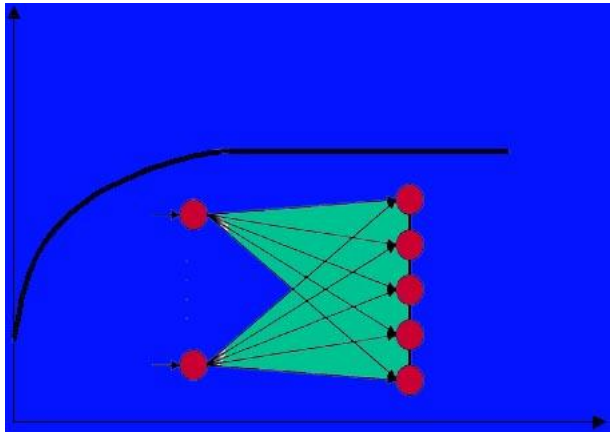

GeoNeurale

- Testing, Testing 1,2,3

by Gene Ballay

PART 1

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Fluid Pressures and Capillary Pressure

- ***Fluid pressure gradients, and the corresponding fluid densities, are directly related to capillary pressure concepts.***
  - Vavra et al have provided us with a ***nice review of cap pressure basics***
  - C L Vavra, J G Kaldi and R M Sneider. Geological Applications of Capillary Pressure: A Review. AAPG V 76 No 6 (June 1992)
- ***Capillary pressure*** (P_c) is ***the difference in pressure across the meniscus in a capillary.***
  - This pressure is ***associated with*** the ***contrast in fluid pressure gradients*** resulting from the ***different densities*** of the ***non-wetting*** (ρ_{nw}) and ***wetting*** (ρ_w) phases.

$$P_c = (\rho_w - \rho_{nw}) * g * h = \Delta \rho * g * h$$

Figure 1

Fluid Pressures and Capillary Pressure

- *Capillary Pressure* and *TVD Height in the reservoir* are *related* as

$$P_c = (\rho_w - \rho_{nw}) * g * h = \Delta \rho * g * h$$

$$h = P_c(\text{Reservoir}) / [\ 0.433 * (\rho_w - \rho_{nw})\ ]$$

- Height = Elevation Above Free Water Level, in *TVD* Feet
- P_c(Reservoir) = Capillary Pressure in *psi*
- $(\rho_w - \rho_{nw})$ = Respective Fluid Densities in gm/cc

