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The Effect of Rock Types on SCAL Data in Carbonates

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6th Annual SPWLA Topical Conference, Abu Dhabi, 15 – 18 FEB 2010
Carbonate Reservoir Rock Typing
Hilton, Abu Dhabi

Presentation outline

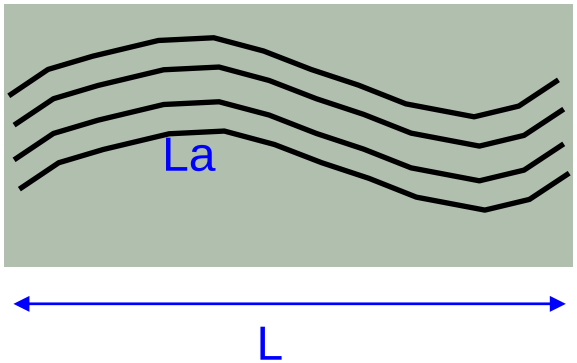
- Rock types
- Formation Resistivity Factor (FF, m)
- Capillary pressure, Resistivity Index
- Relative permeability
- Conclusions

Rock types

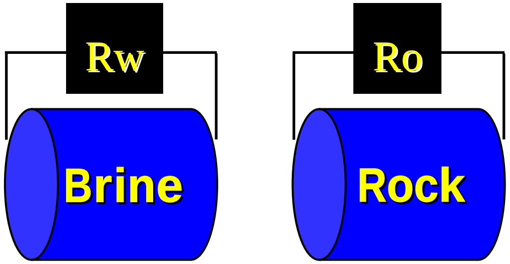
- What is a rock type?
  - Variations in
    - Mineralogy?
    - Pore size?
    - Pore shape?
    - Pore (throat) size distribution?
    - Aspect ratio (pore body by pore throat)?
    - Pore correlation
    - ……………….
- How is a rock type identified?
  - By
    - Poroperm?
    - Resistivity (m & n)?
    - Pc curve? Which one?
    - Kr curve? Which one?
    - XRD? SEM? TS?

Formation Resistivity Factor (FF, m)

Tortuous flow path

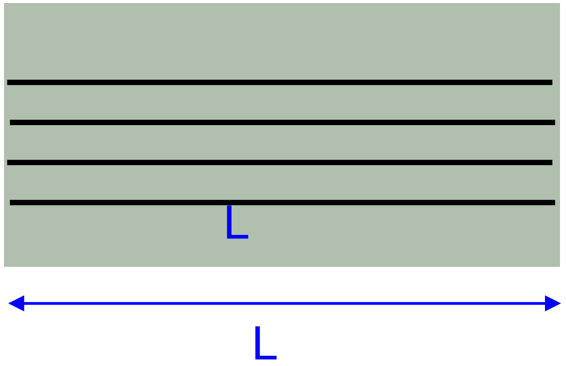


$$FRF = \frac{R_o}{R_w} = \frac{1}{\Phi}\frac{L_a}{L}$$



$$FRF = \frac{R_o}{R_w}$$

Cylindrical tube model



$$FRF = \frac{R_o}{R_w} = \frac{1}{\Phi}$$

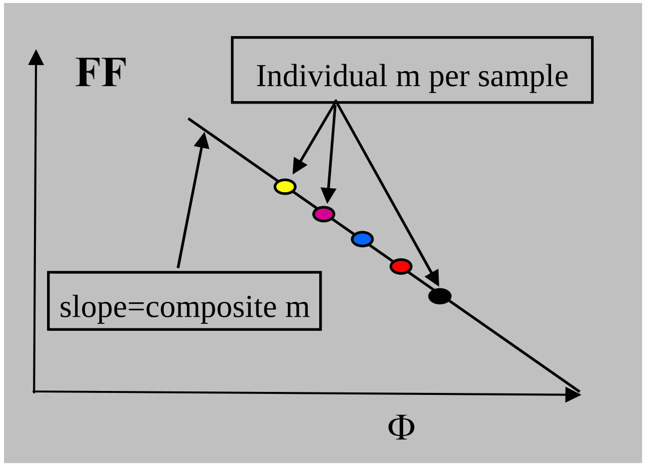
Natural formations have complex pore geometry

Lab-derived

$$FRF = \frac{a}{\Phi^m}$$

where,

- **a** Intercept on the FRF axis
- **Φ** Fractional porosity
- **m** Cementation exponent



