

**An Exercise On
Gas Correction For Bulk Density
And Neutron Porosity Logs**

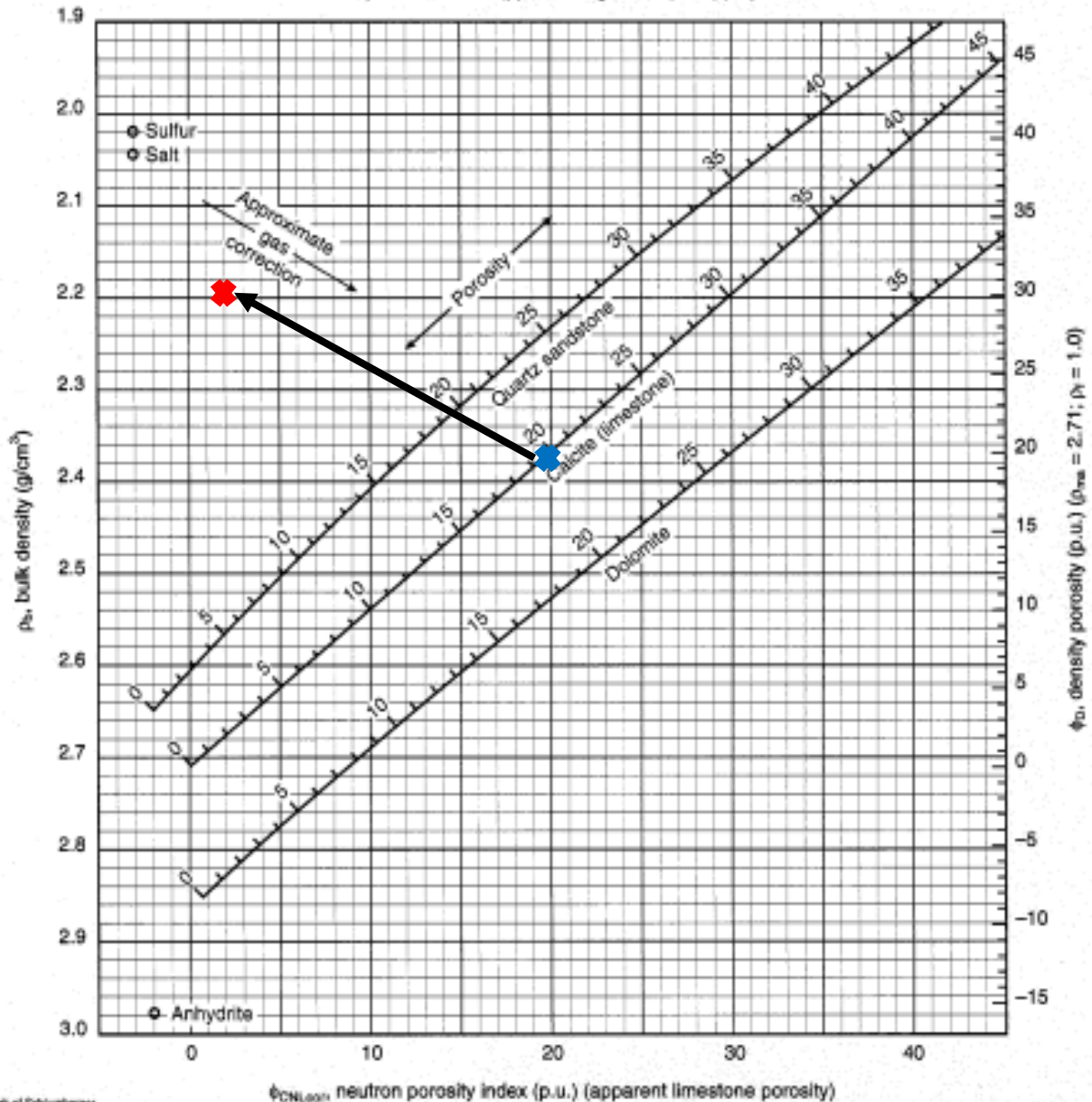
By

**Ko Ko Kyi
Retired Principal Petrophysicist**

Porosity and Lithology Determination from Litho-Density* Log and CNL* Compensated Neutron Log

For CNL curves after 1986 labeled TNPH

Liquid-filled holes ($\rho_f = 1.000 \text{ g/cm}^3$; $C_f = 0 \text{ ppm}$)