Fluid Pressure and Fluid Gradient

- *In the case of a single fluid, Density & Pressure Gradient are related*

Fluid Density = Pressure Gradient / 0.433

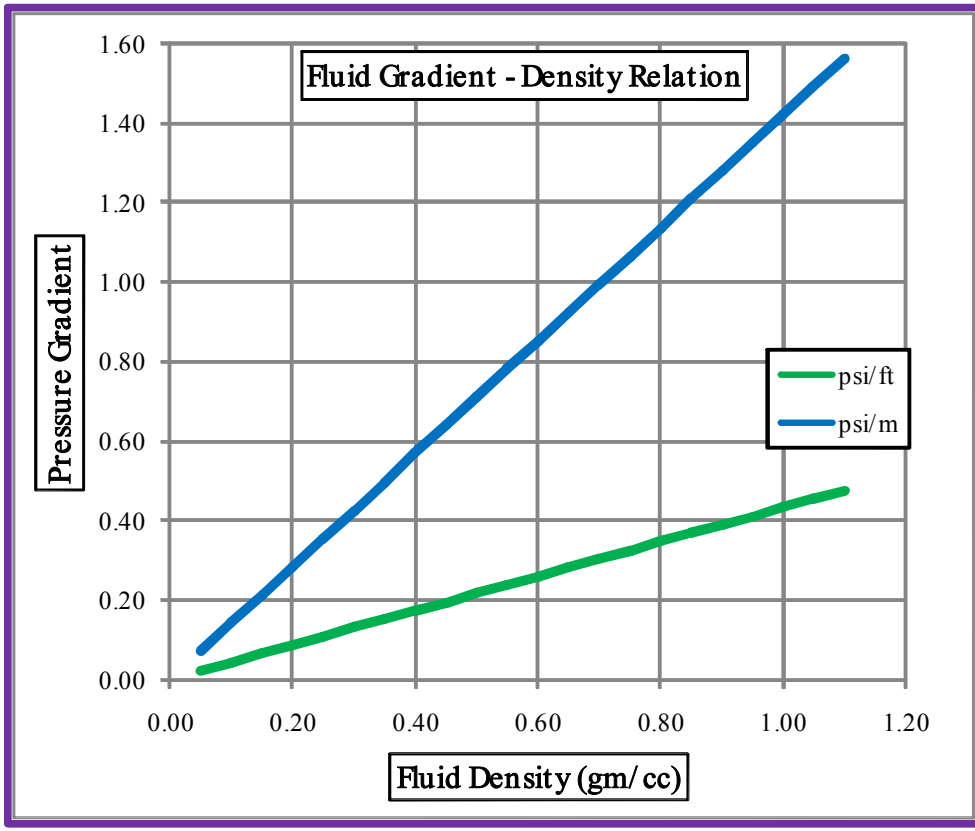


Figure 2

Idealized Pressure Profile

- ***Fluid Gradient*** is that of the ***Mobile Phase***
  - Hydrocarbon, high in the column
  - Brine, low in the zone