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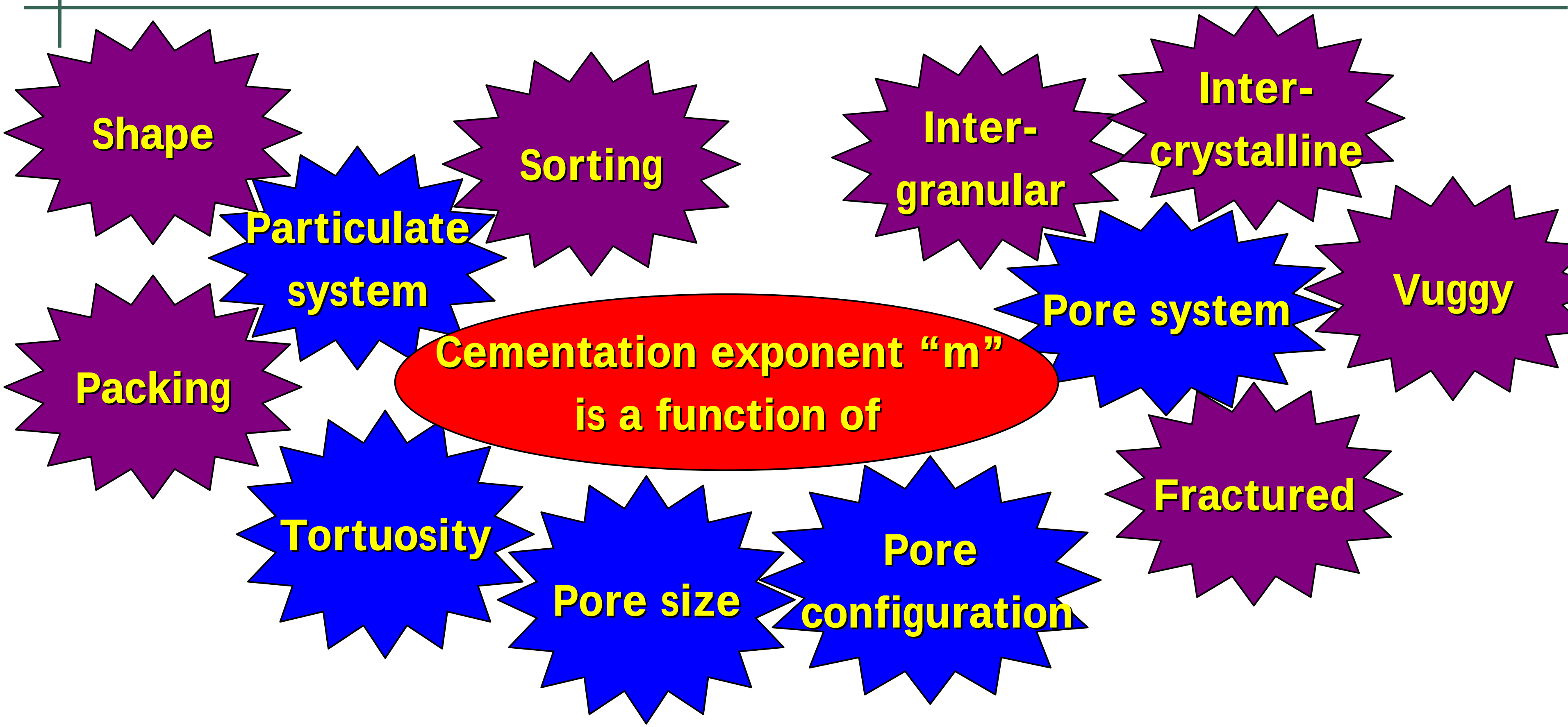
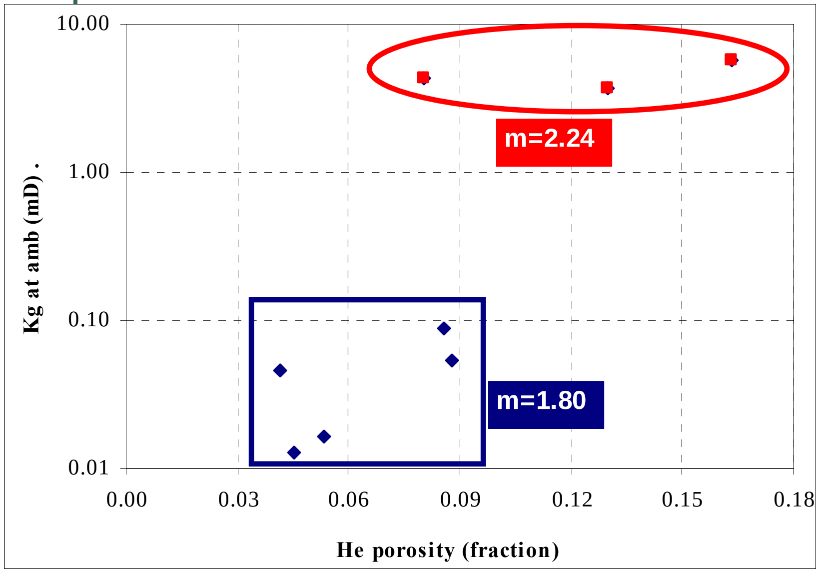
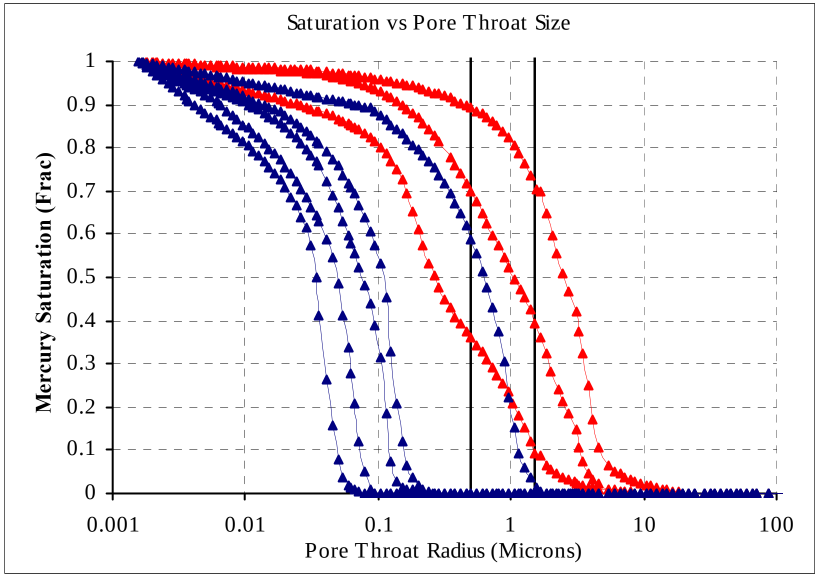
Formation Resistivity Factor (FF, m)

