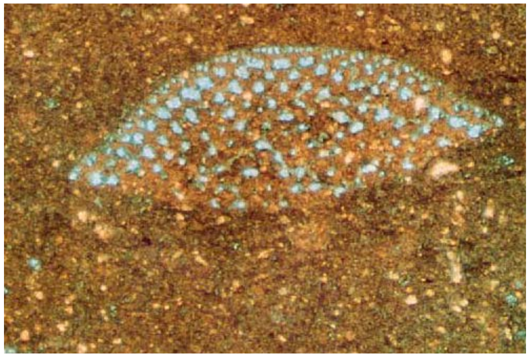
Carbonate Petrophysics



30 pu Limestone
Jerry Lucia

Rudist: Middle East Well
Evaluation Review# 15, 1994
Schlumberger

High Permeability Grainstone:
Petrophysical and Geomechanical
Issues in Carbonate Oilfields.
Austin Boyd

Gene.Ballay@GMail.Com

R. E. (Gene) Ballay, PhD

Carbonate Petrophysics

- •Course ***philosophy***
  - •Draw material from a ***variety of sources***
    - •SPWLA, SPE, AAPG, Leading Edge, etc
    - •Service Companies
- •***Carefully reference*** every source to allow Client follow-up
- •***Illustrate issues*** with actual data to every degree possible
- •***Include parameters*** and ***equations***
  - •Distribute application spreadsheets
  - •Facilitate seamless application of course material
- •***Do Not Champion*** any particular Tool / Technique
  - •Discuss strengths and weaknesses

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Carbonate Petrophysics

- Course ***deliverables***
  - ***Digital, Key Word Searchable*** PDFs
    - Presentation
      - Everything presented during the course, and more
    - Manual
      - Related to the Presentation (above) as a Text Book is related to a Classroom Presentation
    - Exercises
      - Can be "worked during class" or used as "Question / Answer" review
    - ***Spreadsheets*** used to construct supporting graphics
    - Basic petrophysics (Rw vs Salinity &Temp, Fluid Density vs Salinity, Capillary Pressure (Lab to Reservoir, Pc vs Height, Curve Fits), Non-linear (and logarithmic) Curve Fits, Monte Carlo Modeling, etc
    - Illustrates exactly how exhibits were developed
    - Allows locally specific calculations

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Road cut along Hwy 65 in SW Missouri. Although there has been no rain for some time, the dark streaks are water seeping out, which is why there are so many springs and caves in the area.

COURSE OVERVIEW

•Carbonate Petrophysics is for Engineers, Geologists and Team Leaders who require ***an understanding of the complexities of open-hole carbonate log analysis***.

•Participants will learn to ***characterize rock quality visually*** (thin sections, CT-scan, etc) ***and numerically*** (routine core analyses, capillary pressure, etc) and ***relate*** those results ***to both routine and specialty open-hole log responses***.

•The ***complementary nature of the various tools and techniques*** are discussed and ***illustrated with actual carbonate data.***

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ABOUT THE COURSE

•Carbonate Petrophysics ***begins with a contrast of carbonates and sandstones***, followed by ***reservoir classification*** according to ***Lucia's Petrophysical Classification*** methodology.

•Thin sections and CT-Scans are used for ***visualization*** while capillary pressure serves to ***quantify the differing properties***. Capillary pressure concepts are then used to introduce ***Winland's classification protocol***.

•***Archie's exponents*** are discussed within the context of both his original data and later measurements.

•Individual ***logging tools*** (both ***routine and specialty***) are introduced; ***carbonate responses*** are ***illustrated with actual data***.

•The ***complementary attributes of each tool and technique*** are used to identify and evaluate complex carbonate reservoirs, as illustrated with actual applications.

Road cut along Hwy 65 in SW Missouri.

The Geological Society of America conducts a field trip through this area. www.geosociety.org/.

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YOU WILL LEARN HOW TO

•***Recognize the key distinctions*** between ***carbonates and sandstones***, and understand the implications of those differences upon modern logging tool responses and formation evaluation methods

•Perform both ***quick-look and detailed interpretations***, taking into account carbonate complexities

•Design a ***cross-discipline formation evaluation program*** that will characterize the interpretational parameters associated with a specific reservoir, and facilitate complete analyses

•***Both the three and five day options assume*** a basic comfort level with Wireline / LWD measurements and discipline integrated petrophysical analyses