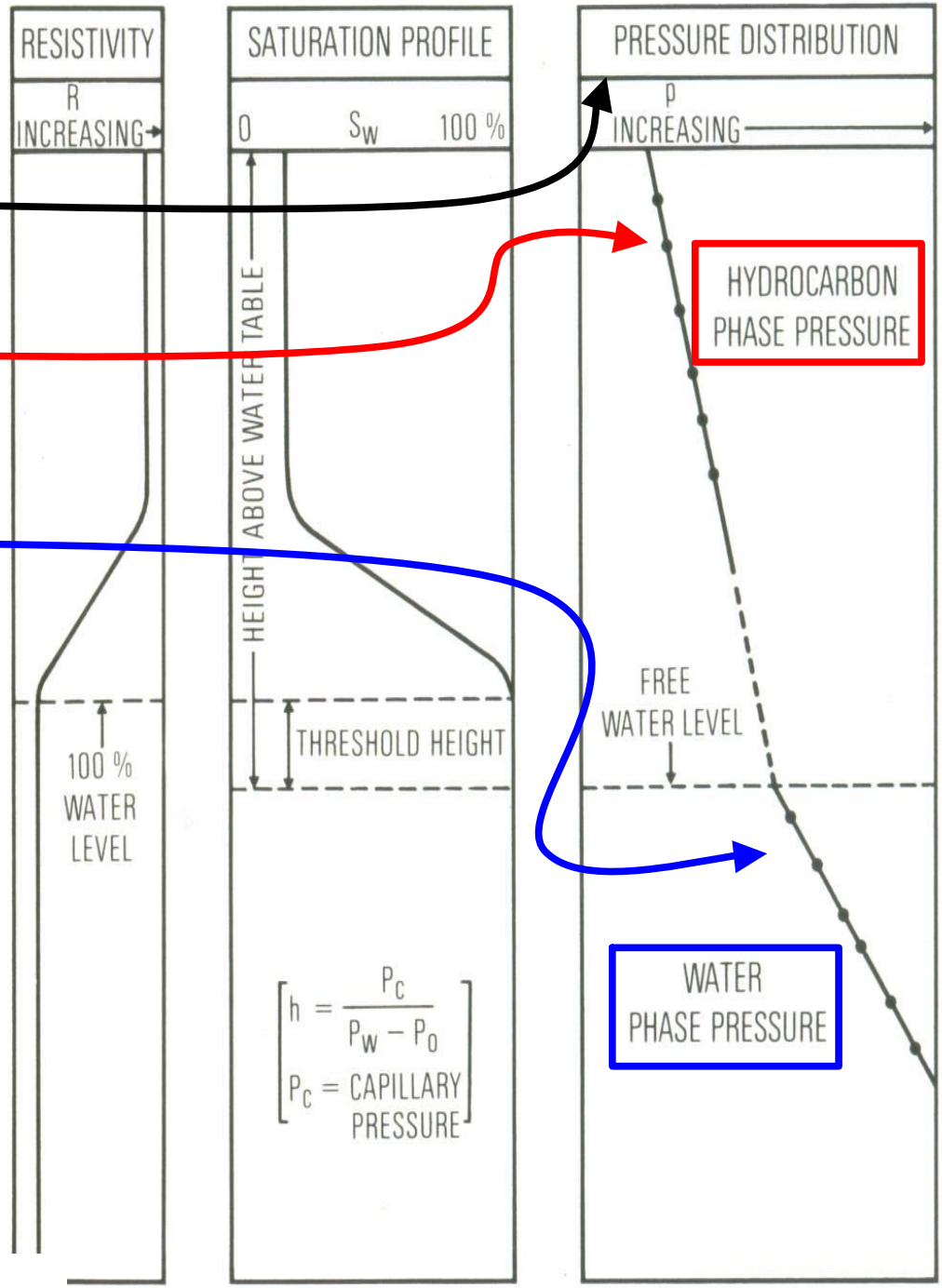