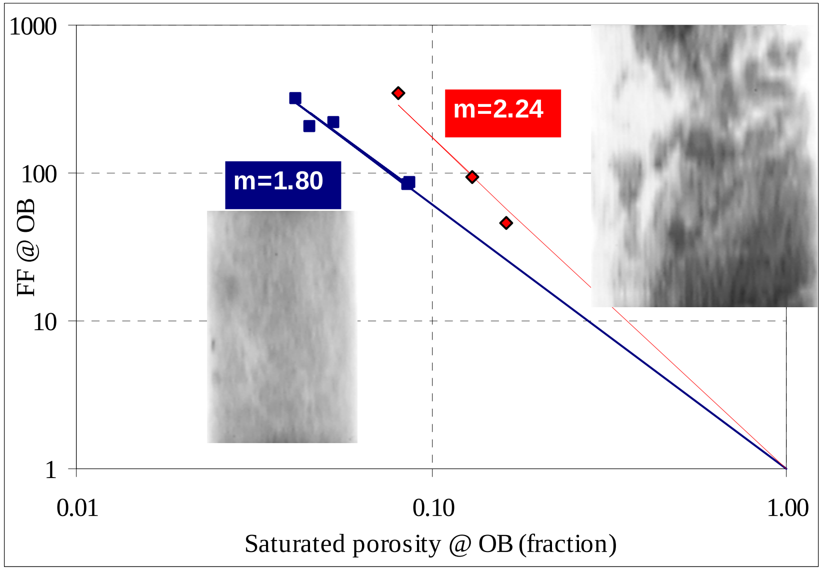


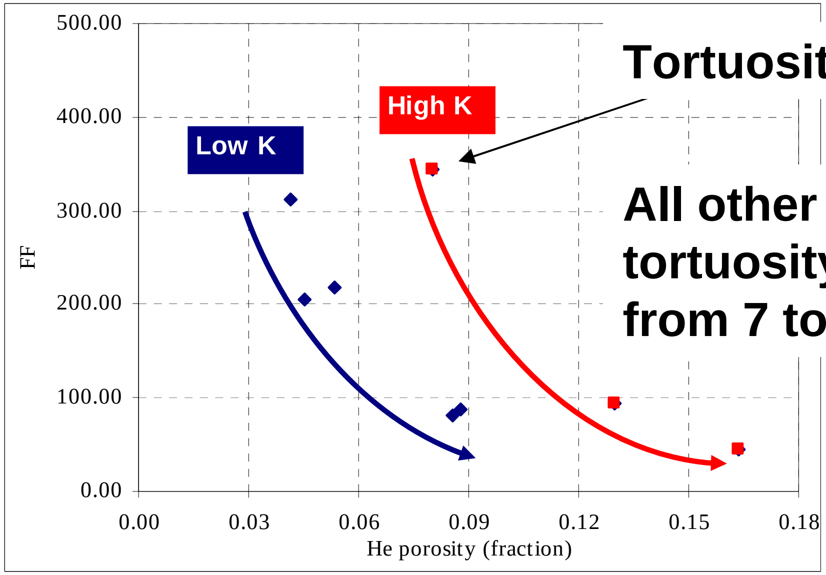
The combination of these factors can produce a countless number of FRF and “m” values for a given porosity

Formation Resistivity Factor (FF, m)





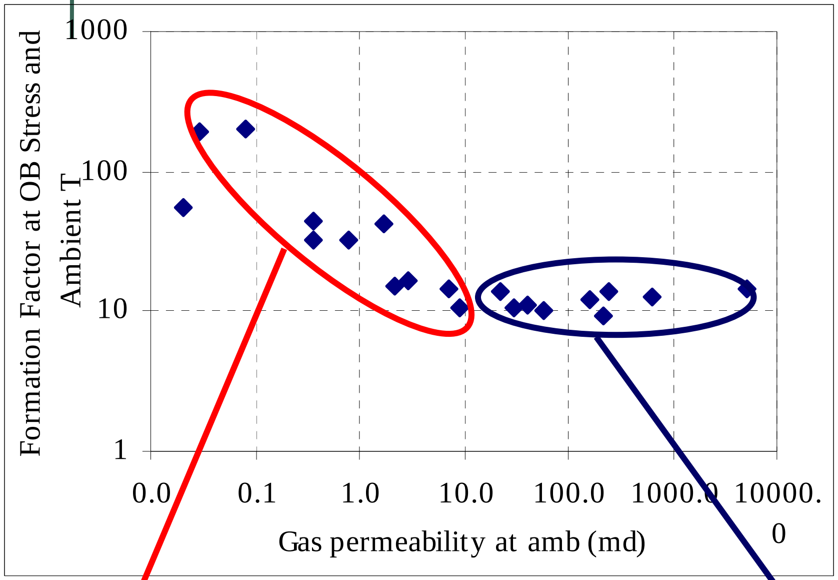


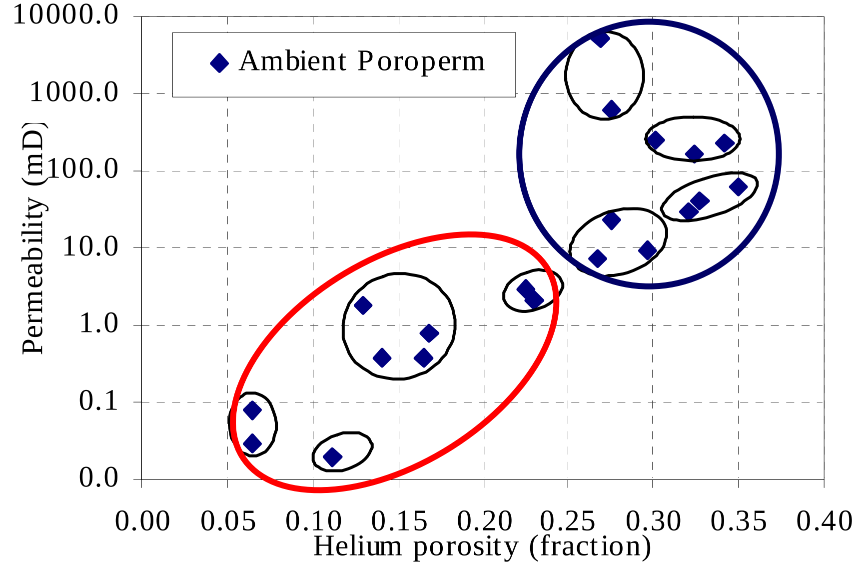


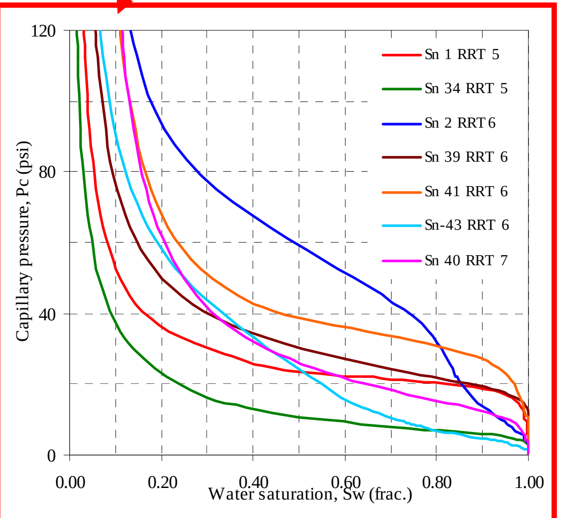
Tortuosity = 27

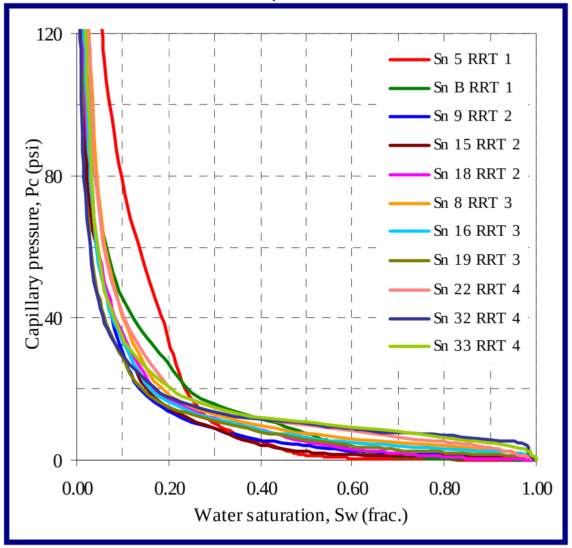
All other samples' tortuosity ranged from 7 to 13

