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# DEEP SUBSURFACE TEMPERATURE STUDIES IN THE BASINS OF NEW MEXICO AND NEIGHBORING GEOLOGIC AREAS

## Precision Continuous Temperature Logging and Comparison with Other Types of Logs

Marshall Reiter
Arthur J. Mansure
Brian K. Peterson

April 1981

MASTER

New Mexico Energy Research and Development Program

## DISCLAIMER

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# DEEP SUBSURFACE TEMPERATURE STUDIES IN THE BASINS OF NEW MEXICO AND NEIGHBORING GEOLOGIC AREAS:

## Precision Continuous Temperature Logging and Comparison with Other Types of Logs

Technical Completion Report
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Principal Investigators:

Marshall Reiter,
Arthur J. Mansure*
and
Brian K. Peterson+

New Mexico Bureau of Mines and Mineral Resources
and Department of Geoscience,
New Mexico Institute of Mining and Technology
Socorro, NM 87801

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*Now at BDM Corporation, Albuquerque, NM
+Now at Atlantic Richfield Company, Anchorage, AK

Abstract

For a variety of well environments, continuous temperature logs at different speeds, taken with appropriate equipment and fast-time-response probes, can yield temperature data often reproducible to several hundreths of a degree centigrade. Larger differences in reproducibility (several tenths of a degree centigrade) probably result from changes in the wellbore. Below the liquid level, the data need not be filtered through the time-response characteristics of the probe to give accurate geothermal gradients (typically ± a few percent) that correlate with lithology. Resulting temperature-gradient logs are qualitatively correlated to other logs, such as induction-conductivity, gamma-ray, seismic, bulk-density, and lithologic logs. The qualitative correlation with the induction-conductivity log appears best. Temperature gradients generally increase when other logs indicate the formation is becoming shaly or clayey (less sandy, silty, or limy), and/or less competent. The practical worth of the temperature-gradient log may be its ability to sense formation properties inside casing and tubing. This characteristic of the temperature-gradient log may allow lithologic identification in shut-in wells and permit useful logging after casing has been set.

## Introduction

Geothermal-gradient measurements may be used for both determinations of heat flow and indications of lithologic changes. Geothermal gradients are determined by continuous or discontinuous temperature logging in wells. The discontinuous method of logging is time consuming; it involves stopping the temperature probe at specific depths (typically 1 to 30 m apart), for a period of time (typically several min.) during which temperature measurements are recorded. The continuous-logging technique involves lowering the temperature probe at a constant speed and recording the temperature in either an analogue or digital mode. Continuous logging reduces field time, allowing deep temperature measurements to be made within a day.

Simmons (1965) has described continous temperature-logging equipment (precision of about .01$^{\circ}$ C) for which the downhole probe is a fast-time-response, unprotected thermistor bead with insulated leads. When it is necessary to protect the thermistor with a stainless-steel housing, the thermal capacity and the time response of the probe are increased. Costain (1970) has shown that, by determining the response time of a probe in a circulating-water bath, it is theoretically possible to inverse-filter measured-temperature data to acquire representative in-situ temperatures. Further theoretical development on the subject has been presented by Conaway (1977). Conaway and Beck (1977) also present temperature data taken in water using the continuous- and discontinuous-logging modes on separate days; these data demonstrate good agreement among geothermal gradients obtained after the inverse-filtering processes.

The time response of the probe and measuring system (i.e., the time required for the system to sense 63% of an imposed instantaneous temperature step) is of fundamental concern in continuous temperature logging. If the time response at the logging speed in the wellbore environment is very small, it is possible to make continuous temperature logs that give reproducibly accurate temperature gradients. It is the essence of this study to demonstrate that, without filtering, temperature measurements may be made over a range of practical logging speeds in a variety of well environments with sufficient precision to yield both gradient data for high quality heat-flow values (± a few percent) and gradient variations that correlate to lithologic variations indicated by other types of commercial logs.