The Devil's Promenade, SW Missouri

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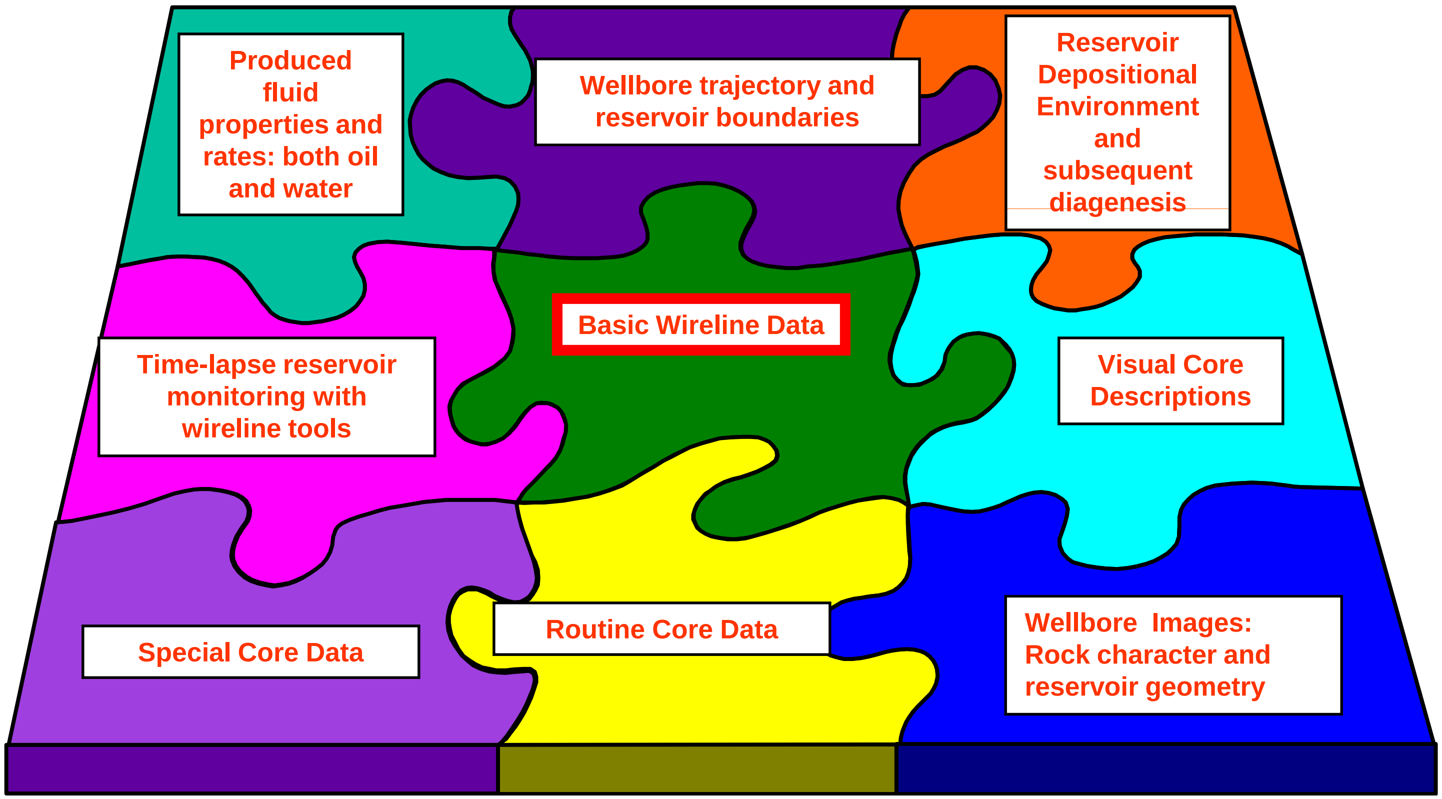
Carbonate Petrophysics

- *Course objective*
  - ***Integrate across discipline*** and ***scale*** and ***timeframes***
    - ***Routine wireline*** (and LWD) measurements are ***typically the basis for field development and depletion***
    - ***Ultimate objective is an integrated / calibrated interpretation*** of that data



Carbonate Petrophysics

- ***Course time-line***
  - ***Three day***
    - Suitable for abbreviated Time Frames
    - Application oriented
    - Five day material is distributed, but not fully developed
  - ***Five day***
    - Includes additional Tool / Technique Theory & Illustrative Applications
- ***Both options assume*** a basic comfort level with Wireline / LWD measurements and discipline integrated petrophysical analyses

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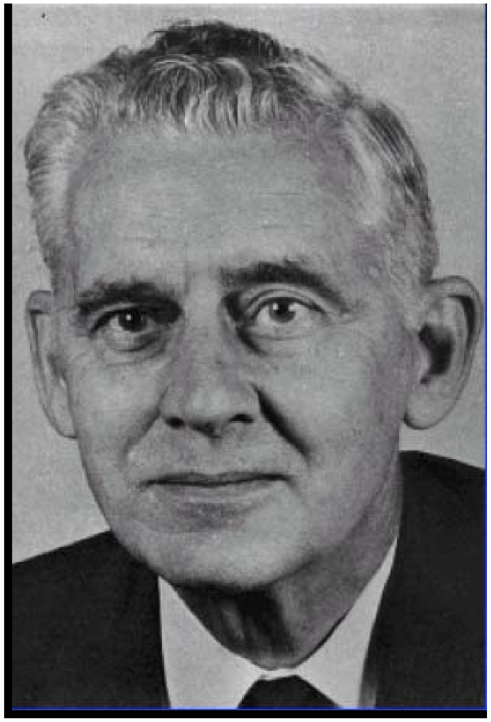
Carbonate Petrophysics



•*Gus Archie* ***introduced*** the world to the term '***petrophysics***' in 1950

•This fundamental vision was ***followed by a carbonate classification system*** in 1952 in which he commented

- •in discussing the petrophysics of limestones, it is ***necessary to first classify*** them
- •the field application of petrophysical relationships in ***limestone*** can be much ***more difficult than in sandstone***, because of variations in ***pore size distribution***

•This course begins with a ***contrast of sandstone and carbonate depositional environments, diagenesis and routine log signatures***

•Basic capillary pressure techniques are related to ***Lucia's Petrophysical Classification*** and ***Winland's protocol***

•***The essence of Carbonate Petrophysics is Pore System Heterogeneity***

•***All available data should be interpreted in an integrated fashion, with an eye towards the Biggest Bang For The Buck***

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Carbonate Petrophysics

•The ***Lucia System*** recognizes that if one is to characterize the relationship between rock fabric and petrophysical parameters, then ***the pore space must be classified*** as it exists today, in terms of petrophysical properties.

