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# Geothermal Gradients in the Delaware-Val Verde Basins of West Texas and Southeast New Mexico †

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## ABSTRACT

There are abnormalities in the temperature vs. depth relationship in the Wolfcamp and older beds of the Delaware - Val Verde Basins of West Texas and Southeast New Mexico. Some major gas-producing areas such as Puckett, Gomez, and Coyanosa have normal subsurface temperature gradients in the deeper beds. Other fields like Toyah, Hershey, and Grey Ranch are "hot spots" with abnormally high gradients. There are also some non-producing high-gradient areas in southeast Eddy County in New Mexico and south Crockett and Val Verde Counties in Texas. Subsurface temperature gradients are a straight-line function to approximately 12,000 ft and then assume a shallow curved line with the gradient increasing with depth. Investigation of 17 wells in one gas field with an average depth of 14,500 ft indicated drilling fluids have little cooling effect and that electric-log temperature surveys represent true bottom-hole temperature.


## INTRODUCTION

With the trend toward deeper drilling, it becomes more important that the oil industry have a better knowledge of subsurface temperatures. This is especially true in the Delaware - Val Verde Basins, where wells are being completed at depths ranging to 23,000 ft and temperatures in excess of 300 F are being encountered. Both the prediction and control of mud and cement properties depend in part upon the knowledge of down-hole temperatures. Accurate temperature prediction is also important in the design of logging and perforating tools. The main goal of this study was to gather all of the temperature data available in the Wolfcamp and older beds of the Delaware - Val Verde Basin area. Using the temperature data collected, gradient maps and curves were constructed. The methods and technique for deriving these exhibits are discussed following.

## DISCUSSION

The first step in collecting and assembling the temperature data was the construction of a base map outlining the generally accepted boundaries of the Delaware - Val Verde Basins. Care was taken not to include wells drilled on the Central Basin Platform, since this is a deep basin study. The geographic description of the basin area by counties was submitted to a computer well-data storage system. The computer retrieval indicated that there were 300 wells drilled below 10,000 ft within the study area. The temperature readings were then taken from electric-log surveys of the wells. An attempt was made to secure temperatures from the various operators who had conducted bottom-hole sampling or pressure surveys, but this was unsuccessful. Fig. 1 represents the usual method of determining the gradient values from surface to total depth. A mean surface temperature of 74 F was used for the upper measurement in each well, and the recorded bottom-hole temperature is the second measurement. A temperature of 74 F was used so as to coincide with work done by previous authors on temperature gradients. Using this method, the formula for calculating the gradient in degrees per 100 ft is:

$$\frac{\textit{Bottom-hole temperature} - 74\ F}{\textit{Total depth}} \times 100$$

Fig. 2 shows the gradient from Wolfcamp to Ellenburger and represents two measured bore-hole temperatures in each well. The upper measurement was taken at depth of the first log run, usually in the Wolfcamp, and the lower from the final log run at total depth in the Ellenburger. The following formula was used to calculate the Wolfcamp to Ellenburger gradient in degrees per 100 ft.

$$\frac{\textit{Bottom-hole temperature} - \textit{up-hole temperature}}{\textit{Total depth} - \textit{depth of up-hole reading}} \times 100$$

After the temperature gradient was calculated for each well, the data were programmed into a computer and the plotter mapped the gradient on a predetermined interval. Approximately 15 percent of the 300 gradients calculated were discarded because values less than 0.50 and greater than 3.00 were considered in error. Both Fig. 1 and Fig. 2 were adjusted manually for contouring irregularities following the computer plot. In comparing the two maps, Fig. 2 shows much greater definition of the temperature gradient "hot spots" in the basin area. Neither map exhibits any abnormalities along the Puckett, Gomez, and Coyanosa gas-producing trend. The highest gradients are in the deeper areas of the basins and the gradient decreases significantly onto the Central Basin Platform. Table 1 shows comparisons of temperature gradients of Wolfcamp and older beds in 12 of the major producing fields of the basin area. The values shown are arithmetic averages.