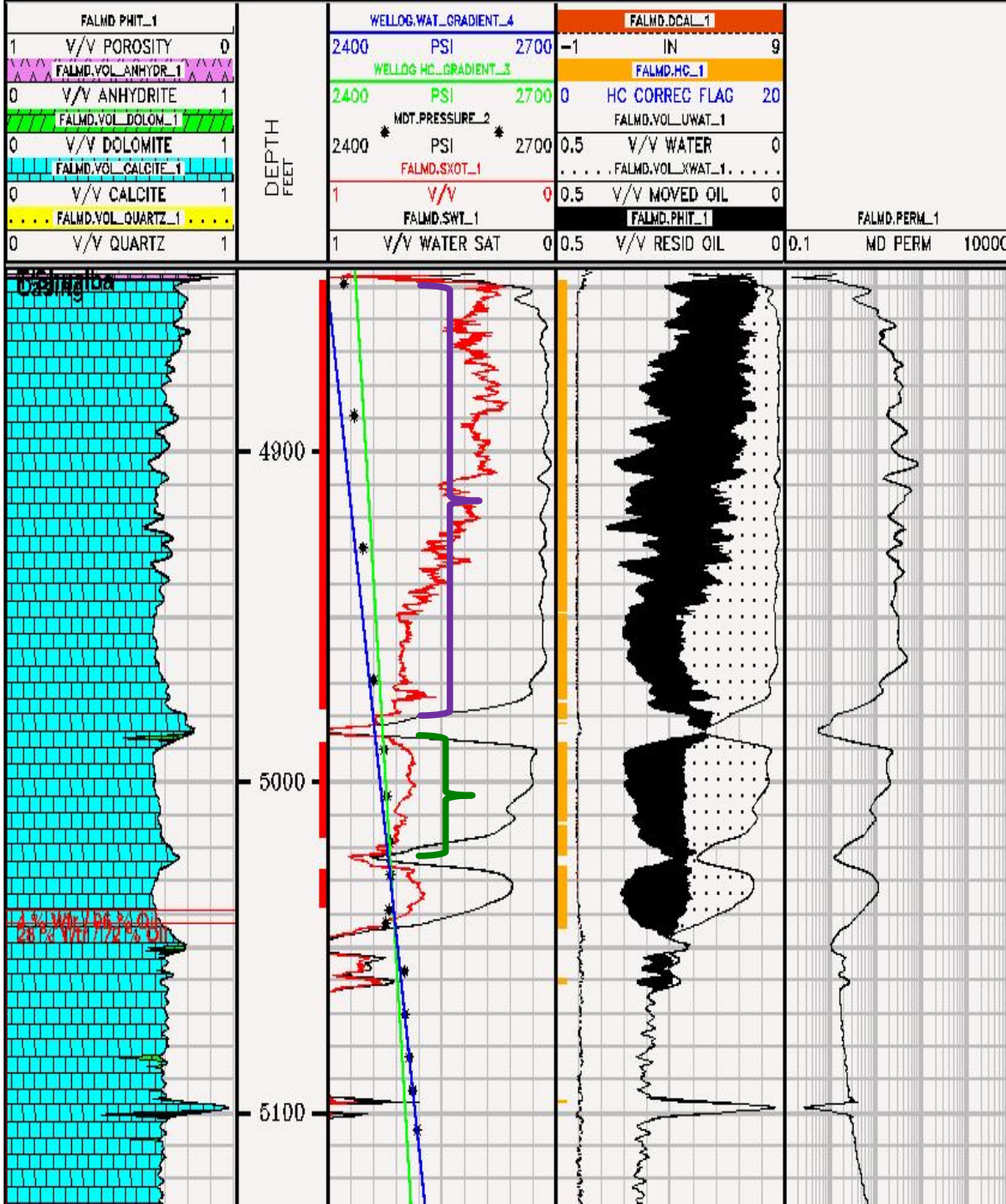