- •The focus is on ***petrophysical properties*** and ***not genesis***.
- •Key issues are ***interparticle vs vuggy porosity*** and ***separate vs touching vugs***
- •In addition to basic porosity (magnitude) determination, one should thus also consider ***pore size and pore type***.

•***Winland's method is Pc based*** and establishes a generalized relation between boundaries on the Phi-Perm crossplot and the (Pc determined) pore throat distribution.

•Common porosity tools (***density, neutron and sonic***) are introduced, and then ***contrasted as a means of pore system classification.***

•***Image logs and nuclear magnetic resonance*** are investigated as ***"modern" alternative, vuggy porosity classification options.***

•The ***Pore System affects*** not only rock quality (porosity vs permeability), but also the ***Archie "m" exponent***, as illustrated with ***laboratory measurements*** and ***thin sections***.

•Cementation ***exponent models***, for estimating "m" as a function of vuggy porosity content, are ***developed and evaluated***.

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Carbonate Petrophysics

•In discussing the petrophysics of limestones, it is ***necessary to first classify*** them

•The ***choice of a classification system may very well depend upon what we have to work with***

Coffee or Tea

R. E. (Gene) Ballay

WWW.GeoNeurale.Com

You have your preferences and I have mine. But being a pragmatist, if my first choice is not available, I'll usually go with the second.

There is something of a parallel when it comes to pore system classification. According to Archie "In discussing the petrophysics of limestone, it is necessary first to classify them in a manner to portray as much as possible the essential pore characteristics of a reservoir".

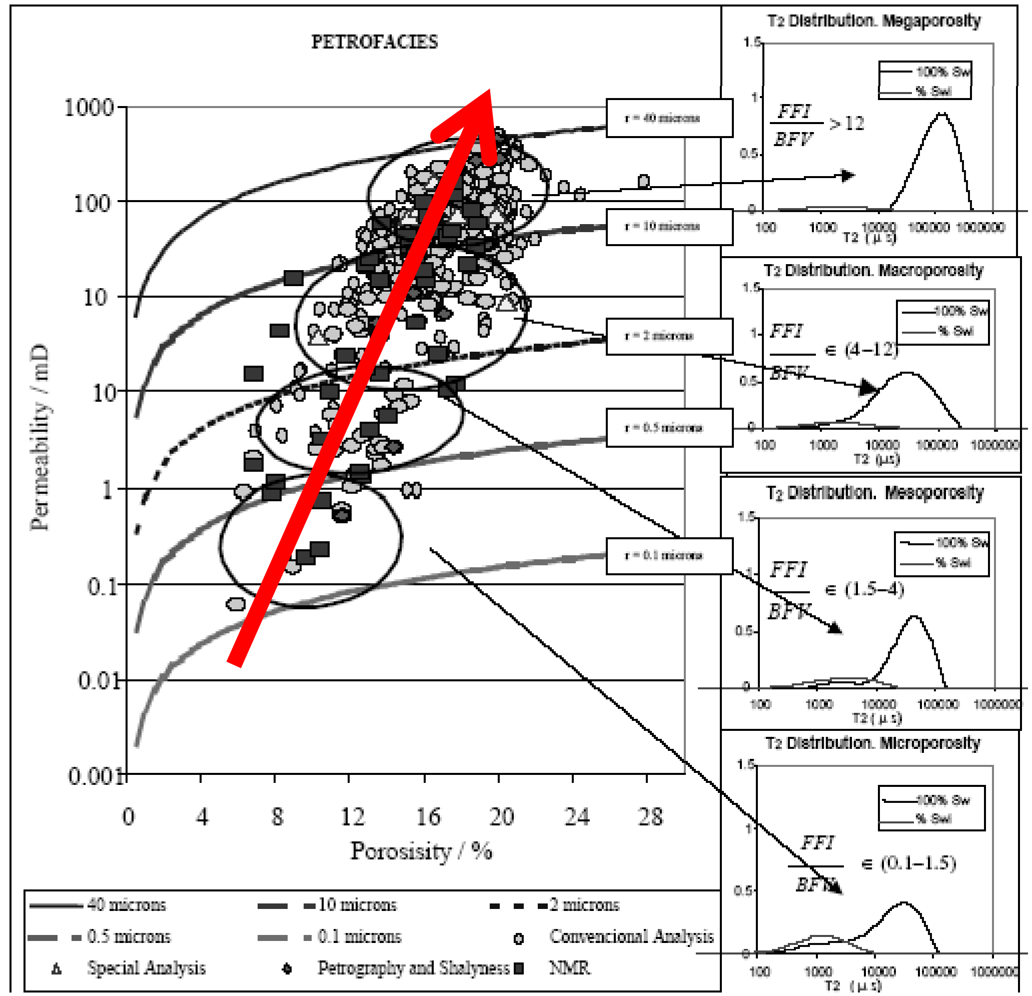
Without meaning to disparage anyone's preferences, and also recognizing that each protocol has its specific strengths, we sometimes find that the available data lends itself to a particular approach. Recognizing the value of a quantitative (as opposed to qualitative) methodology, it then makes sense to use the framework for which the required data is available.

There are two general situations. First, we are on location looking at cuttings, or in the core barn looking at the core, and so a system that can be invoked with visual observations is attractive. The second scenario arises when, perhaps many years later, a field study is being conducted and what we now have to work with are routine and special core analyses reports, along with (hopefully) core photos.

Regardless of the situation, it behooves the petrophysicist to consider a quantitative pore system classification scheme, because: 1) suspect data is more likely to be identified, 2) domains in need of additional measurements will be recognized, and 3) comparisons to analogue reservoirs become possible.

