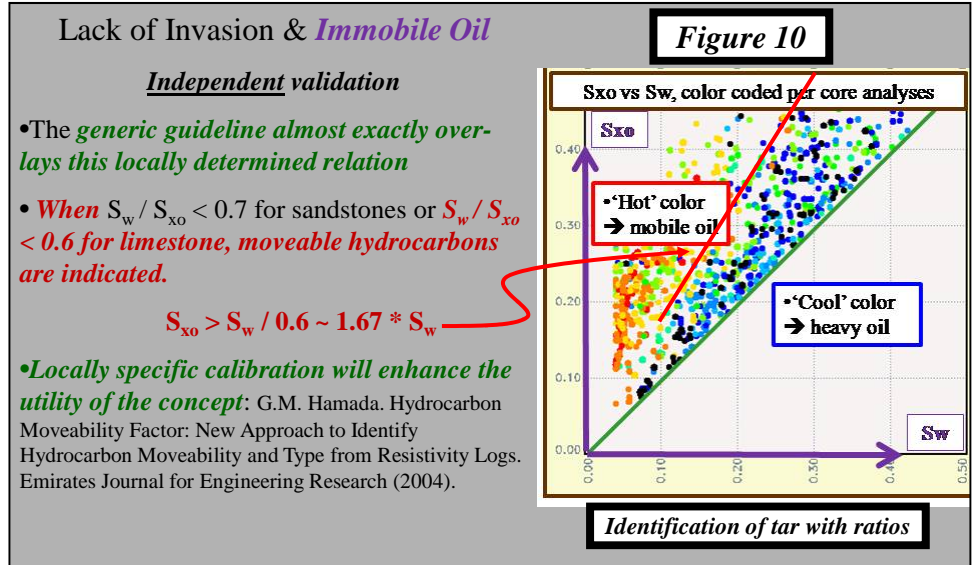
Quick Look: Kansas City - Lansing

MHI=Sw/Sxo = Sqrt[(Rxo/Rt)/(Rmf/Rw)]

$Sw(Rat)$=[(R_w /R_{mf})*(R_{xo} /R_{deep})]^(0.625)

•The *Rxo/Rt quick look* evaluation at *4,810 and 4,900* feet (*top two arrows*) *suggest a wet zone*

•The *Rxo/Rt quick look* evaluation at *4,924 to 4,932* (*lower two arrows*) indicate *presence of hydrocarbons*.

Figure 11

CHAPTER V: COMBINING WATER SATURATION BY RATIO METHOD, MOVEABLE HYDROCARBON INDEX, BULK VOLUME WATER AND ARCHIE WATER SATURATION. Located with Google. Author, date and publication n/a.
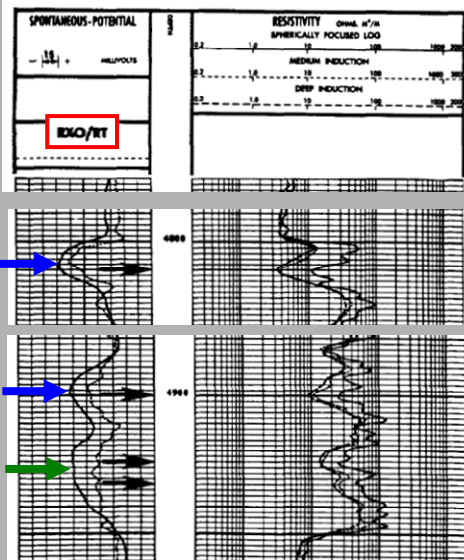
It is for good reason that we utilize historical generic guidelines with caution, but it is surprising how accurate these "get started" values can be.

The utility of the S_w(QL) calculation becomes especially apparent when (as one of several possible examples) one is faced with a variable "m" exponent, such as a vuggy carbonate: Figure 11 (back to the Kansas City – Lansing).