Figure 3

Figure 4

- ***Water column gradient*** described by 0.46 psi/ft → 125,000 ppm NaCl
- ***Fluid sample*** acquired during pressure profile, Geochem yields *122,000 mg/l* TDS (considerably saltier than the mud, suggesting this is formation water
- ***PNL*** from water leg of off-setting well indicative of an approximate *125,000 ppm* brine
- ***Compare and contrast all data for complete evaluation***



•Multi-Dimensional Petrophysics in the Reservoir Description Division - Gene Ballay - Saudi Aramco Journal of Technology

Idealized Pressure Profile

- ***Fluid Gradient*** is that of the ***Mobile Phase***
- ***Oil-Water Contact*** (Sw ~ 50 %) is ***above the HC Entry Pressure Level***
- Hydrocarbon Entry Pressure Reached ***Above FWL***
- Free Water Level is Datum of Zero Capillary Pressure

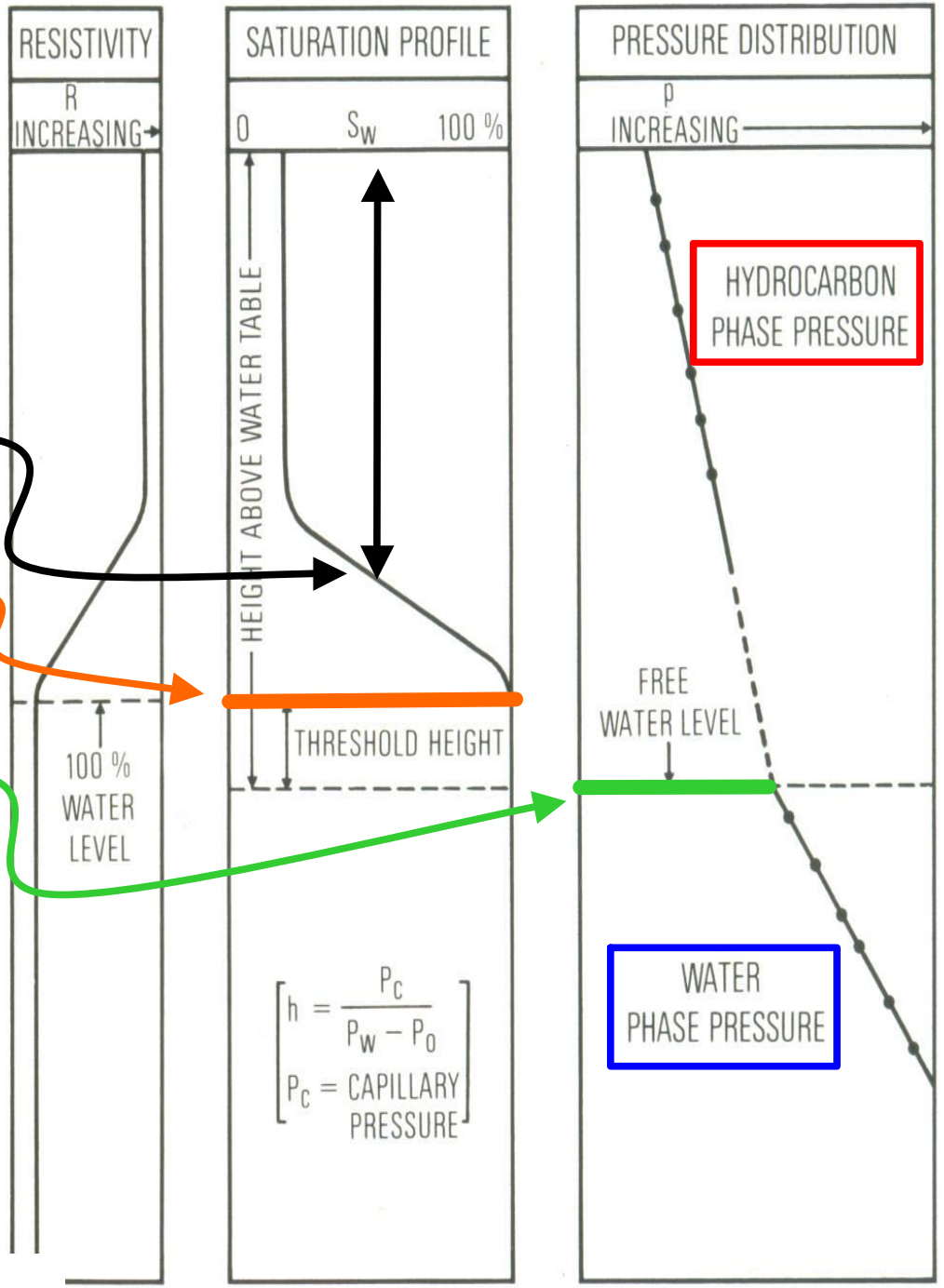


Figure 5

Pressure Profiling for *Fluid Contact*

- Carbonate (non-shale) ***GOC Typically Picked with*** (shallow reading) ***Density-Neutron*** Separation
  - Oil-Water Contact Based Upon (deeper) Resistivity Response
- Combination of ***Invasion*** (lack thereof), ***MF Dissipation*** and ***Different Depths of Investigation*** (density vs neutron) may ***Hide the GOC***
- ***Pressure Profile can Contribute***
  - ***Similar density-neutron relation*** observed across ***clear pressure profile GOC***