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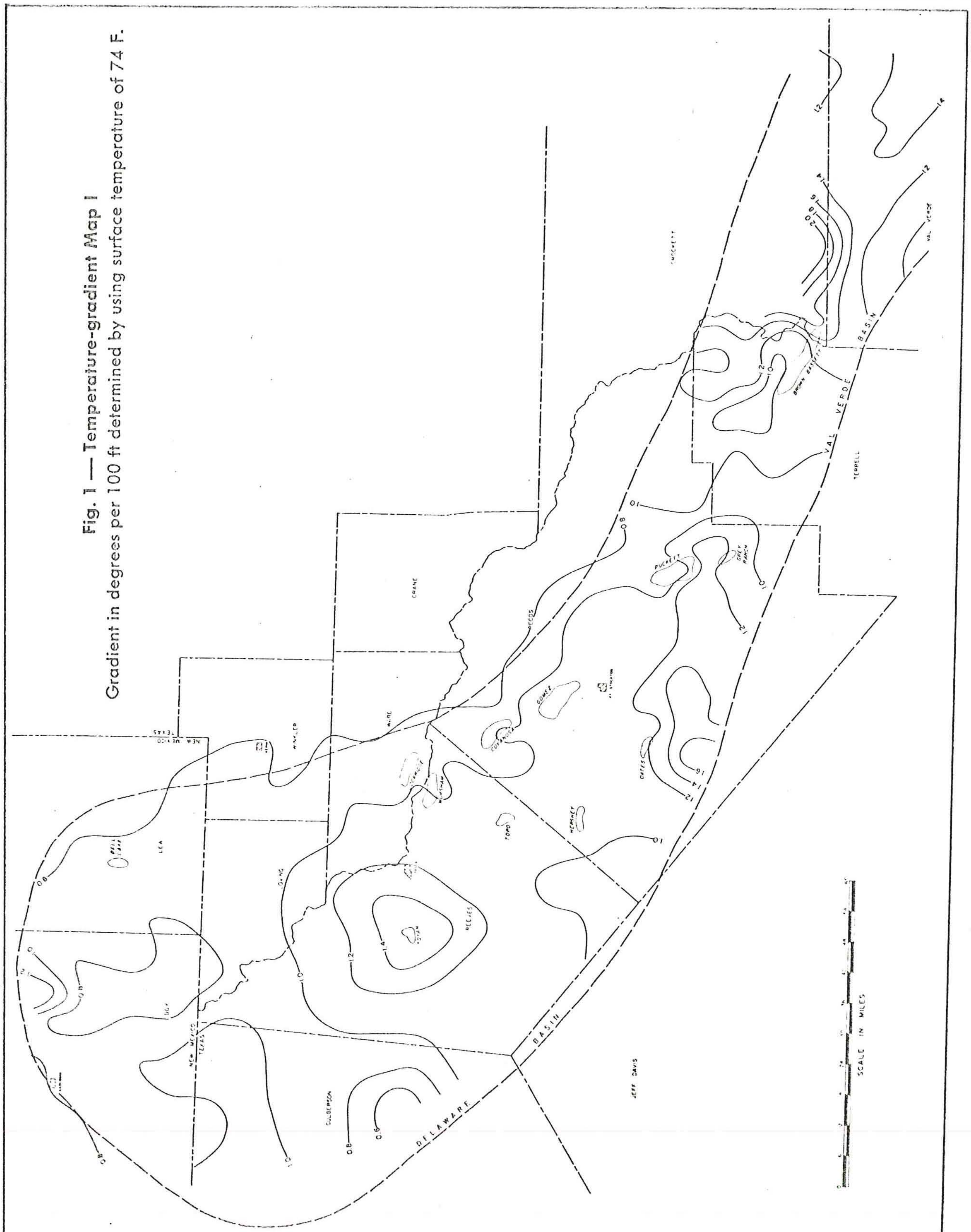