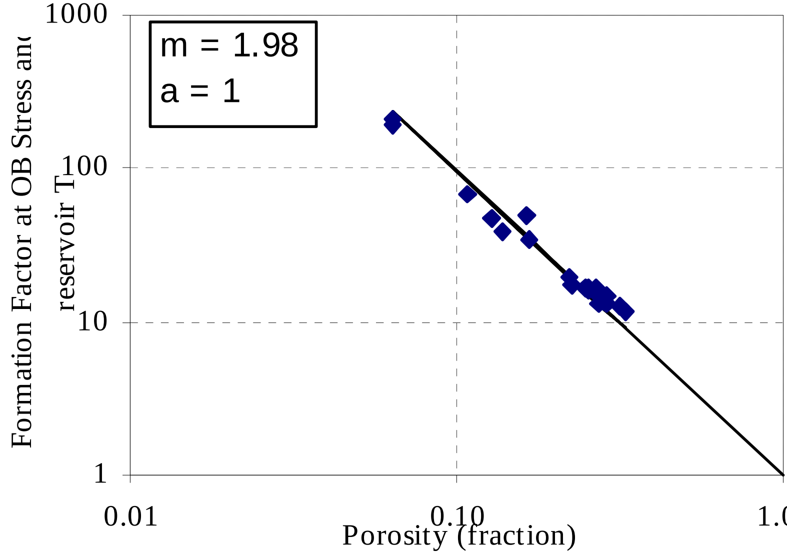
Formation Resistivity Factor (FF, m)









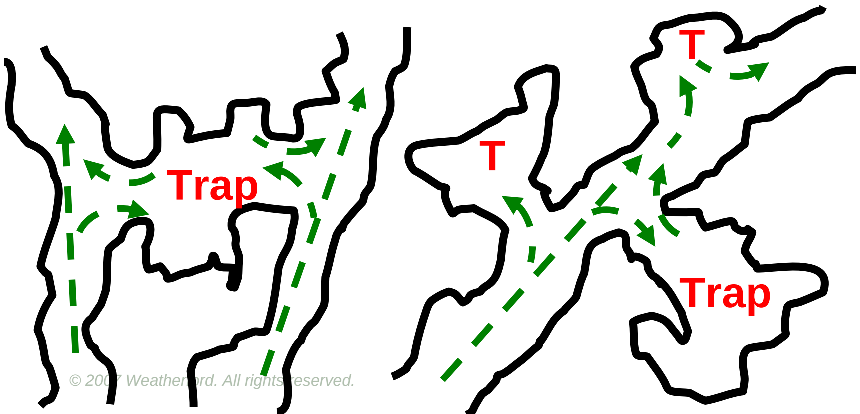


Formation Resistivity Factor (FF, m)

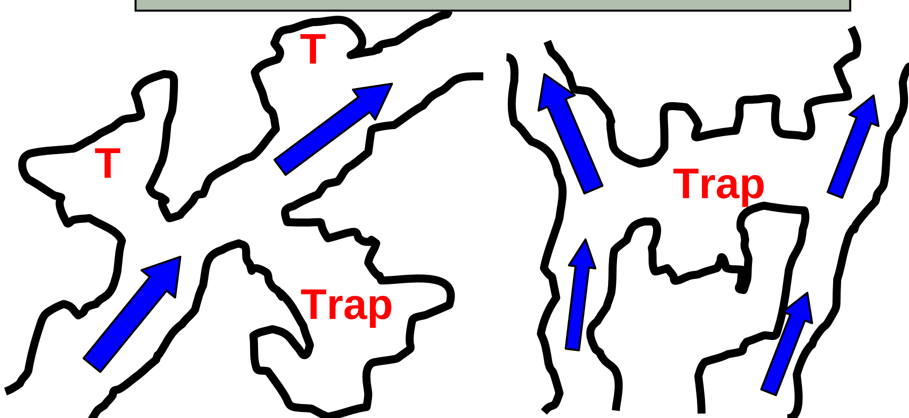
- Only channel pores participate actively in the flow of electric current. Traps are neutral.
- In viscous flow traps are not neutral – Viscous forces promote the transfer of fluids from traps to flowing pores