Carbonate Petrophysics

- ***Integrate*** within a ***systematic classification protocol: <u>benefits</u>***
  - Adds another 'dimension' to our ***understanding of the reservoir***
  - ***Suspect data*** is more likely to be identified
  - Domains in need of ***additional measurements*** will be recognized
  - Comparisons to ***analogue reservoirs*** become possible
  - ***Leverage*** the routine core analyses
- ***Is permeability increasing because***
  - ***Porosity increases?***
  - ***Pore throat size is increasing?***
  - ***Both?***
  - ***How does this relate to expected log signatures?***



DETERMINATION OF ROCK QUALITY IN SANDSTONE CORE PLUG SAMPLES USING NMR. Pedro Romero, Gabriela Bruzual, Ovidio Suárez. SCA2002-51

Carbonate Petrophysics

All available data should be interpreted in an integrated fashion, with an eye towards the Biggest Bang For The Buck. One option is differential in nature.

By taking the derivative of Archie's equation (the same approach will suffice for a shaly sand equation), one is able to quantify the individual impact of each term upon the result, and thus ***recognize where the biggest bang for the buck, in terms of a core analyses program or suite of potential logs, is to be found*** (Figure 1).

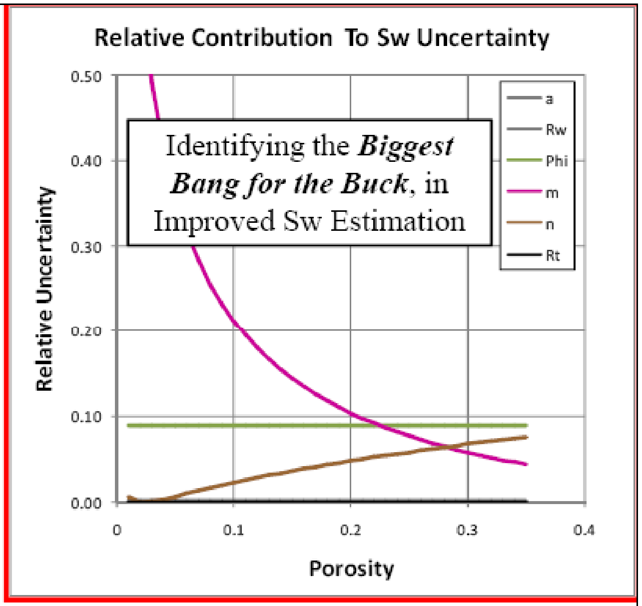
Figure 1

•*Below*: Illustrative Best Estimate of each parameter, with corresponding individual uncertainty, and associated relative uncertainty on Sw(Archie), *at a specific porosity.*

•*Right*: ***Relative impact on Sw(Archie) uncertainty of 'm' & 'n', across a range of porosity values, for a fixed Phi uncertainty.***

Attribute Uncertainties Specified Individually			
Light Green Cells require User Specification			
Light Blue Cells are calculated results			
Attribute	Individual Uncertainty	Best Estimate	Relative Uncertainty On Sw(Archie)
a	0.0%	1.00	0.0000
Rw	4.4%	0.02	0.0019
Phi	15.0%	0.20	0.0900
m	10.0%	2.00	0.1036
n	5.0%	2.00	0.0480
Rt	1.0%	40.00	0.0001
Sw		11%	
Sw^n		1%	
Sw^n=0.367 is an inflection point			

After C. Chen and J. H. Fang. Sensitivity Analysis of the Parameters in Archie's Water Saturation Equation. The Log Analyst. Sept – Oct 1986



•***The relative importance of 'm' and 'n' depend not only upon their specific uncertainty, but also upon the porosity of the interval in question; there is a link***

•Uncertainty resulting from 'a', R_w and R_t is below that of ϕ, 'm' & 'n' in this illustrative example

Carbonate Petrophysics

Another option is <u>statistical</u>. The differential & statistical approaches complement one another. Derivatives are easy to implement at foot-by-foot level while Monte Carlo yields insight into up-side and down-side. Both recognize the inherent attribute linkage.

The only certainty in most of our formation evaluations is the presence of uncertainty and how that issue is (or is not) ***addressed***. At the simplest level one may estimate the Best and Worst Case, for each input attribute, and then bound the evaluation with the resulting extreme values, even as we recognize that the simultaneous occurrence of multiple "best" or "worst" values is an unlikely event.

It is in fact ***relatively simple to address the uncertainty question in a comprehensive, realistic and quantitative fashion***, and to further identify ***where to focus time, and money, in search of an improved evaluation.***

At the simplest level ***our Sw estimates are compromised by uncertainty in the various Archie equation attributes***.

$$S_w^{\,n} = a\,R_w / (\Phi^{\,m}\,R_t)$$

In an earlier article (Risky Business) we took the derivative of Archie's equation (the same approach will suffice for a shaly sand equation), and calculated the individual impact of each term's uncertainty upon S_w to identify where the biggest bang for the buck, in terms of

