
Case Study 3 reflects the logging technology available when the well was drilled. At the time, logging tools could be combined in single tool strings in limited ways. The neutron and density tools could be combined, as could the induction and sonic tools. In the U.S. Gulf Coast, the induction-sonic log was the tool string of choice for the first entry in a well on any run, especially in difficult boreholes, because if no other logging data could be acquired, the acquisition of resistivity and porosity at the same time allowed a reasonable evaluation of the formation. Although current technology permits the simultaneous acquisition of more wireline data, the analysis in this exercise is a good example of the approach that can be used in older wells with this limited suite of data, or other similarly limited suites of data. Techniques shown here are very effective in looking for bypassed pay.

Background

Assume that you are assigned to evaluate the logs of a lower Wilcox sandstone in South Texas. A fairly typical Gulf Coast log package was used to document the well. It consists of an induction electric log with an SP log, a sonic log, and an \( R_{wa} \) quick-look curve. The induction electric log has a deep induction curve, IL, to measure resistivity in the uninvaded zone \( (R_w) \), and a short normal (SN) to measure resistivity in the invaded zone \( (R_i) \). The log package was run on a single tool string, and because it required only one run in the well, it saved your company rig time and money. The log is shown as Figure 10.18.

Drilling operations halted at 10,936 ft after penetration of a sandstone. Gas in the drilling mud increased suddenly and by a large amount: 3200 units over background on the chromatograph. In response to this, mud weight was increased from 14.8 lbs/gal to 15.4 lbs/gal, to confine the gas within the formation. When drilling operations were resumed, gas continued to cut the mud; mud weight was 15.4 lbs/gal going into the hole and 15.2 lbs/gal coming out. Also, the mud logger’s chromatograph maintained about 100 units of gas, even when the well was deepened beyond the zone of initial gas show.

Well site information and other pertinent information:

- \( R_w = 0.022 \) ohm-m at \( T_f \) (from other sources)
- Archie parameters: \( a = 0.62; m = 2.15; n = 2.0 \)
- \( R_{mf} = 0.222 \) ohm-m at \( T_f \)
- formation temperature, \( T_f = 260°F \)
- \( \Delta t_{sh} = 116 \mu \text{sec/ft} \)
- surface temperature = 80°F

Recoverable reserves of gas are to be calculated from the gas volumetric equation (Equation 10.11). The following parameters are needed:

- drainage area = 320 acres
- reservoir thickness (to be determined from the calculations)
- porosity (to be determined from the calculations)
- water saturation (to be determined from the calculations)
- recovery factor = 0.6
- bottom hole pressure (estimated) = 8,100 psi
- \( Z \) factor = 1.229
- surface pressure = 15 psi

Your company has purchased a 25% working interest (WI) in the well, which has a net revenue interest (NRI) of 82.5 percent. (Net revenue interest is the total interest of 100% minus royalties, such as an interest granted to a mineral-rights owner.)

Estimated cost of the well is $1,800,000. Use a product price of $1.90 per mcf to find the return your company can expect on its investment.

Useful equations

The only porosity tool at your disposal is the sonic log, so porosity can be calculated either by the Wyllie time-average equation or the Raymer-Hunt-Gardner equation (see Chapter 4). Because of your knowledge of the geology of the area, you decide that the Wyllie time-average equation (Equation 4.3) will yield the better estimate of porosity:

\[
PHIS = \left( \frac{\Delta t_{log} - \Delta t_{ma}}{\Delta t_{\rho} - \Delta t_{ma}} \right) \times \frac{1}{C_p} \tag{10.26}
\]

where:

\[
C_p = \frac{\Delta t_{sh} \times C}{100}
\]