That is why FRF may not always be correlated to Perm

Viscous Flow

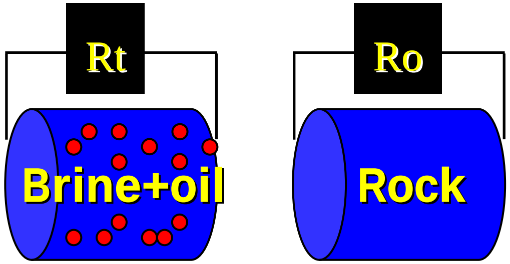


Electric Flow



Capillary Pressure, Resistivity Index

Archie's second equation

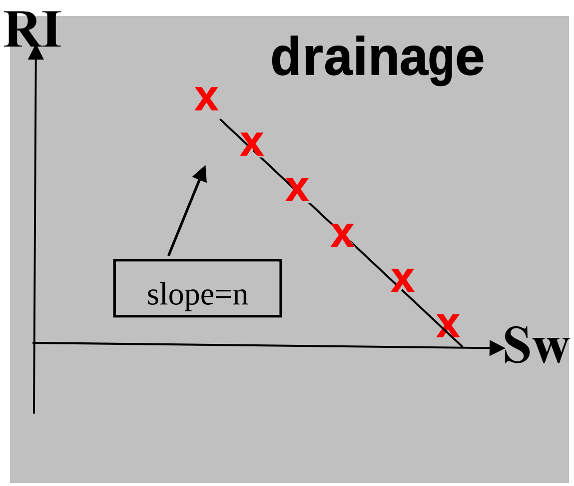


$$FRI = \frac{1}{Sw^n}$$

where,

Sw Water saturation

n Saturation exponent



$$FRI = \frac{Rt}{Ro}$$

n is a function of Wettability and distribution of fluids

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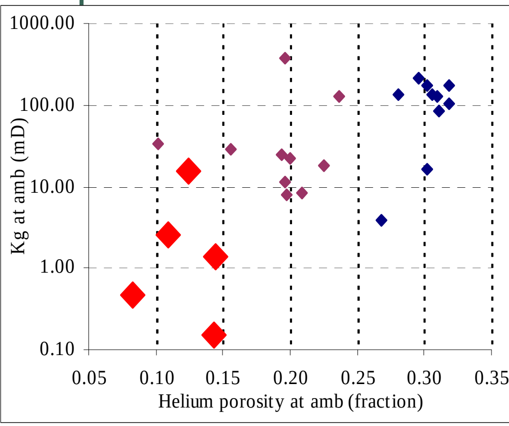
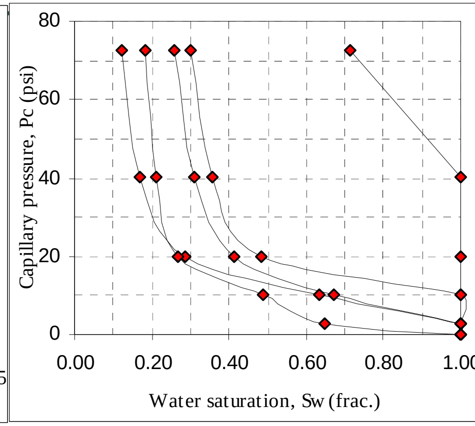
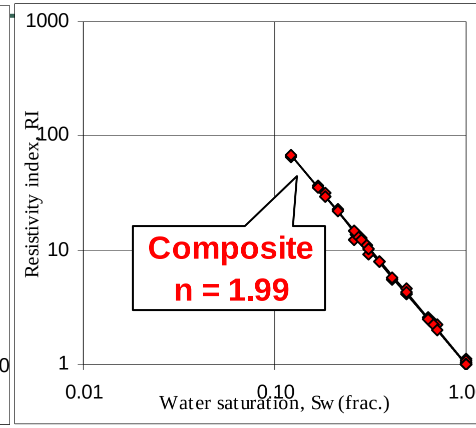
Capillary Pressure, Resistivity Index

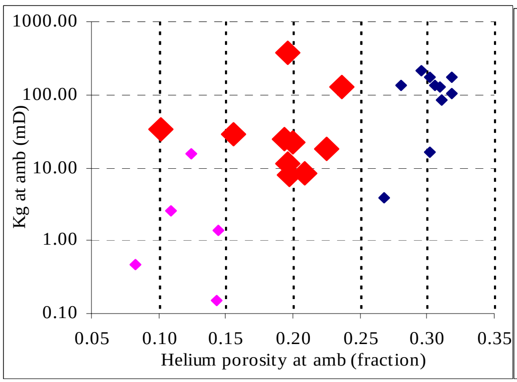


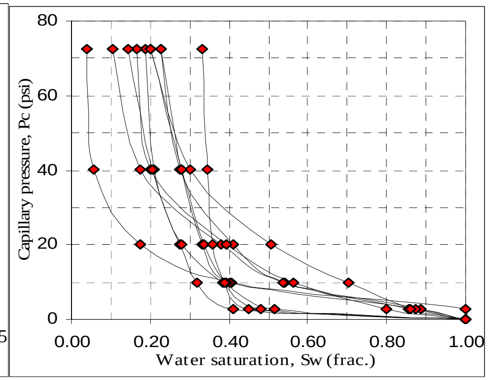


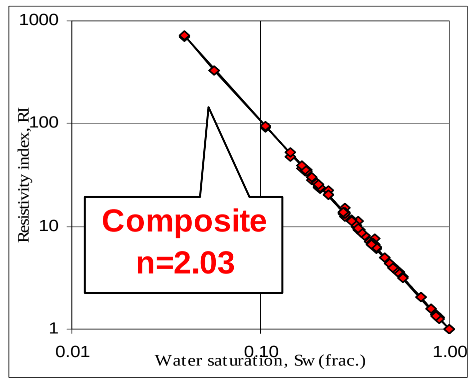


Field A

Low Poroperm
High entry pressure
Variable Swi
Single "n"

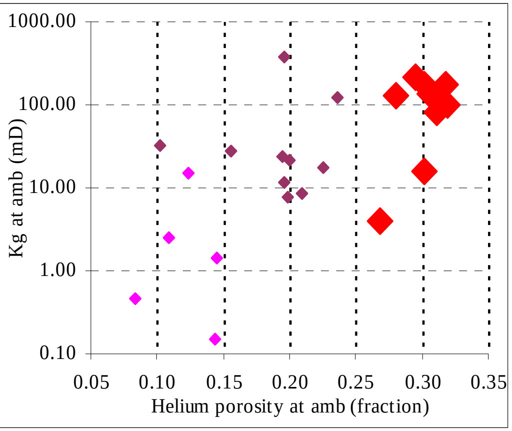


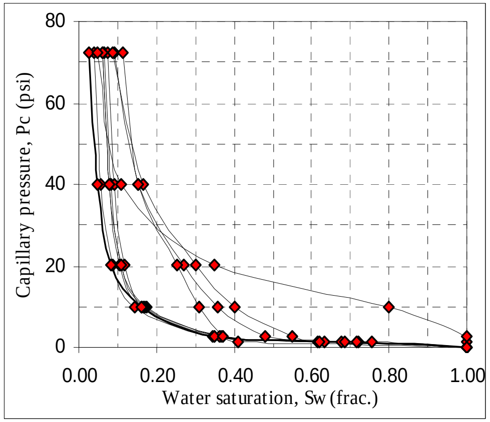


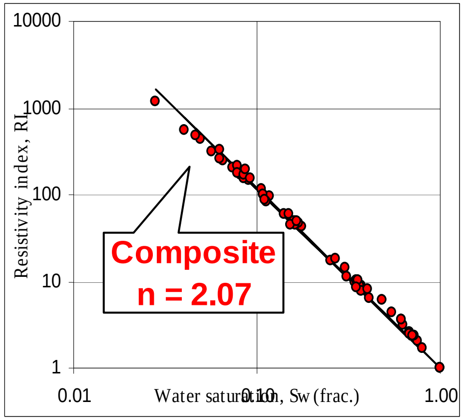


Field B

Moderate Poroperm
Low entry pressure
Variable Swi
Single "n"