Figure 1

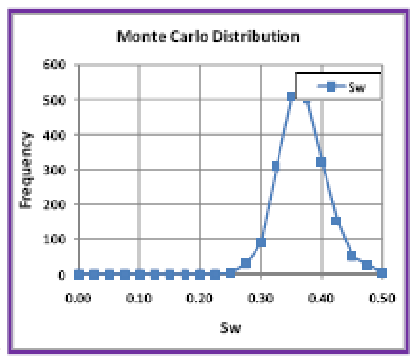
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Monte Carlo Simulation of Sw(Archie)																
Specify Parameters Below						Monte Carlo Statistics						High-Low Numerical Statistics				
Other Tables will update automatically					Cross-check Specs		Monte Carlo Results			Attribute	Low	High	Sw Range for Low Phi			
Attribute	Mean	Std			Porosity		Sw			Porosity	0.18	0.22	0.293	0.366	0.428	0.500
"a"	1				Mean	Std_Dev	Mean	Std_Dev		"m"	1.8	2.2	Sw Range for High Phi			
Rw	0.05				0.200	0.0098	0.357	0.0382		"n"	1.8	2.2	0.239	0.311	0.355	0.409
Rt	10				"m"		"n"									
Phi	0.2	0.0100			Mean	Std_Dev	Mean	Std_Dev				Low m / Low n		Hi m / High n		
"m"	2	0.1000			2.005	0.0970	2.006	0.1025				Sw	0.354			
"n"	2	0.1000					Delta Sw	0.153				Max Delta Sw		0.260		
Sw	0.354															

•Monte Carlo simulation of Sw(Archie) for above user-specified distributions

•"a", R_w and R_t are assumed to be 'well known', but may be varied by a straight-forward extension of the technique

•With these specifications, *there is a 95% probability that S_w is bounded by* 0.357 +/– 2(0.0382) ➔ *$0.28 < S_w < 0.43$*

•The Best / Worst case would have $0.24 < S_w < 0.50$, the difference being the unlikely chance of all Best (or Worst) events occurring simultaneously



2000 Simulations

Carbonate Petrophysics

- In the years since Archie's ground-breaking work, a number of so-called ***non-Archie (ie non-resistivity-based) formation evaluation approaches*** have become possible
  - Each methodology is developed and then evaluated, with actual carbonate data
    - Pulsed neutron
    - Dielectric
    - Borehole gravity meter
    - Nuclear magnetic resonance
  - ***Basic NMR*** is followed by ***Carbonate NMR***
  - Carbonate NMR addresses two ***key carbonate limitations***
    - pore size coupling
    - vuggy porosity of sufficient size that surface relaxation no longer dominates the tool response
- In addition to non-Archie formation evaluation, the ***Specialty Sonic*** offers ***Shear Wave identification / orientation of fractures*** and ***Stoneley Wave permeability estimates***

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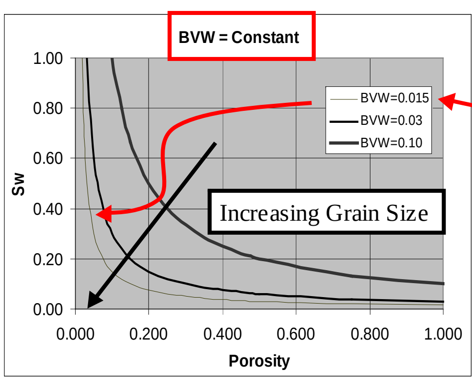
Carbonate Petrophysics

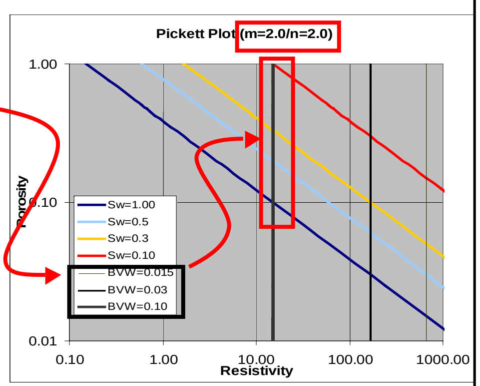
•Additional, ***supplemental tools / techniques*** include

- •***Visualization*** by ***CT Scan***
- •***Laboratory*** determination of ***mineralogy*** (XRD/XRF/etc)
- •***Laboratory*** measurement of ***porosity***
- •***Pressure profiles***
- •***Quick Look formation evaluation*** (Sw from resistivity ratio, etc)
- •***Double Duty Pickett Plots*** (per Roberto Aguilera)
    - •Bulk volume water and / or Permeability grids, superimposed on routine PP

•Grids of constant BVW values can be displayed on the Pickett Plot

•BVW=Constant, for a specific Rock Type, will generally identify water-free production





Grids below the Sw = 100 % line are for visual reference only

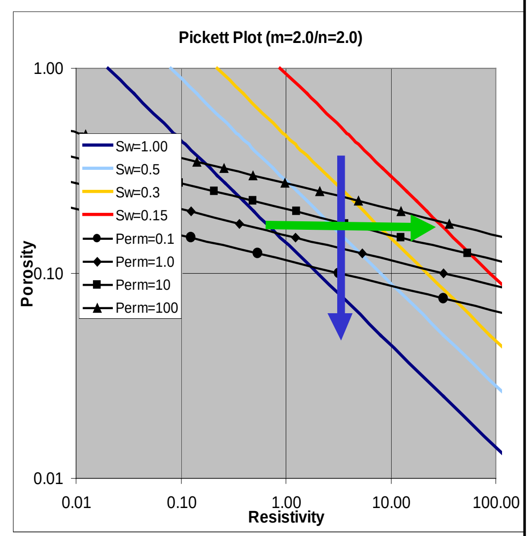
•Locally appropriate permeability relations can be super-imposed on the Pickett Plot

•At a <u>specific porosity</u>, increases in resistivity infer increased permeability (lower Swi => better rock quality)

•At a <u>specific resistivity</u>, lower porosities infer lower perms, and higher Swi