Figure 6

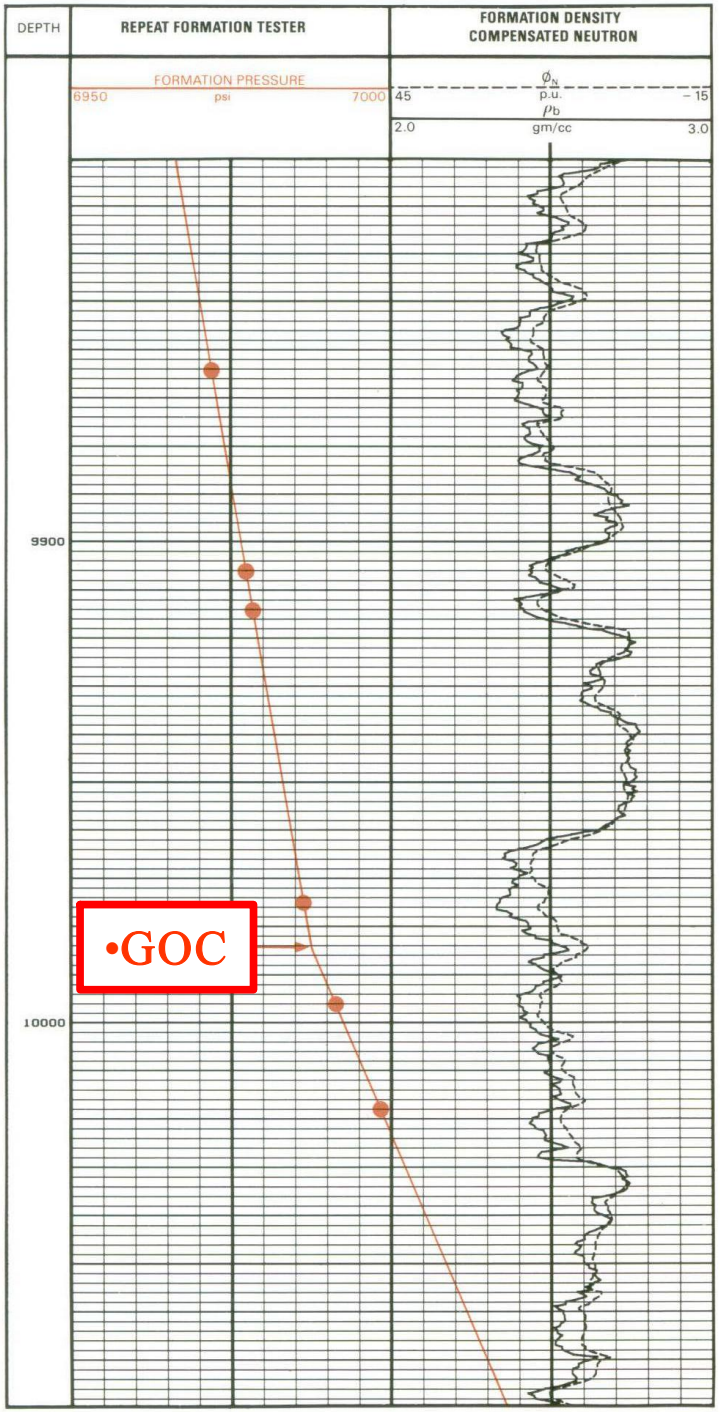
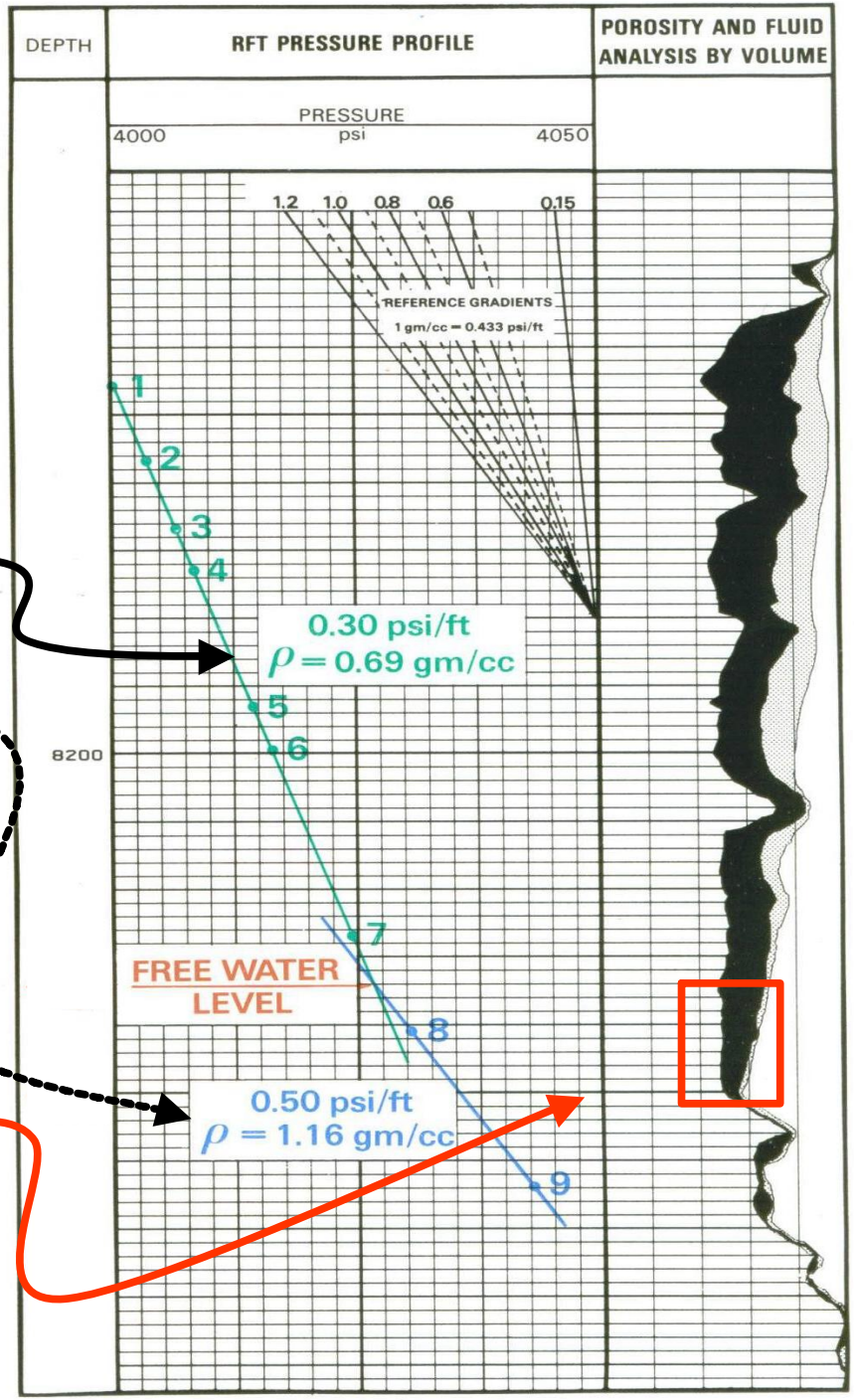