Figure 12

Quick Look: Kansas City - Lansing

Depth (ft)	φ	R_t	R_{xo}	S_{wa}	S_w/S_{xo}	S_{wr}	BVW
4,810 (ft)	0.25	3.5	12	38%	0.61	53%	0.095
4,900 (ft)	0.15	9	25	40%	0.54	47%	0.060
4,920 (ft)	0.11	19	32	37%	0.42	34%	0.041
4,924 (ft)	0.13	14	30	37%	0.48	40%	0.048
4,932 (ft)	0.17	22	45	22%	0.47	39%	0.037
4,936 (ft)	0.09	30	60	36%	0.46	38%	0.032

Where:
R_w = 0.032
R_{mf} = 0.30
S_{wa} = Archie water saturation
S_{wr} = Ratio water saturation

From Density-Neutron.

- The zone at **4810**' has *good porosity* and *low Archie water saturation*.
- The *Moveable Hydrocarbon Index* (S_w/S_{xo} = 0.61) is slightly *greater than 0.60*
- The *Ratio water saturation is high* (53 percent) .
- These *calculations indicate that the zone may be wet*.

CHAPTER V: COMBINING WATER SATURATION BY RATIO METHOD, MOVEABLE HYDROCARBON INDEX, BULK VOLUME WATER AND ARCHIE WATER SATURATION. Located with Google. Author, date and publication n/a.

In this illustration, *water saturation S_{wa} is calculated from routine Archie with "m" taken as 2.0, and S_{wr} from the resistivity ratio*: *Figure 12.*

In those intervals for which similar saturations result, there is confidence. But *should the ratio water saturation be greater than S_w(Archie), further study is required* (have we used the appropriate "m"?). And if the Bulk Volume Water is also high, that concern heightens: *Figure 13.*

BVW is a familiar concept to our NMR friends, but was in fact an important part of petrophysics long before the NMR arrived at the wellbore. In fact, as a commentary on today's fascination with New Ideas / Tools, I once suggested a BVW calculation, only to be told "that method only works in giant Middle East reservoirs", whereas in fact Mr. Buckles actually published his findings in Calgary (which is exactly where I was, when the suggestion was made). R. S. Buckles. Correlating and Averaging Connate Water Saturation Data. 16th Annual Technical Meeting. 1965, CIM. Calgary.

The point of the story is not to focus on the location where it happened (indeed, something similar could have happened almost anywhere), but rather that even Home Town Hero's may not receive the attention they deserve. It was, in fact, Yesterday's Hero's that developed many of today's Quick Look methods, and their papers are genuine classics to read.

Figure 13

Quick Look: Kansas City - Lansing

Depth (ft)	φ	R_t	R_{xo}	S_{wa}	S_w/S_{xo}	S_{wr}	BVW
4,810 (ft)	0.25	3.5	12	38%	0.61	53%	0.095
4,900 (ft)	0.15	9	25	40%	0.54	47%	0.060
4,920 (ft)	0.11	19	32	37%	0.42	34%	0.041
4,924 (ft)	0.13	14	30	37%	0.48	40%	0.048
4,932 (ft)	0.17	22	45	22%	0.47	39%	0.037
4,936 (ft)	0.09	30	60	36%	0.46	38%	0.032

Where:
R_w = 0.032
R_{mf} = 0.30
S_{wa} = Archie water saturation
S_{wr} = Ratio water saturation

- The *calculation which further indicates the zone may be wet is the very high bulk volume water value (0.095)*
  - This *BVW* is based upon $\Phi * S_w$(Archie), with "m" = 2.0, and *will increase if S_w(Ratio) is used for the calculation* (ie the zone will look even "wetter")

CHAPTER V: COMBINING WATER SATURATION BY RATIO METHOD, MOVEABLE HYDROCARBON INDEX, BULK VOLUME WATER AND ARCHIE WATER SATURATION. Located with Google. Author, date and publication n/a.

Buckles was not the only proponent of Bulk Volume Water. R. L. Morris and W. P Biggs (Using Log-derived values of Water Saturation and Porosity) *tell us "Cursory examination of Sw and Phi (separately) be misleading* …. For a given rock type and/or grain size, a correlation exists between irreducible water saturation and porosity….Therefore, *don't stop your log analysis with the computation of water saturation and porosity. Plot these values to predict production*."