•**Perm estimate is** ***only valid far above the transition zone***

•Linear extrapolation to left of Sw=100 % line (graphic at right) is for visual reference only



Five Day Schedule

Day 1

Start	Stop	Duration	Topic
830	915	45	Course Introduction
915	930	15	Carbonate vs Sandstone
930	945	15	Break
945	1000	15	Thin Sections
1000	1045	45	Lucia Petrophysical Classification
1045	1100	15	Break
1100	1200	60	Lucia Classification (+ Exercise)
1200	1300	60	Lunch
1300	1400	60	Capillary Pressure (+ Exercise)
1400	1415	15	Break
1415	1500	45	Rock Quality and Cutoffs
1500	1515	15	Break
1515	1545	30	CT Scan with Carb Examples
1545	1615	30	GR in Carbonate (+ Exercise)
1615	1630	15	Review and Feedback

Day 2

Start	Stop	Duration	Topic
830	945	75	Sonic in Carbonate (+ Exercise)
945	1000	15	Break
1000	1100	60	Carb Rhob / Pef (+ Exercise)
1100	1115	15	Break
1115	1145	30	Carb LWD Rhob / Pef
1145	1200	15	Carbonate Neutron
1200	1300	60	Lunch
1300	1345	45	Carb Neutron (+ Exercise)
1345	1400	15	Break
1400	1500	60	Identification of Vuggy Porosity
1500	1515	15	Break
1515	1615	60	Specialty Sonic in Carb (+ Exercise)
1615	1630	15	Review and Feedback

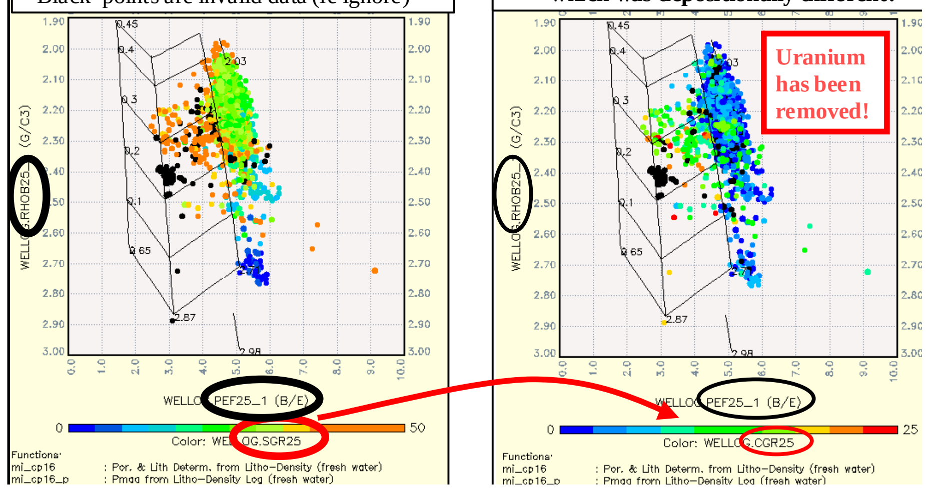
Time line may be modified to accommodate local requirements

- In the ***clastic*** world, ***GR*** activity is often (but not always) a result of clay, and therefore ***indicative of a decrease in rock quality***
- In ***carbonates*** it's not uncommon to find the ***GR*** being driven by ***uranium***, in a fashion that is ***not necessarily indicative of rock quality***
  - The presence of uranium, and the associated ***higher GR, can signal stylolites, fractures, super-perm and / or general increases or decreases in quality and / or mineralogy***
- One ***key distinction between sand and carbonate*** is then the ***utility and meaning (or lack thereof) of SP / GR response***

Carbonate versus Sandstone

- Trend parallel to LS line, but offset
- Pef is qualitative, not quantitative
- Higher GR corresponds to better quality limestone and increase in dolomitization
- Black points are invalid data (ie ignore)

- ***Limestone generally clean, throughout***
  - ***LS GR activity was essentially all uranium***
- **Dolomite is higher non-uranium GR activity**
  - **Did dolomitization occur in rock which was depositionally different?**



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Five Day Schedule

Day 3

Start	Stop	Duration	Topic
830	915	45	Phi / Mineralogy from Core
915	945	30	XRD/XRF/etc Mineralogy
945	1000	15	Break
1000	1045	45	Resistivity Tools & Constraints
1045	1100	15	Archie's 'm' Exponent
1100	1115	15	Break
1115	1200	45	Archie's 'm' Exp (+ Exercise)
1200	1300	60	Lunch
1300	1345	45	Cmnt Exp Variations & Pore Geometry
1345	1415	30	"m" Estimates From Vuggy Porosity Ratio
1415	1430	15	Break
1430	1500	30	"m" Estimates From Vuggy Porosity Ratio
1500	1530	30	Archie's "n" Exponent (+ Exercise)
1530	1545	15	Break
1545	1615	30	Low Resistivity Pay in Carbonates
1615	1630	15	Review and Feedback

Day 4

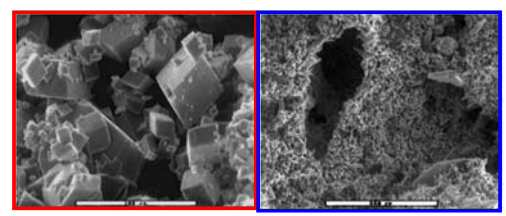
Start	Stop	Duration	Topic
830	900	30	Quick Look Techniques
900	930	30	Pickett Plot
930	945	15	Break
945	1030	45	Pickett Plot (+ Exercise)
1030	1045	15	Pulsed Neutron Log
1045	1100	15	Break
1100	1200	60	PNL (+ Exercise)
1200	1300	60	Lunch
1300	1345	45	PNL Log-inject-log
1345	1400	15	Break
1400	1445	45	BH Gravity Meter
1445	1530	45	Pressure Profiles (+ Exercise)
1530	1545	15	Break
1545	1615	30	Correlation Techniques
1615	1630	15	Review and Feedback

• **Carbonate** - Diagenesis includes ……...***dissolution***

• Surface example of how carbonate reservoir rock can be modified.