Figure 7

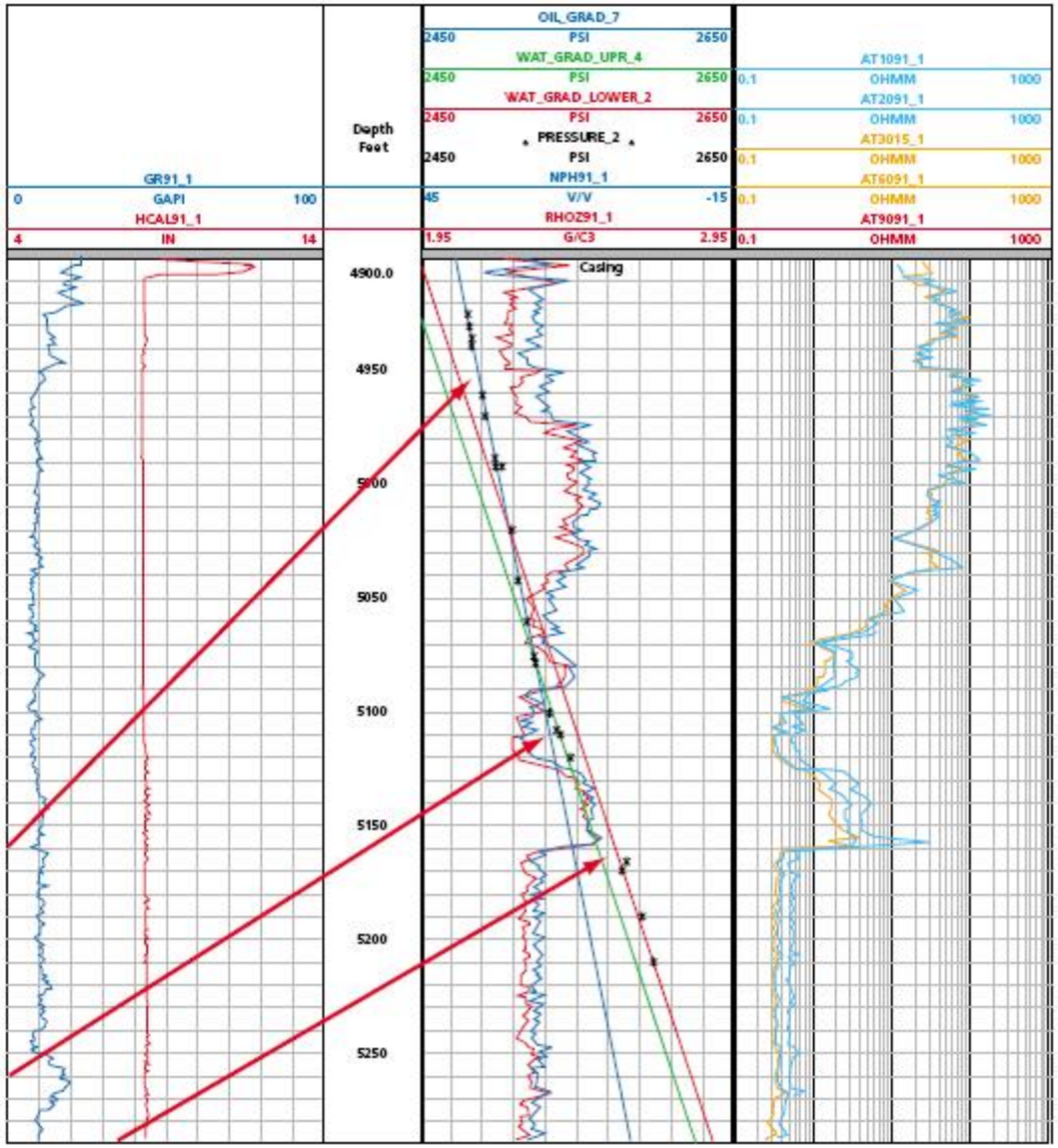
- ***Fluid Gradient*** is that of the ***Mobile Phase***
  - ***Hydrocarbon***, high in the column
  - ***Brine***, low in the zone
- ***Free Water Level*** is datum of zero capillary pressure
- ***Hydrocarbon Below 'FWL' is Immobile*** (note lack of moved oil in log analyses) and Pressure Gradient that of Brine



Fluid Pressures and Continuity

- The upper section is hydrocarbon bearing, as can be seen by the relatively high resistivity, while the lower reservoir is water filled.
- ***Pressure points*** (black) fall along a gradient that corresponds to ***oil*** (blue) at the top of the well and along ***water gradients*** (***green*** and ***red***) at the bottom.
- ***Simple enough, oil over water, but why don't all the water points fall along the same line?***
- *Exhibit following*

Figure 8



Pre-production Profile

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

Fluid Pressures and Continuity

- *The lower-quality rock from 5,120 to 5,160 feet constitutes a barrier*
  - The water above and below has the same density (gradient), but the lower zone is offset to a higher pressure.
  - *Pressure maintenance injection, into the lower interval, will not be effective in the hydrocarbon column.*
  - Furthermore, this barrier *may extend up into the hydrocarbon column, and thereby additionally impact primary depletion*
- *These barriers may, or may not, be apparent at routine wireline log resolution*