Critical Bulk Volume Water

Figure 14

• The *calculation which further indicates the zone may be wet is the high bulk volume water (0.095)*

• *Carbonate reservoirs with a bulk volume water value greater than ~ 0.04 may be wet*

http://www.kgs.ku.edu/Gemini/Help/PfEFFER/Pfeffer-theory4.html#bvw_pickett

Bulk Volume Water Reference Values

Critical Bulk Volume Water

Figure 15

• *BVW can also be deduced from Lucia* (or a locally preferred methodology)

•*Fluid saturation depends upon porosity and rock-fabric class*, as can be *demonstrated with the capillary pressure curves*

• Select *specific reservoir height*

　• Equates to some specific mercury capillary pressure

• *Plot saturation against porosity* for each rock-fabric class, *at specified height*

• In nonvuggy carbonates the *plot separates into three classes*

Courtesy of Jerry Lucia

• *Class 3, the lowest quality, corresponds to BVW ~ (0.10)*(0.43) ~ 0.043*

　• *Consistent with preceding KGS exhibit*

•*An NMR log would nicely supplement this evaluation*

 Obviously, locally specific parameters are the best, but lacking that we proceed exactly as we do with all the other *not-well-known* parameters that we are forced to use: a literature survey, or today a Google search: *Figure 14.*
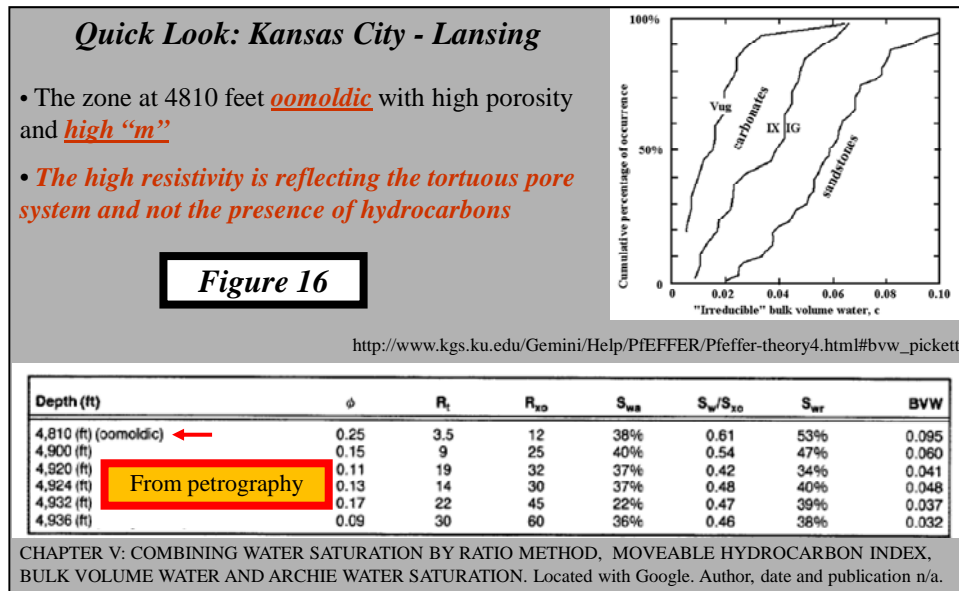
Interestingly, if there is a locally developed Rock Quality Characterization scheme, the Critical Bulk Volume Water value may be an integral (but possibly not initially obvious) part of that methodology: *Figure 15*. "Coffee or Tea" by Ballay and multiple other references, follow on Morris & Biggs and Buckles. And finally, although we have not discussed the Pickett Plot here, Aguilera (2002 & 2004) and Ballay (Double Duty, 2008) have demonstrated the relation between that graphic and Bulk Volume Water.

In older fields there won't be an NMR, but *if we are lucky enough to have a modern log suite, with NMR data, that will nicely supplement these calculations*.

