THE STATISTICAL ANALYSES OF SANDSTONE RESERVOIRS -- VAL VERDE BASIN, TEXAS

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Abstract
The statistical analyses of wireline logging data can be used as a guideline to predict the reservoir performance of the Permian and Pennsylvanian sandstone reservoirs in the Val Verde Basin of Southwest Texas. This study shows that the higher the statistical deviation of the logging data associated with the sand, the lower and the more erratic the natural gas production.

Introduction
The sandstone reservoirs producing natural gas in the Val Verde Basin of Texas (Figure 1) are composed of Permian and Pennsylvanian-aged strata (Figure 2). As a standard practice, the wellbores are air-drilled and the decision to complete the well may consider the following guidelines:

1) the presence and quality of gas flares emitted during the drilling of the well, and
2) the quality of the sand as revealed through the well log evaluation process.

The typical open hole logging suite is run without the presence of fluid in the well bore. The standard logging suite is composed of a gamma ray, neutron porosity, density porosity, Pe measurements, and a temperature survey (Figure 3). The better producing sandstone reservoirs normally exhibit these minimum criteria parameters or well log responses,

1) a "clean gamma ray", that is, a gamma ray values in the sandstone reservoirs of less than 60 API units,
2) sufficient porosity, a crossplot of the density and neutron porosities in excess of 8%,
3) a photoelectric value, Pe, of less than 2.5 b.u., and
3) temperature anomalies that show the entry of natural gas from the formation into the wellbore.

The behavior of the density porosity (DPHI), the density correction (DRHO), and the value of the fractional standard deviation (FSD) of DPHI and DHRO show that the well logs that exhibit higher values of these measurements tend to have lower gas production rates.

Methods of analyses
Statistical population -- The logging measurements were selected from a pool of publicly released well logs from the area of interest, the Val Verde Basin of Southwest Texas. The geographical area extends from Edwards County, Texas to Terrell County, Texas. The statistical populations represent sandstone reservoirs from the Wolfcamp, Cisco, Canyon, and Strawn aged formations. The well logs were commercial products of the service companies operating in the area of interest. The well logs represent surveys from air-drilled wellbores and wellbores in which fluid was loaded into the well immediately after drilling to facilitate the logging process. Wellbores that are drilled with conventional mud systems do not exhibit the range of variation in the logging measurements as do the air-drilled wellbores. These conventionally drilled wells were eliminated from the study. The sample population includes only wells drilled in the last five years. The production reports of the monthly cumulative gas production were retrieved through a commercial production reporting service. Production figures represent average monthly rates for a minimum period of three months and in the majority of cases, the preceding calendar year, 1996. In addition, these sandstone reservoirs are hydraulically stimulated to provide the requisite reservoir enhancement.

Density logging tools - The density logging tool measurements are made from a pad mounted device that extends from the tool body to the borehole wall(Figure 4). The density pad contains at least two detectors and a gamma ray source. The near and far detectors measure the electron density of the formation adjacent to the density pad. The electron density is converted to a bulk density(ρb). The bulk density is translated into a density porosity (DPHI) value depending upon the matrix of the formation. The density pad can be affected by the rugosity of the surface of the borehole wall. In the air-drilled well, gas entry from the formation into the wellbore creates rugose hole conditions where the pad may partially lose contact with the borehole wall. If the pad loses contact, the near and far detectors will be reading different count rates. To insure that both detectors respond to the same volume of the formation, a correction is made to the bulk density. This density correction, DRHO, is calculated from the reading of the long spaced detector and the bulk density reading. Borehole rugosity is reflected by an increase in the DRHO value. It is the ranges of the DPHI and DRHO values that provide the basis for evaluating the gas producibility.

Statistical measurements

Figure 3 shows the "pay zone" of a well drilled in Terrell County, Texas. The well is currently producing 5 mmcf/month. Table 1 shows the statistical summary for the "pay zone" in Figure 3. The arithmetic mean , or **average,** was used to measure the logging responses of the gamma ray, porosity, temperature, Pe, and DRHO values in the zone of interest. The **standard deviation of the mean** was used to measure the dispersion about the arithmetic mean. The **fractional standard deviation** is the ratio of the standard deviation to the mean and shows the percentage of dispersion about the arithmetic mean. This statistical summary was developed for each of the wells in the study. Figure 3 and the associated statistical summary is typical of the responses in the survey. The dispersion relative to the average DPHI and DRHO may be attributed to

1) natural fracturing intersecting the wellbore,
2) gas entering the well bore and causing erratic surface features, or
3) reservoir heterogeneity, i.e. thin shale laminations within the "pay sand".