## Equipment Description

The thermistor temperature probe in our logging system is attached to a commercial logging cable, raised and lowered by a hydraulic hoist. The cable is connected by slip rings to a digital measuring and recording system. Grease injection equipment is used to maintain the wellhead pressure gauged prior to logging.

The probe assembly with attached sinking bar has an experimentally determined time constant of approximately two seconds in an ice-water bath, about ten seconds in circulating oil, and about ten minutes in still air. The 100KΩ isocurve thermistor is encased in a cone-shaped stainless-steel housing designed to withstand 20,000 PSI. (Figure 1, right, shows the stainless-steel housing of the probe with thermistor lead wires; figure 1, left, shows the probe molded in viton ready for logging operations.) The probe has great impact strength, allows penetration of drilling mud and grease without clogging, and increases the surface area for better heat transfer. Leads from the thermistor pass through the molded viton connection, which thermally isolates the probe from the cable and sinking bar. This connection forms the water-tight mechanical bond between the cable and the stainless-steel housing. The 2400-m length of 0.556 cm o.d. cable has 4 tefzel insulated conductors of 7.4Ω/100 m.

The measuring and recording unit consists of a microprocessor control device, a 5½ significant-figure DVM, a depth-measuring system, and a thermal printer. The DVM is used in a 4-wire mode to measure the resistance of the thermistor. Constant logging speed is maintained by monitoring an odometer-speedometer system driven by the depth-measuring pulley in the measuring-head assembly. The microprocessor control measures depth by counting the pulses of an optical limit switch operating across a perforated wheel turning with the odometer drive. The microprocessor triggers the DVM at prescribed depth intervals (e.g., 1.52 m) and causes the depth, time, and probe resistance to be printed. When the depth is fixed, the timing circuitry in the microprocessor triggers the DVM at prescribed time intervals.

Temperatures are determined from DVM resistance measurements by linearly interpolating isocurve-thermistor tables listing resistance every 0.56°C. The calculated accuracy of the DVM measurement is about 0.02°C for a 100KΩ isocurve thermistor at temperatures between 0°C and 232°C (including self-heating effects); the stated resolution of the DVM measurement is about .001°C. Accuracy of the DVM 100KΩ-isocurve-thermistor system between 25°C and 150°C was experimentally evaluated at several temperatures in a circulating-oil bath by comparison to a Muller-bridge platinum-probe system. Two different thermistors were used in the study; one agreed with the platinum-probe temperatures to within 0.40°C, the other agreed to within 0.06°C, which is the precision of the comparison. These results were taken into account when comparing temperature logs. The temperature stability of a probe over a year was determined in an ice-water bath to be at least 0.06°C. While the reel was turning, the noise level of the logging system was estimated with the probe in an ice-water bath to be about .001°C. Random noise in the system was reduced by programming the DVM to average ten readings taken over a 1.3-second interval for each recorded measurement.

Data Presentation

In this section unfiltered temperature and temperature-gradient data are presented for the sites at Datil, San Ysidro, Gavilon, and Bluff State (Table 1 presents this data,

Table 2 presents well locations and descriptions). The logged part of the Datil well penetrates a series of ash-flow and ash-fall tuffs; the other wells penetrate a variety of sedimentary sections found in the Colorado Plateau. Datil is a plugged back, unperforated exploration test; San Ysidro and Gavilon are perforated observation wells; and Bluff State is a perforated shut-in oil well. Temperatures and temperature gradients above the liquid level are not compared because the time constant of the probe in air or gas is too large for unfiltered data to be accurate. Discrete temperature measurements made with the single thermistor probe are used to calculate the temperature-gradient logs. Except for the Gavilon log on 14-11-77, the temperature recording interval is 1.52 m. Locations marked on the logs by "CAL" indicate those depths where interruptions in the continous logging (such as equipment calibration) resulted in data-recording gaps. The study presents temperature data gathered from a variety of wellbore environments over a range of practical logging speeds (Table 1).