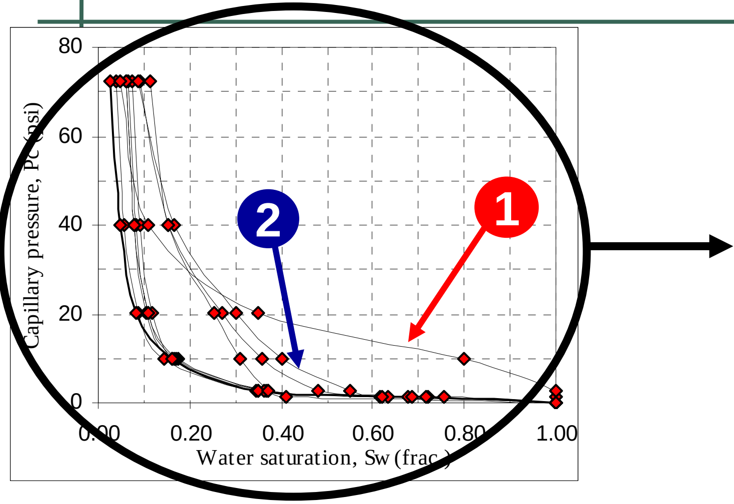


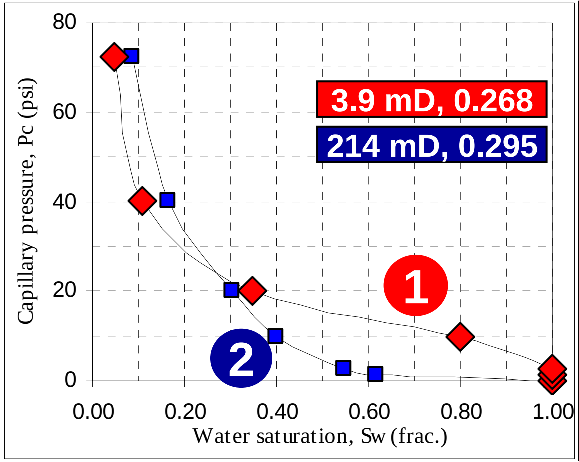


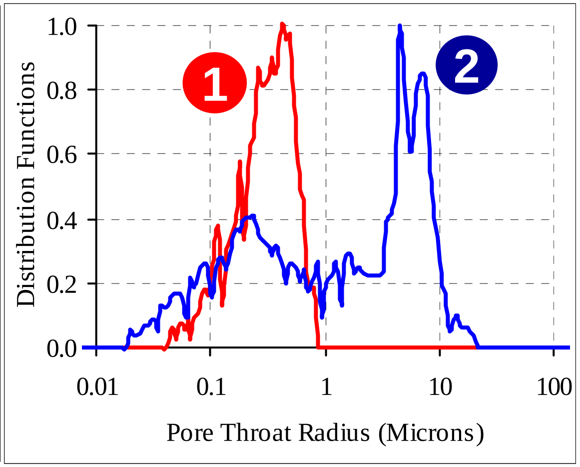
Field C

High Poroperm
Lower entry pressure
Low Swi
Single "n"

Capillary Pressure, Resistivity Index







- Curve 1 represents a finer grained sample with smaller pore sizes
- Curve 2 represents a coarser grained sample with large pore sizes
- Both samples have similar “m” and “n” exponents
- Permeability may not be correlated with Swi
- Permeability is a good qualitative index for the entry pressure

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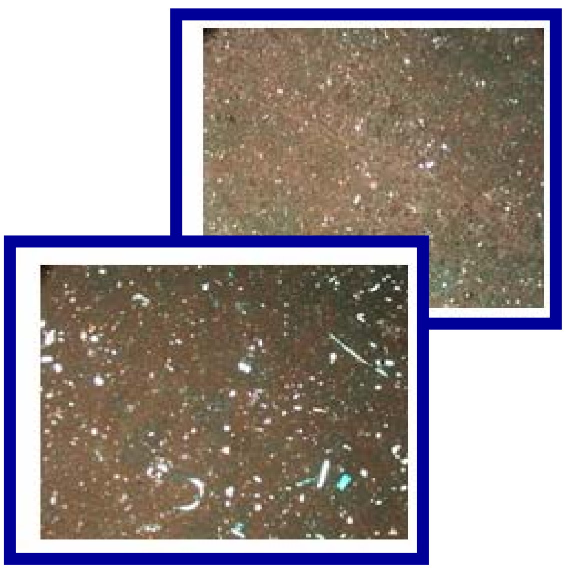
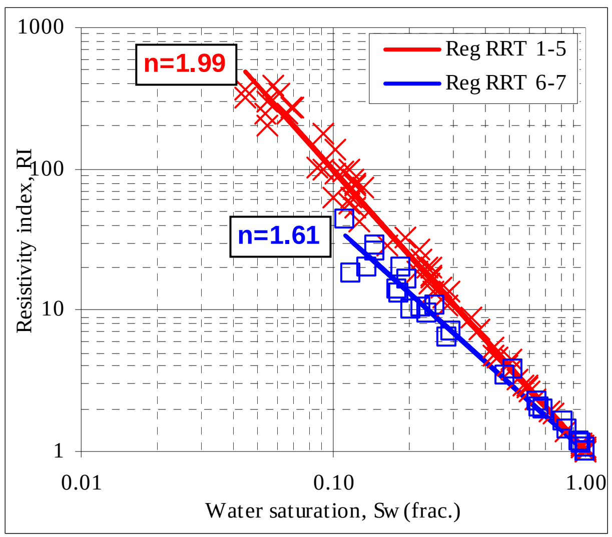
Capillary Pressure, Resistivity Index

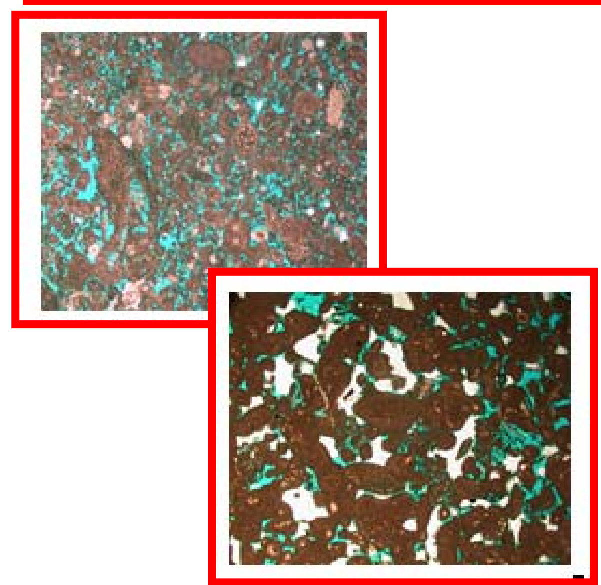
- There can be instances where “n” is different for different RRT in primary drainage
- Vuggy and heterogeneous samples gave “n” around 2
- Less heterogeneous samples gave “n” as low as 1.6