**Fig. 1 — Temperature-gradient Map I**
Gradient in degrees per 100 ft determined by using surface temperature of 74 F.

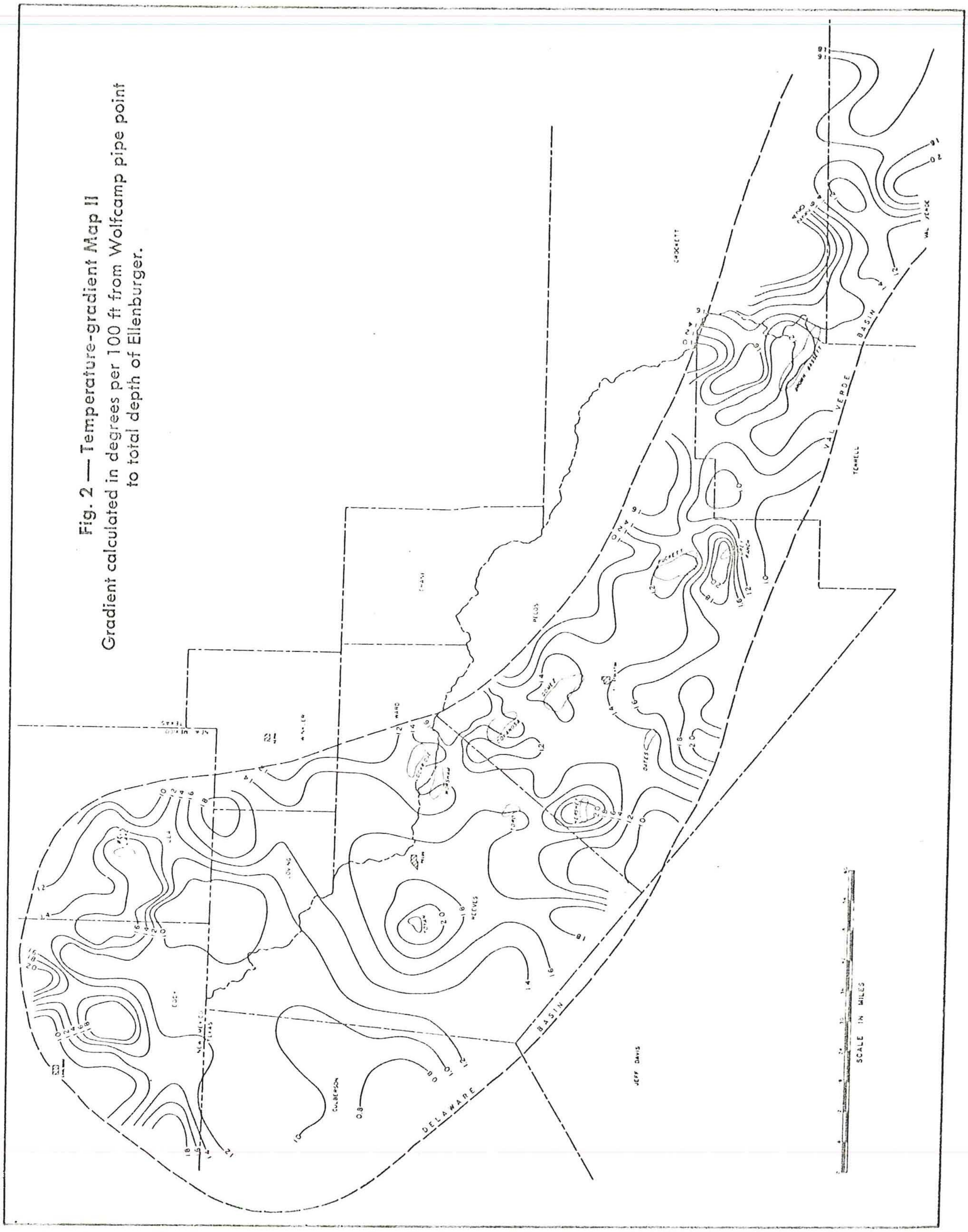


Fig. 2 — Temperature-gradient Map II
Gradient calculated in degrees per 100 ft from Wolfcamp pipe point to total depth of Ellenburger.