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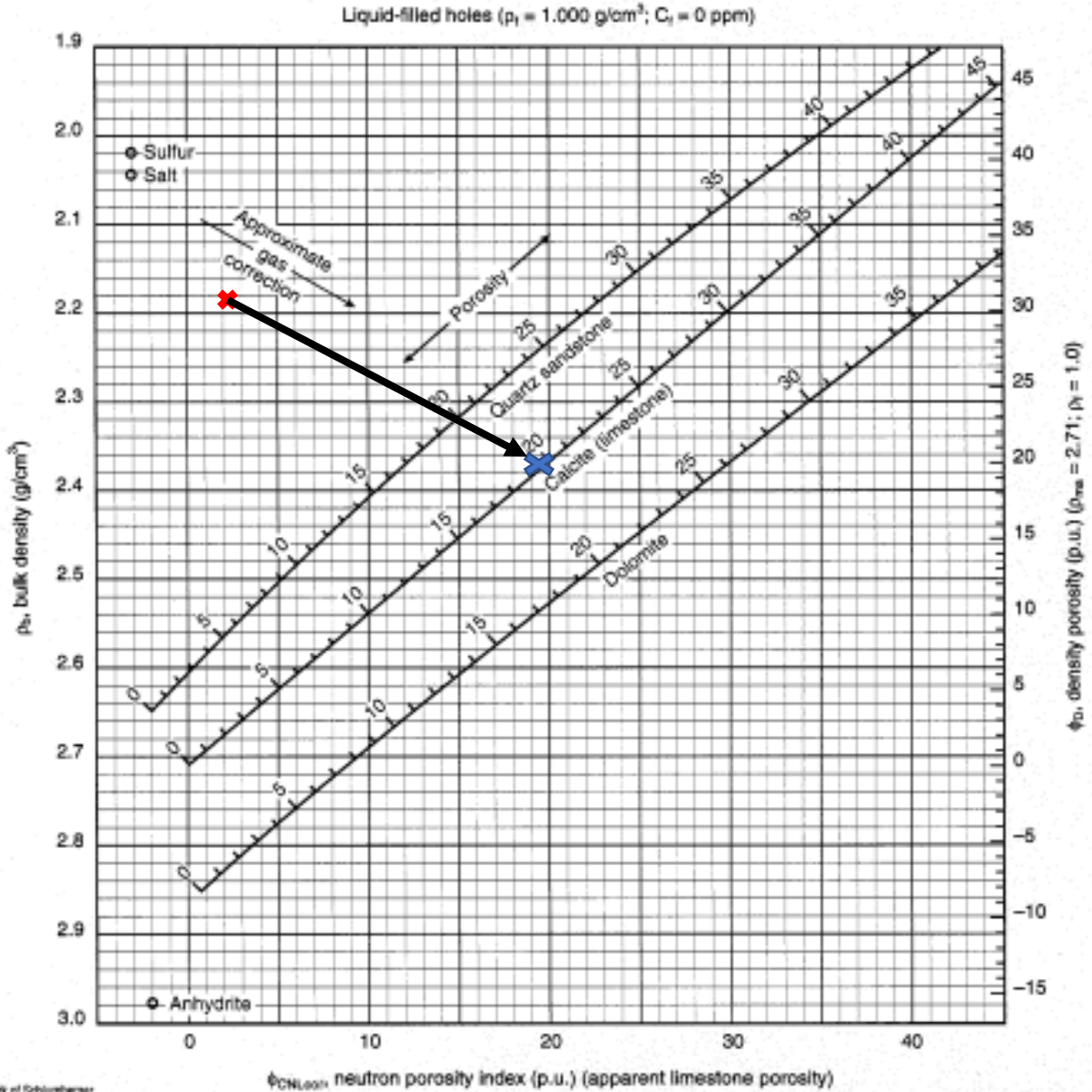
Gas Effect on Neutron Porosity and Bulk Density Logs

Initially: Clean water bearing (100% water) Limestone with 20% porosity
 Original data point (Blue): $N\phi_i = 20\%$ and $R_{\text{hob}} = 2.37 \text{ g/cc}$
 After filling up the 20% porosity totally (100%) with gas having density of 0.1 g/cc and Gas $N\phi_i$ 10%
 The data point (Red) moves to $N\phi_i = 2\%$ and $R_{\text{hob}} = 2.19 \text{ g/cc}$
 because of gas effect on the neutron porosity and bulk density logs.