•Wackstone and mudstone



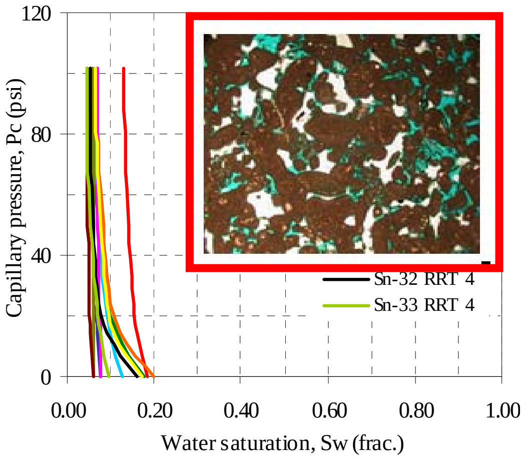


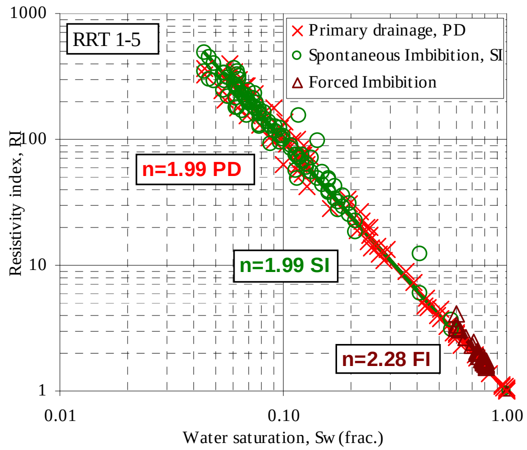
•Rudist, skeletal, peloid rudstone and peloid floastone

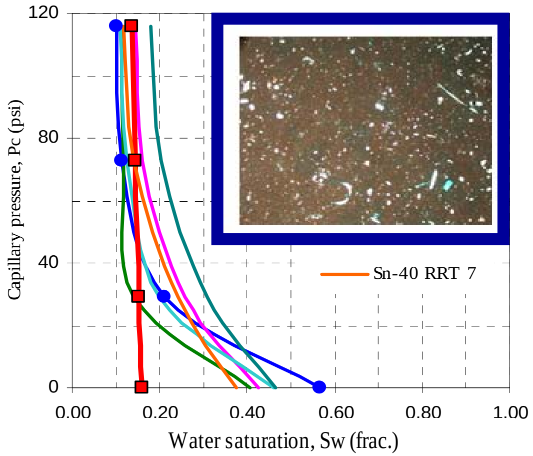


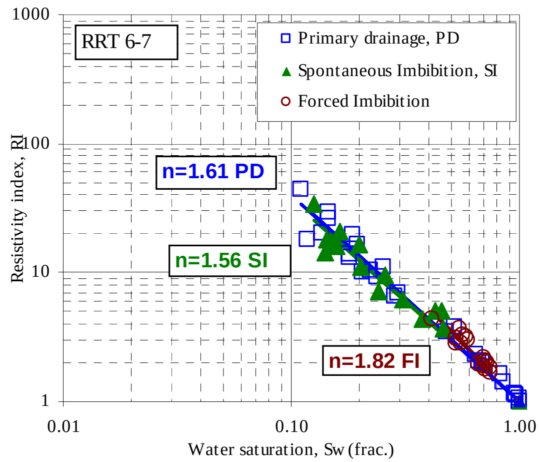
Capillary Pressure, Resistivity Index

- **High quality and poor quality samples were invaded with the same oil at the same reservoir conditions**
- **Spontaneous imbibition behavior was dramatically different**







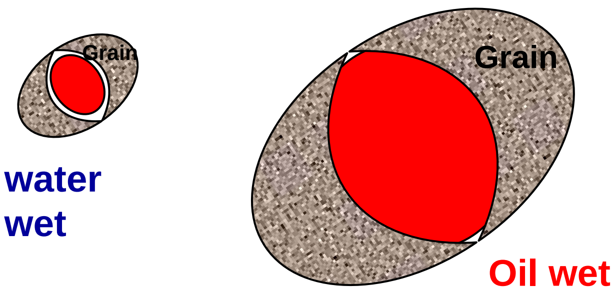


- Different rock types can lead to differences in
  - Mineralogy
  - Pore sizes
  - Pore size distribution
  - Aspect ratio
- Differences in these parameters cause multiple effects which can be hard to predict