Quick Look algorithms do not replace modern tools and techniques, but rather supplement them. Understanding Buckles, Morris & Biggs, etc provide the baseline upon which we can better interpret today's high technology options.

In this particular case the author also had petrography, which reveals that the pore system across the questioned interval is oomoldic: *Figure 16.*

Quick Look: Kansas City - Lansing

• The zone at 4810 feet *oomoldic* with high porosity and *high "m"*

• *The high resistivity is reflecting the tortuous pore system and not the presence of hydrocarbons*

Figure 16

http://www.kgs.ku.edu/Gemini/Help/PfEFFER/Pfeffer-theory4.html#bvw_pickett

Depth (ft)	ϕ	R_t	R_{xo}	S_{wa}	S_w/S_{xo}	S_{wr}	BVW
4,810 (ft) (oomoldic) ←	0.25	3.5	12	38%	0.61	53%	0.095
4,900 (ft)	0.15	9	25	40%	0.54	47%	0.060
4,920 (ft)	0.11	19	32	37%	0.42	34%	0.041
4,924 (ft) From petrography	0.13	14	30	37%	0.48	40%	0.048
4,932 (ft)	0.17	22	45	22%	0.47	39%	0.037
4,936 (ft)	0.09	30	60	36%	0.46	38%	0.032

CHAPTER V: COMBINING WATER SATURATION BY RATIO METHOD, MOVEABLE HYDROCARBON INDEX, BULK VOLUME WATER AND ARCHIE WATER SATURATION. Located with Google. Author, date and publication n/a.

The resistivity increase, which S_w("m"=2) would interpret as hydrocarbon, is in fact the result of a tortuous pore system, and not the presence of hydrocarbons. It is the Quick Look resistivity ratio saturation that raises the Red Flag.

"Quick Look" Reference Material

There are a number of *on-line resources to which one may refer for these, and additional, concepts.*

Ross Crain's On-line Tutorial: www.spec2000.net/index.

Kansas Geological Survey Tutorial: www.kgs.ku.edu/Gemini.

Baker Hughes Tutorial: www.bakerhughesdirect.com/.

For locale specific over-views and suggestions, we have found Schlumberger's Oil Field Review and Middle East & Asia Well Review to be very useful: www.slb.com/.

See References for more.

Summary

In today's environment, the hand calculator on our desk has more computational power than did the computer that first sent man to the moon. We benefit in many ways from this power, but it behooves us to *remember "the basics".*

Quick Look interpretations serve many functions. Legacy files will often include QL results, which should be well understood before moving forward. Not only do the QL interpretations provide a rapid first-look at a well, but they also serve as a benchmark against modern computerized results.

When the basic porosity logs are displayed appropriately, *Phi(QL) is estimated by simply drawing a line "down the middle"* and R_w *follows from a ratio of the resistivities*. These calculations may be invoked even as depth shifting / splicing is done, so that *just as soon as the digital database is complete, we are also ready to characterize (first pass) the porosity, R_w(Resistivity Ratio) and S_w(Resistivity Ratio)*.

Later (final) calculations will typically be more sophisticated, but even then the QL estimates will provide a valuable benchmark. For example, we have personally observed, repeatedly, probabilistic results that predicted hydrocarbons across an interval for which the QL was "wet": *the QL was correct*. Not to demean probabilistic models at all, but those calculations can be very dependent upon initialization parameters.

Quick Look algorithms do not replace modern tools and techniques, but rather supplement them. Understanding Buckles, Morris & Biggs and the many other Yesterday's Hero *provide the baseline upon which we can better interpret today's high technology options*.

Acknowledgement

As a 17 year old in Army Boot Camp some 50 years ago, I came to meet and ultimately respect an unusual individual: Drill Sergeant Herb Rettke. At a time when drill sergeants had near unquestioned authority, Herb realized that the best training was accomplished with individually-specific motivation (and not with screams, threats and brutality). And in an era when racial profiling was common, Herb was color blind.