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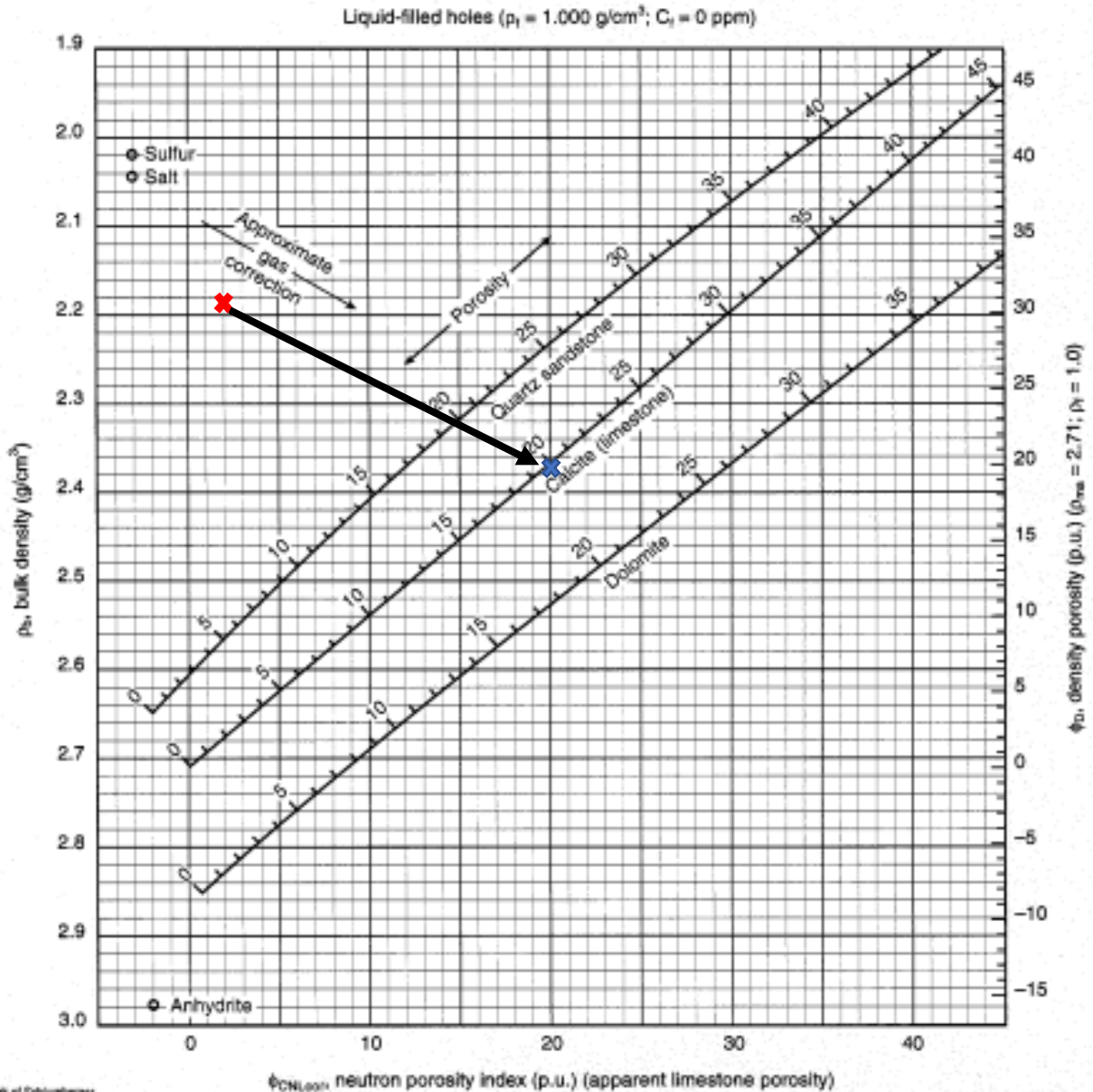


Correction for Gas Effect on Neutron Porosity and Bulk Density Logs

A gas bearing formation will have low bulk density leading to high apparent porosity, based on the density log, due to low density of the gas and a very low porosity, based on neutron porosity log, due to low hydrogen index of gas. Both the bulk density log and neutron porosity log need to be corrected for gas effect to bring the data point back to the original 100% water bearing condition,