Conclusions

Activity on the DPHI and DHRO is generally considered a positive attribute in evaluating well logs. The reasoning is that the anomalous activity in the DPHI value is thought to be the result of natural fracture systems that contribute to the conductive flow of hydrocarbons to the wellbore. Figure 1 displays the tectonic activity that has impacted the mechanical properties of these rock strata. It is most plausible that natural fractures would be present in many of the wells in this study. These low matrix permeability sandstone reservoirs require hydraulic fracturing to economically produce. Naturally fractured reservoirs tend to develop multiple hydraulic fractures when stimulated. This results in increased screen-out potential, higher net treating pressures, increased leakoff, loss of fluid efficiency, less confinement, and reduced propped fracture lengths. The net result is poor production performance. In those wells with very little evidence of natural fracturing, fewer multiple hydraulic fractures would be produced. Therefore, the negative consequences of the multiple fracture scenario described above would be mitigated. This results in longer effective frac lengths that exhibit higher production rates. Figure 5 and Figure 6 support this hypothesis. Figure 5 and Figure 6 compare the FSD of DPHI and DRHO to the average production from a one month interval. The graphs show that the greater the statistical dispersion the lower the monthly production rates. That is, the greater the reservoir heterogeneity as reflected by statistical measurements, the greater the probability of poor reservoir performance.

References

Young, Hugh: *Statistical Treatment of Experimental Data,* McGraw-Hill, New York (1962) 172.

Table 1

STATISTICAL SUMMARY

FUNCTION	GAMMA RAY	NPHI	DPHI	TEMP	DRHO
AVERAGE	67 API	7%	21%	148	.26 g/cc
STDEV	14 API	1.5%	6%	2	.08 g/cc
FSD	.22	.21	.28	.014	.30

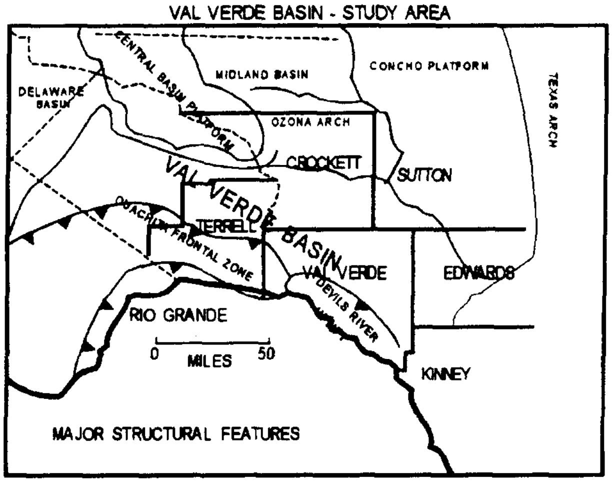

Figure 1 - Location of counties in the Val Verde Basin and *the major structural features affecting the basin.*

SYSTEM	SERIES	STRATIGRAPHIC UNIT
PERMIAN	OCHOAN GUADALUPIAN LEONARDIAN WOLFCAMPIAN	WOLFCAMP
PENNSYLVANIAN		CISCO CANYON STRAWN

Figure 2 - Stratigraphic column of Permian - *Pennsylvanian producing gas reservoirs in the Val* Verde Basin.

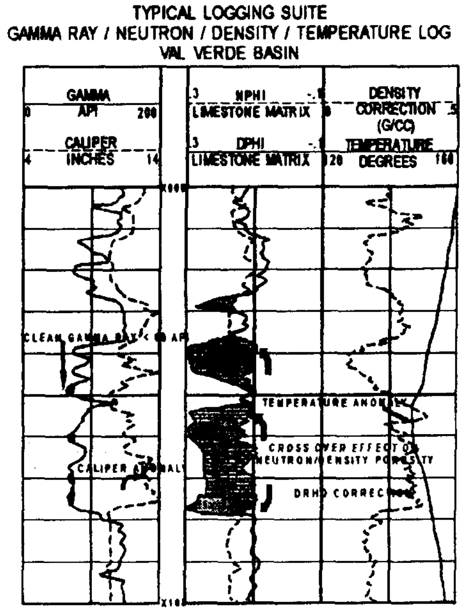

Figure 3 - The logging response in an air drilled well in the Val Verde Basin. The log exhibits the minimum criteria parameters of a "clean" gamma ray, "crossover" effect, porosity greater than 8%, and a temperature anomaly.

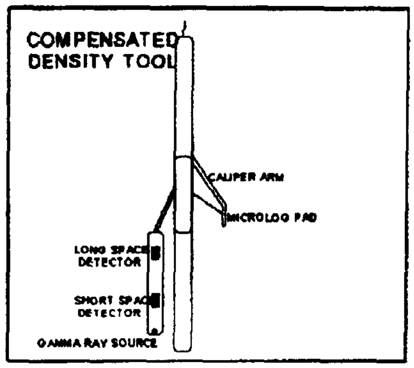

Figure 4 - Compensated density logging tool showing the locations of the short and long space detectors.

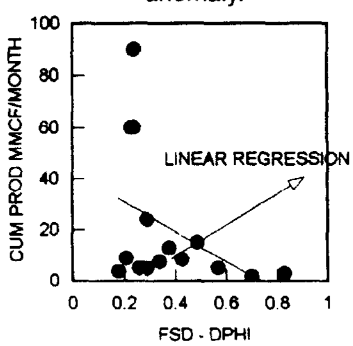

Figure 5

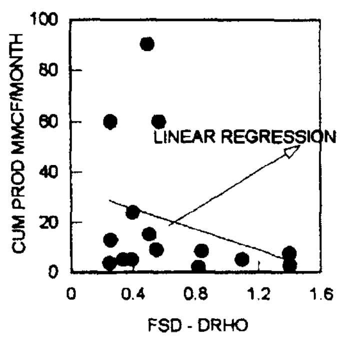

Figure 6