In 1966 Herb had already served his country as an infantryman in an earlier war, and he would go on to serve two additional infantry tours in a second war (and rise to the rank of Sergeant Major). In the years to come, as I observed oil company management leave the night/weekend duty to their underlings, while they enjoyed their time off, it struck me that their version of 'walk the talk' was very different than Herb's.

In Y2003 I was able to find Herb (via Google) living only 250 miles from me, and we have been in regular contact since. If a stranger were to meet Herb today, their immediate impression would be 'a soft-spoken grandfather type', and they would never realize his sincere devotion to his country, where he literally put his life on the line. This brings to mind another experience: as a university physics instructor, I repeatedly observed that the best exam scores were seldom made by the people who dominated the classroom conversation.

References

Aguilera , Roberto. Incorporating capillary pressure, pore throat aperture radii, height above free-water table, and Winland r35 values on Pickett plots. AAPG Bulletin, v. 86, no. 4 (April 2002), pp. 605–624

Aguilera, Roberto. Integration of geology, petrophysics, and reservoir engineering for characterization of carbonate reservoirs through Pickett plots. AAPG Bulletin, v. 88, no. 4 (April 2004), pp. 433–446

Allen, David et al. Invasion Revisited. Oilfield Review. July 1991.

Author, date and publication n/a. Found with Google Search. Chapter V: Combining Water Saturation by Ratio Method, Moveable Hydrocarbon Index, Bulk Volume Water and Archie Water Saturation.

Ballay, Gene. Multidimensional Petrophysics. Saudi Aramco Journal of Technology. Winter 2000/2001.

Ballay, Gene. Porosity Log Quality Control in a Giant Carbonate. SPE Abu Dhabi. 1994.

Ballay, Gene and Roy Cox. Formation Evaluation: Carbonate versus Sandstone. March, 2005. www.GeoNeurale.com.

Ballay, Gene. Double Duty With The Old and The New. March, 2008. www.GeoNeurale.com.

Ballay, Gene. Testing, Testing, 1 2 3. Sept, 2008. www.GeoNeurale.com.

Ballay, Gene. 2 for 1 or 1 + 1 = 3. October, 2008. www.GeoNeurale.com.

Ballay, Gene. Risky Business. March, 2009. www.GeoNeurale.com.

Ballay, Gene. Good News and Bad News. Jan, 2009. www.GeoNeurale.com.

Ballay, Gene. Rolling the Dice. July, 2009. www.GeoNeurale.com.

Ballay, Gene. Coffee or Tea. Sept, 2009. www.GeoNeurale.com.

Ballay, Gene. Split Personality. Dec, 2009. www.GeoNeurale.com.

Ballay, Gene. Facts are Stubborn, Statistics are more Pliable. Feb, 2010. www.GeoNeurale.com.

Ballay, Gene. Visual Basics. April, 2010. www.GeoNeurale.com.

Ballay, Gene. The Biggest Bang for the Buck. April, 2011. www.GeoNeurale.com.

Ballay, Gene. The Law of Averages. June, 2011. www.GeoNeurale.com.

Ballay, Gene. The "m" Exponent in Carbonate Petrophysics. Jan, 2012. www.GeoNeurale.com.

Ballay, Gene and Nelson Suarez. Archie's "n" Exponent: The rest of the Story. June, 2012. www.GeoNeurale.com.

Ballay, Gene. Eyes Wide Shut. www.GeoNeurale.com. Sept., 2014.

Boyd, Austin et al. The Lowdown on Low-Resistivity Pay. Oilfield Review. Autumn 1995.

Brown, A. and S. Husseini : Permeability from Well Logs, Shaybah Field, Saudi Arabia. SPWLA 18th Annual Logging Symposium, June 1977

Diederix, K. M. Anomalous Relationships Between Resistivity Index and Water Saturations in the Rotliegend Sandstone (The Netherlands), Transactions of the SPWLA 23rd Annual Logging Symposium, Corpus Christi, Texas, July 6-9, 1982, Paper X.

Diederix, K. M. Anomalous Relationships Between Resistivity Index and Water Saturations. The Technical Review, Vol 36 No 4, 1987.