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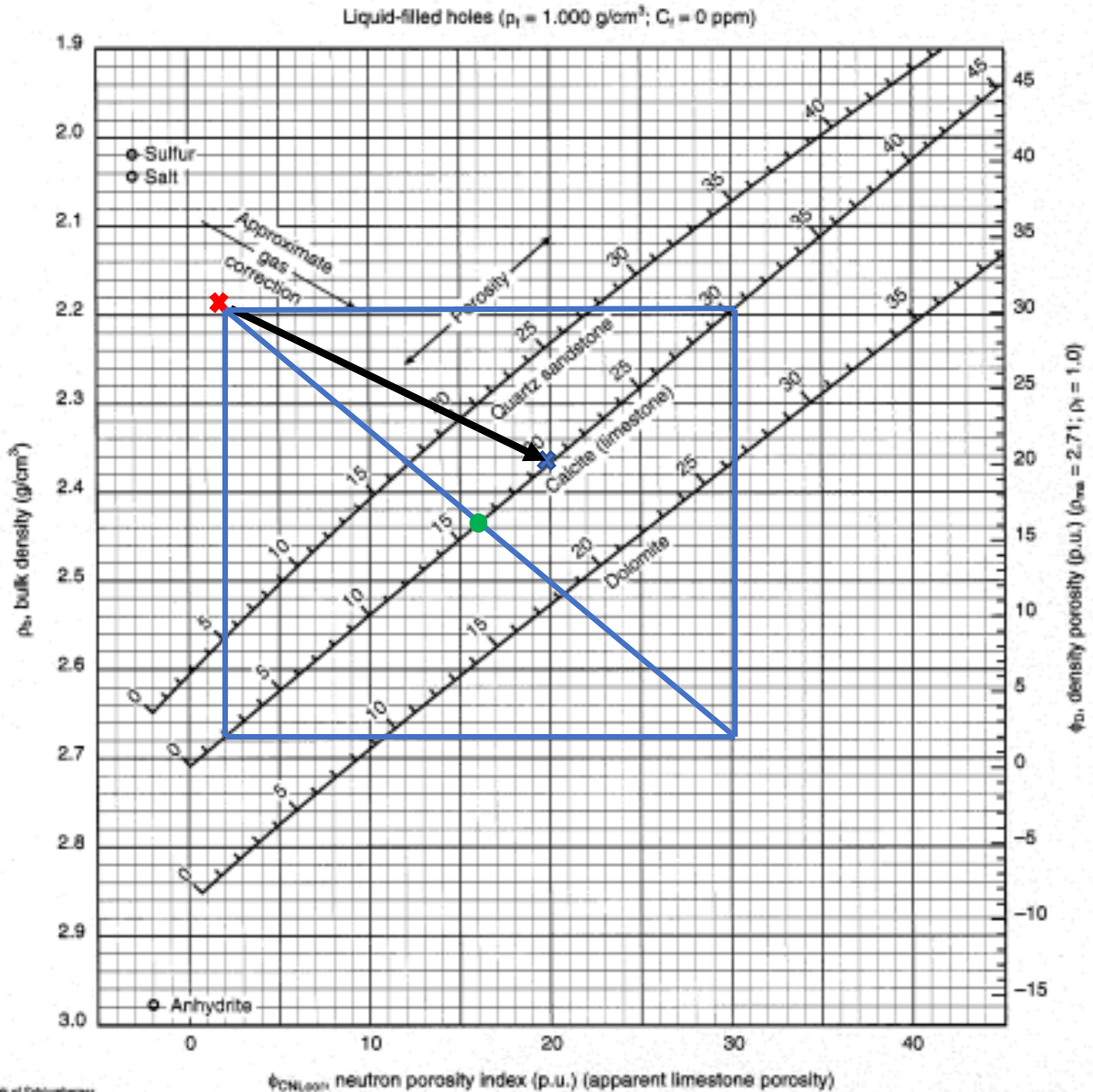
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Correction for Gas Effect on Neutron Porosity and Bulk Density Logs

- It is relatively easy to bring back the gas bearing point to its original water bearing point provided the gas properties and gas saturation are known.
- In most cases these information are not readily available.
- Some other methods need to be used to correct the porosity for the gas effect.

Porosity and Lithology Determination from Litho-Density* Log and CNL* Compensated Neutron Log

For CNL curves after 1986 labeled TNPH



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Correction for Gas Effect on Neutron Porosity and Bulk Density Logs

- One possible approximate graphical method is shown above.
- Draw a horizontal line from the gas point at 2.19 g/cc density, intersecting the limestone (calcite) matrix line. Draw a vertical line from the gas point at 2% Nphi, intersecting the limestone matrix line. Complete the rectangle as shown.
- Draw a diagonal line from the gas point to the opposite corner of the rectangle.
- The diagonal line intersects the limestone matrix line at a gas-corrected porosity of 16% (Green dot). This value is 4% lower than original 20% porosity of the limestone.