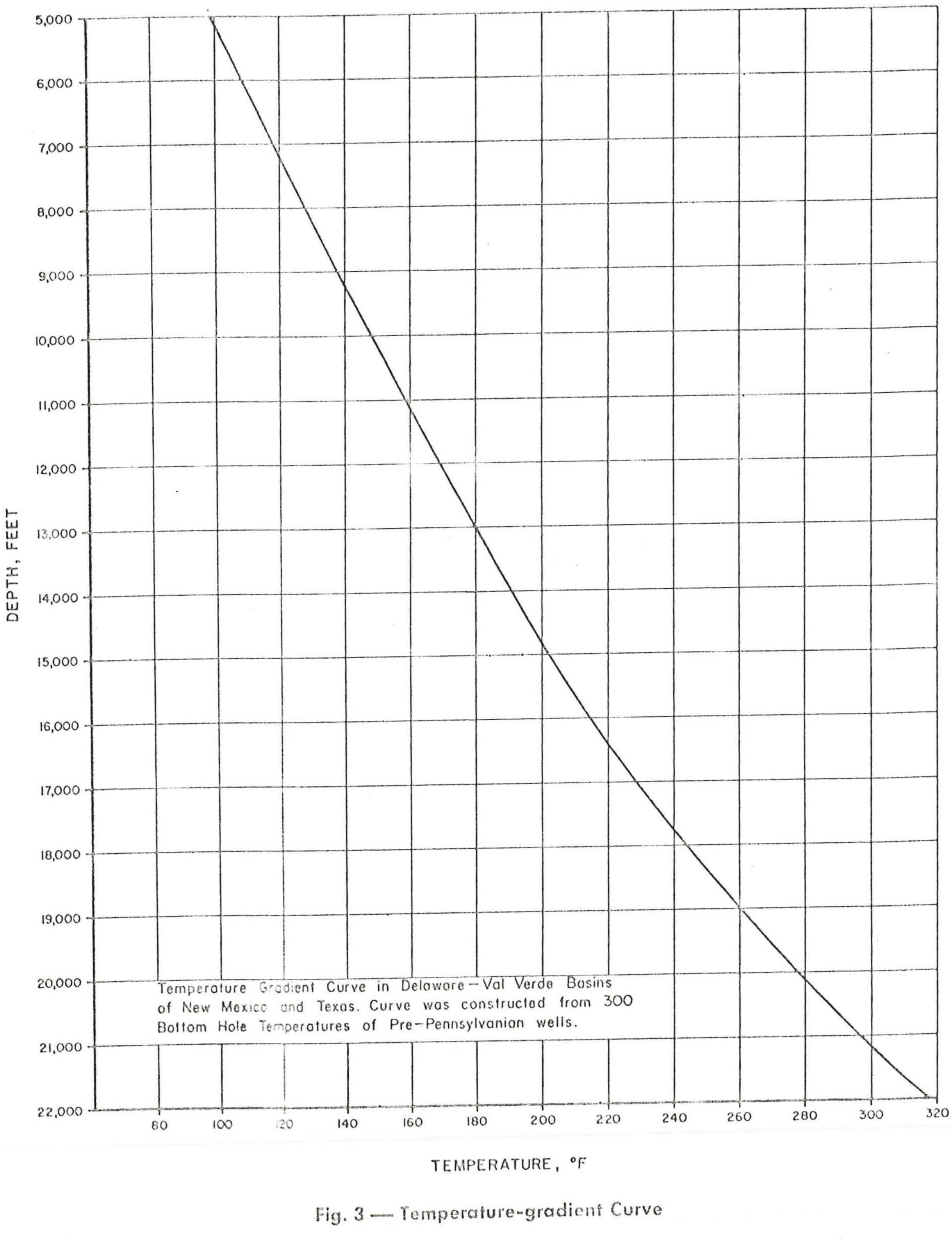


Fig. 3 — Temperature-gradient Curve

**Table 1**

Comparison of Temperature Gradients Related to Wolfcamp and Older Formations in 12 Major Fields of the Delaware — Val Verde Basins

| Field Name | Number of Wells Investigated | Upper Measurement Depth, Ft | Upper Measurement Formation | Lower Measurement Depth, Ft | Lower Measurement Formation | Average Bottom-hole Temperature, Deg F | Average Temperature Gradient |
|---|---|---|---|---|---|---|---|
| Bell Lake | 5 | 12,500 | Penn | 15,500 | Devonian | 206 | 1.6 |
| Brown-Bassett | 8 | 6,300 | Wolfcamp | 15,000 | Ellenburger | 235 | 1.3 |
| Coyanosa | 18 | 10,000 | Wolfcamp | 15,500 | Ellenburger | 221 | 1.4 |
| Gomez | 25 | 10,600 | Wolfcamp | 21,800 | Ellenburger | 314 | 1.4 |
| Grey Ranch | 5 | 10,400 | Wolfcamp | 15,300 | Ellenburger | 265 | 2.2 |
| Hershey | 4 | 13,300 | Wolfcamp | 16,500 | Simpson | 259 | 2.1 |
| Lockridge | 10 | 11,300 | Wolfcamp | 20,000 | Ellenburger | 268 | 1.3 |
| Oates | 8 | 10,000 | Wolfcamp | 16,800 | Devonian | 263 | 1.3 |
| Puckett | 20 | 7,100 | Wolfcamp | 14,400 | Ellenburger | 213 | 1.2 |
| Toro | 7 | 13,300 | Wolfcamp | 20,500 | Ellenburger | 289 | 1.6 |
| Toyah | 5 | 5,400 | Delaware | 12,800 | Devonian | 282 | 2.1 |
| Worsham | 8 | 10,500 | Wolfcamp | 17,300 | Ellenburger | 203 | 1.3 |