• One ***key distinction between sand and carbonate*** is that of ***clay effects versus pore size distribution***

Eureka Springs, Arkansas



•Environmental scanning electron microscope images,

•On the ***left***, a crystalline dolomite with ***φ= 47% and m = 1.95***.

•On the ***right***, a moldic bioclastic packstone with ***φ = 36% and m = 3.27***.

•This large ***variation in m illustrates the importance of rock texture on petrophysical evaluation.***

Electrical Properties of Porous Rocks by Carlos Torres-Verdín, University of Texas

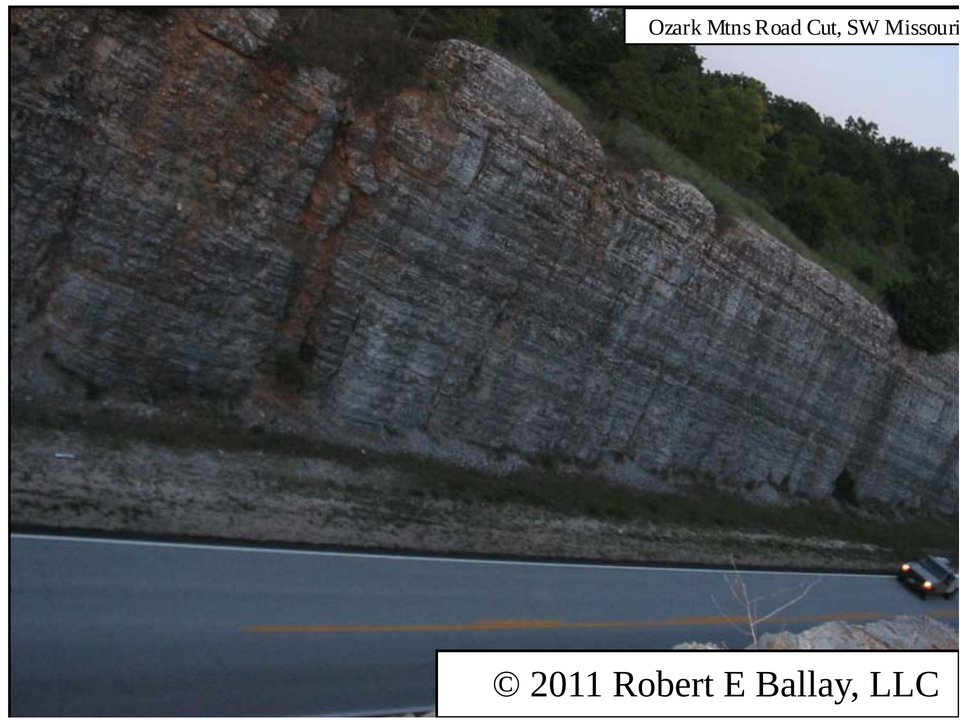
• In many regards, a ***key distinction between sand and carbonate***, is also one of accounting for ***clay conductivity*** 'short circuits' ***versus variations in pore system tortuosity*** associated with changes from intercrystalline / interparticle to vuggy porosity.

Five Day Schedule

Day 5

Start	Stop	Duration	Topic
830	945	75	Image Log (+ Exercise)
945	1000	15	Break
1000	1030	30	Dielectric Log
1030	1045	15	Wireline "m" Estimates Compared to Core
1045	1100	15	Break
1100	1200	60	Basic NMR (+ Exercise)
1200	1300	60	Lunch
1300	1315	15	Basic NMR (Hydrocarbon Effects)
1315	1400	45	Carbonate NMR
1400	1415	15	Break
1415	1500	45	Carbonate NMR (+ Exercise)
1500	1530	30	Core Calibrated Wireline "m" Estimates
1530	1545	15	Break
1545	1600	15	Daily Review and Feedback
1600	1615	15	Jerry Lucia: Here is how it works
1615	1630	15	Course Summary

Carbonate Bluffs along Steel Creek, NW Arkansas



Ozark Mtns Road Cut, SW Missouri

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Three Day Schedule

Day 1

Start	Stop	Duration	Topic
830	845	15	Course Introduction & Overview
845	900	15	Carbonate vs Sandstone (+GR Exercise)
900	950	50	Capillary Pressure (+ Exercise)
950	1000	10	Break
1000	1050	50	Lucia PP Classification (+ Exercise)
1050	1100	10	Break
1100	1200	60	Routine Sonic in Carbonate (+ Exercise)
1200	1300	60	Lunch
1300	1330	30	Density & Neutron in Carbonate (+ Exercise)
1330	1420	50	Identification of Vuggy Porosity
1420	1430	10	Break
1430	1445	15	Light Hydrocarbon Issues (Wireline & LWD)
1445	1530	45	Specialty Sonic Applications (+ Exercise)
1530	1540	10	Break
1540	1610	30	Rock Quality & Cutoffs
1610	1620	10	Resistivity Measurements
1620	1630	10	Summary