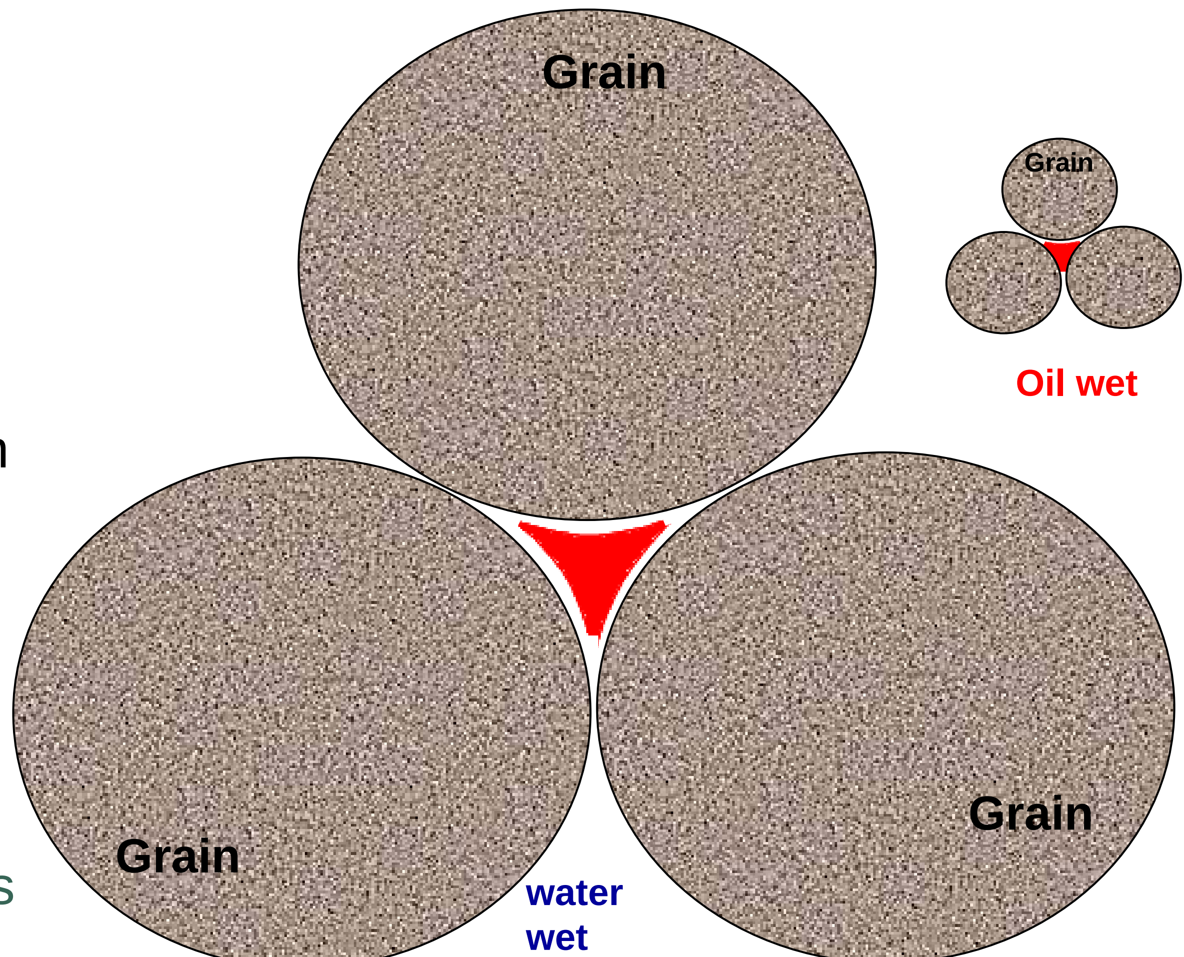
Capillary Pressure, Resistivity Index

- Different rock types may lead to different Wettability conditions even when using similar fluids and conditions

Concave pores

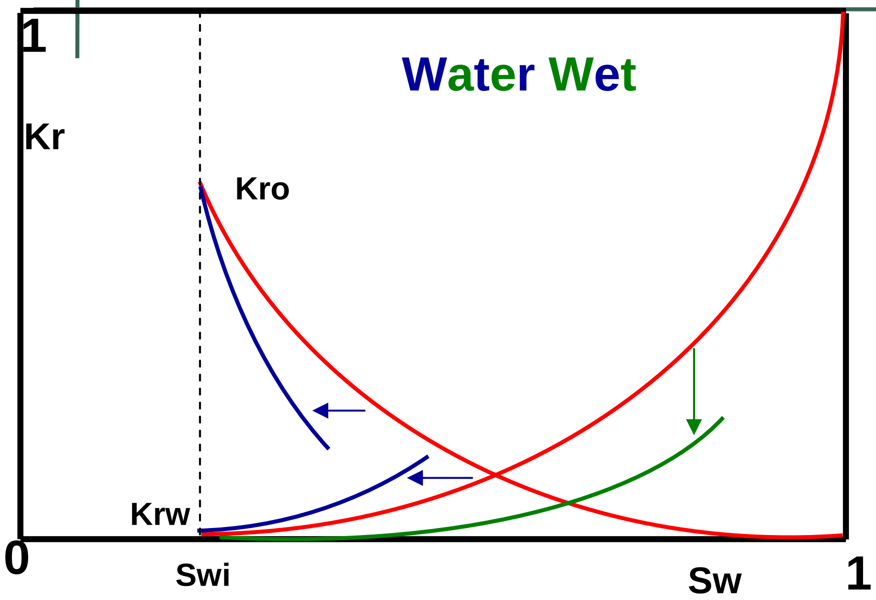


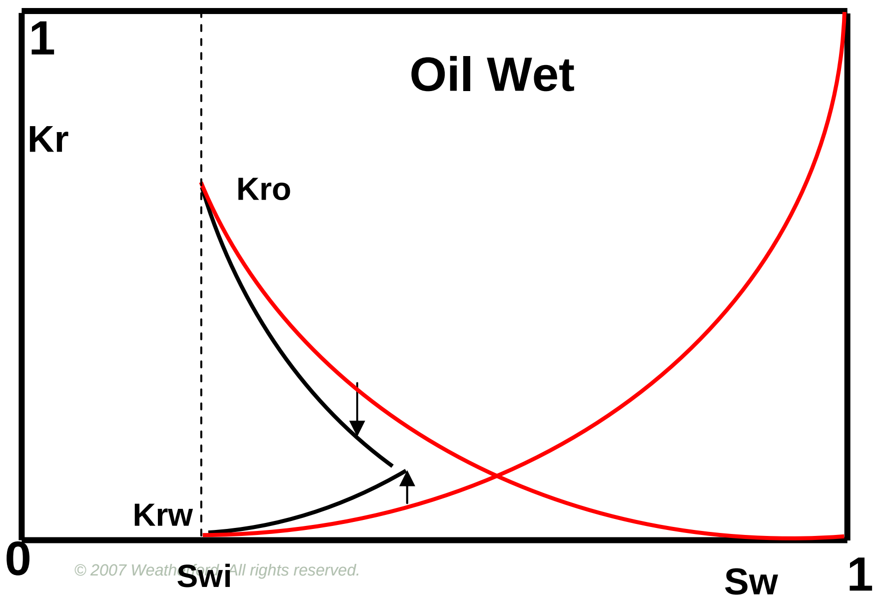
Convex pores



- From the Augmented Laplace Equation it is shown that (Kovscek et. al. 1993)
  - Small convex pores become oil wet before the big convex pores
  - Big concave pores become oil wet before the small concave pores

Relative Permeability Hysteresis





For water-wet porous medium

During imbibition, oil trapping causes lower mobile oil saturation

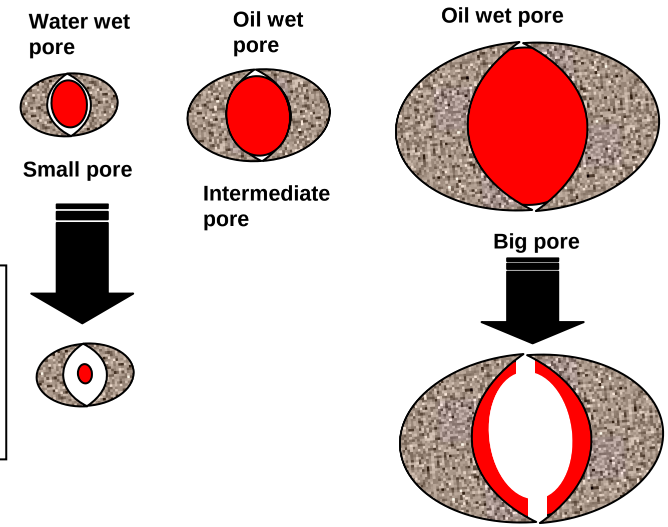
End of drainage

However, Oil trapping may hinder water flow and thus may lead to lower Krw

(Masalmeh 2001)

For mixed-wet porous medium

End of drainage



Start of Imbibition

Displaces big oil wet pores and small water wet pores

(Masalmeh 2001)

Conclusions

- Resistivity may not always be a tool to define RRT’s
- Variations in “m” and “n” exponents strongly indicate differences in RRT’s
- “m” and “n’ tend to increase with vuggy and heterogeneous samples
- Different RRT’s can induce different Wettability conditions which yield major differences in flow behavior.
- Changes in PSD may have only minor effects on rel perm

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Thank You

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