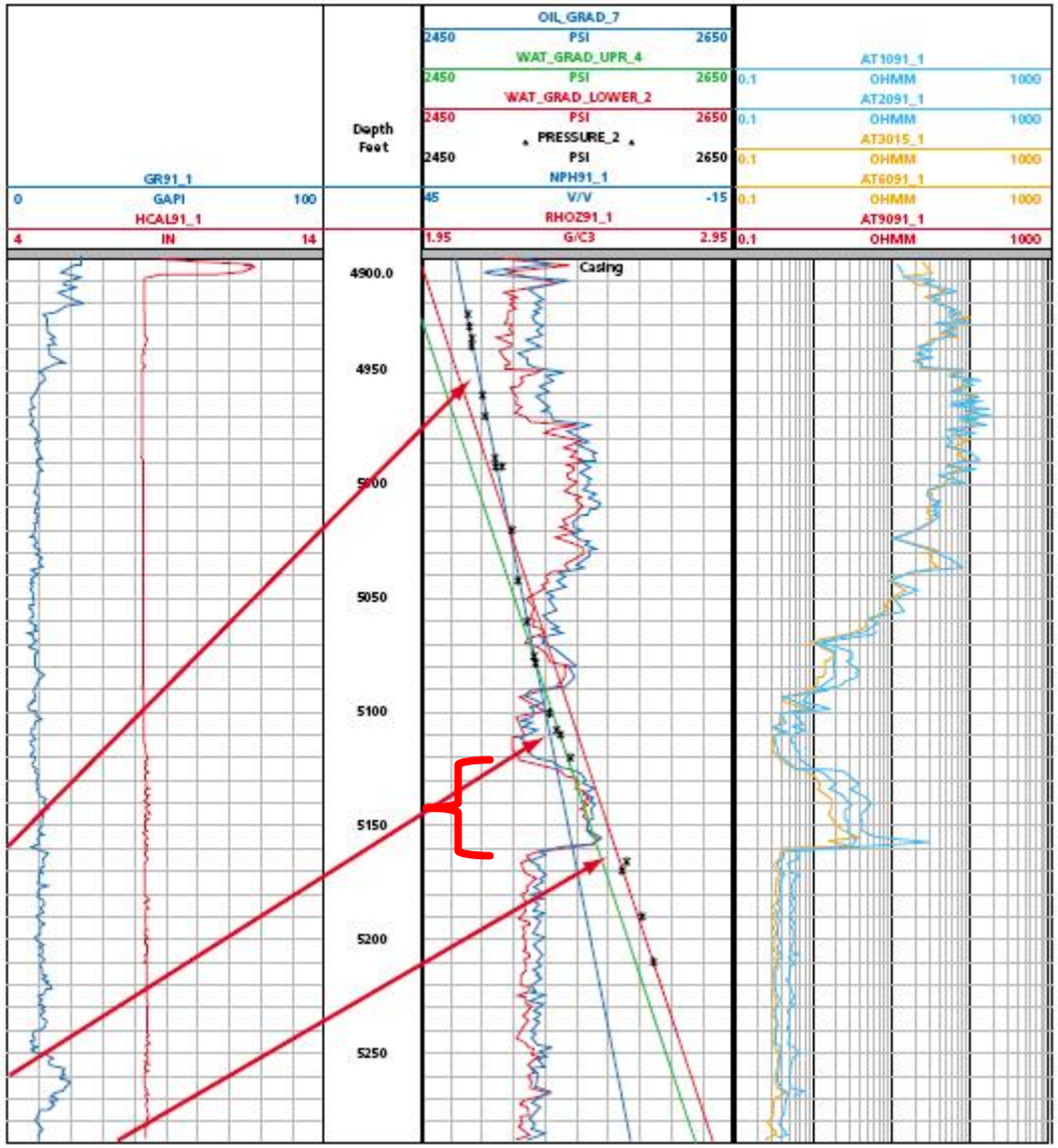


Figure 9

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

Discontinuous Pressure Profile

- Deviations from profile are not always fluid related
- Deepest Formation Pressure *(6a)* Above Expected Gradient
- ***Local Experience*** Infers ***Super-charging*** is ***unlikely***
  - *Exhibit following*
- ***Thin Stylolite*** is providing an Effective Permeability Barrier

Figure 10