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Averaging Methods for Gas Correction

Initial conditions: Clean (clay free), water bearing limestone with 20% porosity. Data point: $N_{phi} = 20\%$ and $R_{hob} = 2.37 \text{ g/cc}$

After completely filling up the 20% porosity with gas of density 0.1 g/cc and N_{phi} (gas) of 10%, the water point (Blue) has moved to gas point (Red) with values of $N_{phi} = 2\%$ and $R_{hob} = 2.19 \text{ g/cc}$

If gas correction is NOT performed on these values, the apparent porosity computed will be wrong.

Porosity from Density log, $D_{phi} = (R_{hom} - R_{hob}) / (R_{hom} - R_{how})$
 $= (2.71 - 2.19) / (2.71 - 1.00) = 0.304 = 30.4\%$ (Too High)

Porosity from $N_{phi} = 2\%$ (Too Low)

Note: If R_{hogas} of 0.1 g/cc is used for fluid density instead of 1 g/cc in computing porosity from bulk density log, the D_{phi} will be more accurate. Unfortunately, the gas density is rarely known in real life situations.

Different Averaging Methods for Gas Correction

Arithmetic Average Method

$$Phit = (D_{phi} + N_{phi}) / 2 = (30.4 + 2) / 2 = 16.2\%$$

Weighted Average (2/3 + 1/3) Method

$$Phit = (2 \times D_{phi} + N_{phi}) / 3 = (2 \times 30.4 + 2) / 3 = 20.9\%$$

Weighted Average (7/9 + 2/9) Method

$$Phit = (7 \times D_{phi} + 2 \times N_{phi}) / 9 = (7 \times 30.4 + 2 \times 2) / 9 = 24.1\%$$

Gaynard's Equation (Root Mean Square Method)

$$Phit = \sqrt{(D_{phi}^2 + N_{phi}^2) / 2} = \sqrt{(30.4^2 + 2^2) / 2} = 21.5\%$$

Note: The (2/3 + 1/3) averaging method gives the closest value to the original porosity of 20%

The iterative method of gas correction, using a suitable computer software, will probably result in better estimate of the porosity.

Comparison of Results

Method	Result	Remarks
Initial condition	Clean, 100% water bearing limestone with 20% porosity P_{hit}	$R_{hob} = 2.37 \text{ g/cc}$ $N_{phi} = 20\% \text{ (LSPU)}$
After saturating 100% with gas of 0.1 g/cc and $N_{phigas} = 10\%$	$R_{hob} = 2.19 \text{ g/cc}$ $N_{phi} = 2\% \text{ (LSPU)}$	$D_{phi} = 30.4\%$ $N_{phi} = 2\% \text{ (LSPU)}$
Approximate graphical gas correction method	$P_{hit} = 16\%$	The corrected porosity is 4% lower than the original porosity of 20%
Arithmetic Average	$P_{hit} = 16.2\%$	Lower than the original porosity of 20%
$(2/3+1/3)$ Average	$P_{hit} = 20.9\%$	Closest to the original porosity of 20%
$(7/9+2/9)$ Average	$P_{hit} = 24.1\%$	Higher than the original porosity of 20%
Gaymard's Average (Root MeanSquare)	$P_{hit} = 21.5\%$	Close to the original porosity of 20%

Note: LSPU = Limestone Porosity Units

Additional Notes

- Although Limestone Matrix was used in the previous exercise, the same procedure for gas correction can be applied to Sandstone (Quartz) or Dolomite Matrix.
- In the exercise, clean water bearing Limestone matrix was used. The 20% porosity was then saturated 100% with gas for demonstration purpose and ease of calculation.
- In real reservoirs, the formation rock will have some shales (or clays) and **cannot** be 100% saturated with gas as in the exercise.
- Shaliness of the rock and partial saturation with gas (e.g. 80% gas and 20% water) will make the exercise much harder to work out by hand.
- In such a case, it will be better to use a suitable software to correct for gas effect on the density and neutron porosity logs iteratively.
- As an approximation, weighted averaging methods can be used to estimate the gas-corrected porosity based on bulk density and neutron porosity logs.
- It should be noted that when calculating weighted averages, both the density derived porosity D_{phi} and the neutron porosity N_{phi} must be in the same rock matrix unit, either limestone, sandstone or dolomite units.
- For sandstone matrix, D_{phi} must be computed using sandstone matrix density of 2.65 g/cc and N_{phi} (which has been recorded in limestone porosity units) must be converted into sandstone porosity units using appropriate correction charts, before doing the weighted average calculations.
- The similar procedure as above is applied in case of pure dolomite formation, using the proper matrix density for dolomite and dolomite matrix conversion for N_{phi} if it was recorded in Limestone Porosity Units.

The End