The temperature-gradient curve presented in Fig. 3 represents 300 temperature control points taken between 5,000 ft and 22,000 ft. The minimum temperature plotted was 98 F and the maximum 320 F. The curve shows a straight-line gradient of 1.0 deg per 100 ft down to an approximate depth of 12,000 ft. At this depth it becomes a curved line down to the maximum depth shown of 22,000 ft. There were 77 wells in which the gradient was calculated between 10,000 and 15,000 and the average was found to be 1.3 degrees per 100 ft; 100 wells between 15,000 and 20,000 ft showed an average gradient of 1.4 deg and 60 wells below 20,000 ft showed an average of 1.6 deg.

It has been widely believed that temperatures measured in wells during or soon after circulation of drilling fluids are not necessarily true formation temperatures. A correction factor, varied with depth, is applied to adjust for the cooling of the formation by the drilling fluids. Table 2 shows the comparison of electric-log temperatures with temperatures recorded from bottom-hole pressure surveys in the Puckett Ellenburger Field. Available surveys on 17 wells, with an average total depth of 14,500 ft, showed temperature values remarkably similar using the two recording methods and with an elapsed period between surveys exceeding 30 days.

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**Table 2**

Comparison of Electric-log Temperatures With Temperatures Recorded from Bottom-hole Pressure Survey in Puckett Ellenburger Field, Pecos County, Texas

| Well Name | Date | Total Depth, Ft | Electric-Log Temperature Survey, Deg F | Date | Depth, Ft | Temperature from BHP Survey, Deg F |
|---|---|---|---|---|---|---|
| Evelyn Jo #1 | 9-19-54 | 13,472 | 196 | 11- 2-54 | 13,418 | 195 |
| Fisher Bonsack #1 | 4-29-54 | 14,428 | 200 | 5-24-54 | 14,403 | 204 |
| Glenna #1 | 4-30-52 | 14,525 | 225 | 7-26-54 | 14,490 | 226 |
| Glenna #2 | 12-11-54 | 14,516 | 318 | 1- 5-55 | 14,446 | 204 |
| Odom "A" #1 | 11- 7-53 | 15,307 | 225 | 12-15-53 | 14,942 | 200 |
| Odom "C" #1 | 5-23-54 | 14,760 | 305 | 7- 2-54 | 14,665 | 207 |
| Odom "D" #1 | 8-24-54 | 15,275 | 251 | 10-21-54 | 14,870 | 208 |
| Odom "D" #2 | 4-20-61 | 15,112 | 223 | 5-11-61 | 15,033 | 222 |
| Odom "E" #1 | 6- 3-58 | 14,307 | 212 | 9-29-58 | 14,762 | 207 |
| Puckett "C" #1 | 5- 3-53 | 14,923 | 208 | 7-26-54 | 14,518 | 199 |
| Puckett "D" #1 | 4-25-53 | 14,327 | 200 | 5-16-53 | 14,310 | 260 |
| Puckett "E" #1 | 3-25-53 | 15,075 | 210 | 7-26-54 | 14,775 | 201 |
| Puckett "K" #1 | 3-24-54 | 13,780 | 198 | 7-26-54 | 13,674 | 197 |
| Pucket "L" #1 | 11-21-54 | 14,777 | 205 | 1- 4-55 | 14,708 | 206 |
| Robbins "A" #1 | 3-25-55 | 12,647 | 190 | 4-28-55 | 13,126 | 192 |
| Rosa "A" #1 | 11-16-58 | 14,829 | 214 | 2-13-59 | 14,784 | 207 |
| Rosa Mitchell #1 | 11-30-57 | 14,404 | 268 | 3-26-58 | 14,357 | 203 |