Elshahawi, H. and K. Fathy, S. Hiekal. Capillary Pressure and Rock Wettability Effects on Wireline Formation Tester Measurements. SPE Annual Technical Conference. Houston, Texas, October 1999.

El Din, S. Serag, M.R. Dernaika, I. Al Hosani, L. Hannon and S.M. Skjæveland. Whole Core vs. Plugs: Integrating Log and Core Data To Decrease Uncertainty in Petrophysical Interpretation and STOIP Calculations. 2010 Abu Dhabi International Petroleum Exhibition & Conference, Abu Dhabi, UAE.

Focke, J. W. and D. Munn. Cementation Exponents in Middle Eastern Carbonate Reservoirs. SPE 1987.

George, Bovan. A Case Study Integrating the Physics of Mud-Filtrate Invasion with the Physics of Resistivity Logging. MS Thesis. University of Texas. 2003. Download from UT site.

George, Bovan and C. Torres-Verdin, M. Delshad, R. Sigal, F. Zouioueche & B. Anderson. A Case Study Integrating the Physics of Mud-Filtrate Invasion with the Physics of Induction Logging: Assessment of In-situ Hydrocarbon Saturation in the Presence of Deep Invasion and Highly Saline Connate Water. Download from University of Texas site.

Griffiths, R. and A. Carnegie, A. Gyllensten, M. T. Ribeiro, A. Prasodjo, and Y. Sallam. Estimating S_w with a volume measurement. World Oil, October 2006

Griffiths, R. et al. Evaluation of Low Resistivity Pay in Carbonates – A Breakthrough. SPWLA 47th Symposium. June, 2006.

Gyllensten, Asbjorn et al. A new saturation model for Low Resistivity Pay in carbonates. SPWLA ME Regional Symposium. April, 2007.

Hamada, G. M. Hydrocarbon Moveability Factor: New Approach to Identify Hydrocarbon Moveability and Type from Resistivity Logs. Emirates Journal for Engineering Research. 2004.

Holtz, M. H. and R. P. Major. Petrophysical Characterization of Permian Shallow-Water Dolostone. SPE 75214, 2002.
http://www.beg.utexas.edu/mainweb/presentations/2002_presentations/holtz_spe0402ab.pdf

Kennedy, M. C. Solutions to some problems in the analysis of well logs in carbonate rocks. Geological applications of well logs: AAPG Methods in Exploration, No 13, 2002.

Kuttan, K., J.B. Kulla, and R.G Neumann. Freshwater Influx in the Gippsland Basin: Impact on Formation Evaluation, Hydrocarbon Volumes and Hydrocarbon Migration. The APEA Journal, 1986.

Lucia, Jerry. Origin and petrophysics of dolostone pore space. Geological Society, London, Special Publications. 2004; v. 235; p. 141-155".

Mazzullo, S. J. Overview of Porosity Evolution in Carbonate Reservoirs. Search and Discovery Article #40134 (2004)

Wang, Fred P. and Jerry Lucia. Comparison of Empirical Models for Calculating the Vuggy Porosity and Cementation Exponent of Carbonates from Log Responses Bureau of Economic Geology, UT. 1993.

Verwer, Klaas and Gregor P. Eberli, Ralf J. Weger. Effect of pore structure on electrical resistivity in carbonates. AAPG Bulletin, v. 95, no. 2, Feb 2011.

Biography

R. E. (Gene) Ballay's 36 years (18 homes, 15 countries) in petrophysics includes both research and operations assignments with carbonate experience ranging from individual Niagaran reefs in Michigan to the Lisburne in Alaska through 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, each bringing on-line multi-billion barrel increments.

Subsequent to retirement from Saudi Aramco he established Robert E Ballay LLC, which provided physics - petrophysics consulting services.

He served in the US Army as a Microwave Repairman and in the US Navy as an Electronics Technician: he is a USPA Parachutist, a PADI nitrox certified Dive Master and a Life Member of Disabled American Veterans.

Mississippian limestone

Chattanooga shale