Time line may be modified to accommodate local requirements

- The ***Three Day course is application oriented*** and suitable for abbreviated Time Frames
- ***Both options assume*** a basic comfort level with Wireline / LWD measurements and discipline integrated petrophysical analyses

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Day 2

Start	Stop	Duration	Topic
830	930	60	Archie's "m" Exponent (+ Exercise)
930	940	10	Break
940	1030	50	Cement Exponent Variations and Pore Geometry
1030	1050	20	"m" Estimates From Vuggy Porosity Ratio
1050	1100	10	Break
1100	1200	60	"m" Estimates From Vuggy Porosity Ratio
1200	1300	60	Lunch
1300	1345	45	Archie's "n" Exponent (+ Exercise)
1345	1400	15	Low Resistivity Pay in Carbonates
1400	1410	10	Break
1410	1450	40	Pickett Plot
1450	1510	20	The Non-Archie Toolbox & Fresh Water Challenge
1510	1520	10	Break
1520	1620	60	Basic NMR (+ Exercise)
1620	1630	10	Summary

Day 3

Start	Stop	Duration	Topic
830	950	80	Carbonate NMR (+ Exercise)
950	1000	10	Break
1000	1020	20	Core Calibrated Wireline "m" Estimates
1020	1050	30	Dielectric Log
1050	1100	10	Break
1100	1120	20	Wireline "m" Estimates Compared to Core
1120	1200	40	PNL
1200	1300	60	Lunch
1300	1315	15	PNL
1315	1400	45	Pressure Profiles (+ Exercise)
1400	1410	10	Break
1410	1500	50	Image Logs (+ Exercise)
1500	1520	20	CT Scan
1520	1530	10	Break
1530	1550	20	XRD/XRF/Mineralogy
1550	1610	20	Phi / Mineralogy from Core
1610	1620	10	Jerry Lucia: Here is how it works
1620	1630	10	Summary

Carbonate Petrophysics

- Client Considerations
- My ***First, and Top Priority***, is to ensure a-priori that the Course meets the Client's expectation.
- The ***focus of the Course is on carbonate matrix issues, and not fractured reservoirs.***
- ***Course Content issues for Client Consideration*** are summarized ***following***
  - ***Please read and consider carefully***

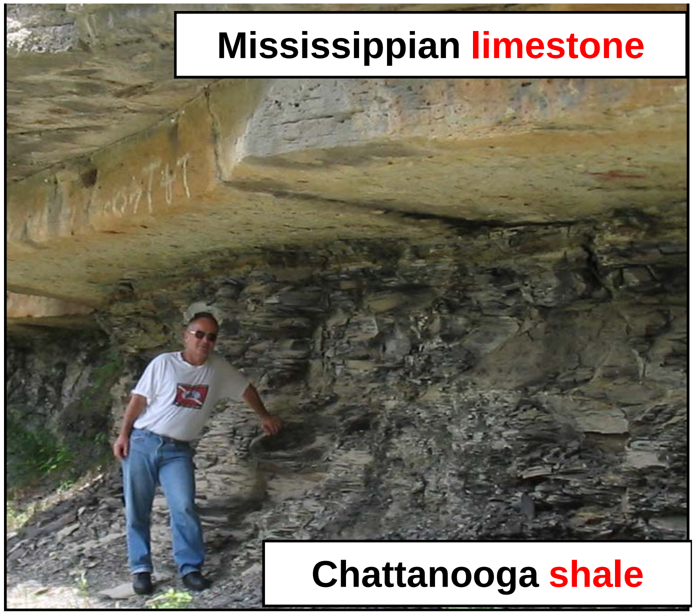
Carbonate Petrophysics - Client Considerations

- Material is delivered in two forms
  - The Manual, which plays the role of a text book
  - The Presentation, which is drawn from the Manual, but expanded upon and optimized with respect to fonts and color codes
- Modules for the basic techniques typically begin with an introduction to the physics behind the actual measurements.
  - This is a conscious and deliberate decision, based upon my experience as both a practicing petrophysicist and as an instructor.
    - Many times I have discovered that even those with several years of experience, are not aware of some of the basic physical principles, and have thus compromised their use of the measurements.
  - I realize, however, that there are audiences which are not interested in the Basic Physics and possibly not even in an Introduction to Basic Tools / Techniques.
  - ***Please review*** the default set-up ***to ensure it satisfies your objectives.***
- *Continued in following exhibit*

Carbonate Petrophysics - Client Considerations

- Not all modules (Field Studies, for example) in the Manual are covered in the presentation, but rather are included for future review and reference, when the basic tools and techniques have been developed in class.
  - There may be audiences which are 'application oriented'. Please review the default set-up to ensure it satisfies your objectives.
- ***Most of the modules have an Application Example included, which can be 'worked in class', or 'reviewed in class' or 'left for the attendee to review in their leisure'.*** I have found that some folks like to have problems to work and others don't care for them (and in fact disapprove of spending course time in this manner): I typically ask this very question in the Introduction Phase. If possible, however, it is better to know the preference in advance. Key Issues are:
  - Are they the 'kind of problems' that you are looking for in the course?
  - Shall they be 'reviewed' or 'worked' in class, or left for attendees to 'review at their leisure'.
  - Please note that allowing time for problem solving will mean less time for technique presentation, as the time allocated in the course schedule will be adhered to in either situation (unless the audience requests otherwise).
- My ***First, and Top Priority***, is to ***ensure a-priori that the Course meets the Client's expectation. Please work with me, in advance of scheduling the course, to ensure that every requirement has been considered.***

R. E. (Gene) Ballay's ***35 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 training & consulting.

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