## Wellbore Temperature Fluctuations

Wellbore temperature fluctuations as a function of time (after stopping the probe) are shown in Figure 2 for several fixed depths. Initial high-amplitude fluctuations observed when stopping the probe are common in most wells and result from interactions between the stationary probe assembly (and sinking bar) and the well fluids. Figure 2 shows an example at Datil. Temperatures measured using the discontinuous-logging technique may be in error because of transient effects if sufficient time is not allowed to record measurements at each depth. After transients have subsided (20 to 30 minutes), fluctuations of several hundreths of a degree centigrade are noticed (Figure 2). These fluctuations are similar in magnitude to those observed by Gretener (1967) and by Diment (1967) but may sometimes occur over intervals as small as 10 seconds (e.g., see Datil at approximately 74.5 minutes).

## Heat-flow Considerations

Heat-flow values are typically made by multiplying temperature gradients over intervals of 5 to 30 m by the corresponding rock thermal conductivity. Figures 3a-3d show temperature-gradient logs for the four wells in the study. These logs were taken on various dates, at different logging speeds, moving both downhole and uphole. Quantitative agreement between the logs is good (Table 1). These logs (especially the downhole logs) yield accurate gradients for heat-flow determinations.

## Comparison of Temperatures

Comparison of temperatures at numerous depths between downhole logs indicates both systematic and non-systematic differences (Table 1). At Datil, systematic temperature differences between logs may result from both depth offsets and probe response. If the 4-3-79 (d) log was 0.6 m deeper than the 26-7-78 (d) log, a systematic difference of .03$^{\circ}$C is expected, assuming a temperature gradient of 50$^{\circ}$C/km. Temperature differences of approximately .013$^{\circ}$C might be expected from different probe response due to different logging speeds. (It can be shown that the temperature lag between two logs is approximately: the velocity difference x the temperature gradient x the time constant of the probe.) Non-systematic errors of about ± .02°C are expected from the observed wellbore temperature fluctuations (Figure 2).

At San Ysidro the temperature differences between logs are smaller than the accuracy of comparison for the two different probes used (±.06°C). This is also the case for the upper part of Gavilon between 920 m and 1418 m. In the lower part of Gavilon, there is a systematic temperature difference between the two logs. Depth offsets of 1 to 2 m will produce temperature differences of .036°C to .072°C if the in-situ gradient is 36°C/km. The time response of the probe is 10 seconds in oil, which would produce a .036°C temperature difference between the two logs. The time response of the probe in the Gavilon well is probably longer than 10 seconds because the oil is gas-cut. Gas-cut oil could produce a greater temperature difference between the two logs and may contribute to the increased variability of the temperature differences. The accuracy of comparing two different probes (±.06°C) may also contribute to temperature differences between logs.

At Bluff State, temperature differences between logs are greatest. The faster log shows consistently higher temperatures at depth which is inconsistent with temperature lag resulting from probe response. Since Bluff State is a shut-in oil well, the large variability of temperature differences between the two logs (especially in the bottom part of the well) suggests a highly viscous, gas-cut fluid, which in the small-diameter tubing could collect around the probe, varying the probe response and causing an uneven rate of descent. Additional contributions to temperature differences between the logs may come about from well liquid conditions changing with time, and from disturbances to fluids as the well is opened to pressure control equipment or as valves are changed immediately before logging.

Temperatures taken during uphole logging are always greater than those taken during downhole logging (Table 1). To some extent this probably results from the warming effect of the cable and sinking-bar assembly preceeding the probe uphole. Near the liquid-gas interface discrepancies of several degrees occur between downhole and uphole logs; these discrepancies can be used to locate liquid levels. Agreement between temperatures of downhole and uphole logs in liquid is generally better than .4°C, except for Datil where agreement is typically better than 1°C. Uphole data provide a check of the reproducibility of the measuring system.

Comparison of Temperature Gradients

Table 1 presents comparisons of temperature gradients between logs for the study sites. Except for Bluff State, there is agreement between downhole gradients of approximately 2% or better for gradients averaged over many 9 m intervals. These average-percentage differences between downhole gradients will be proportionally less if the gradient interval is lengthened, e.g., from 9 m to 30 m. The average-percentage difference between the two downhole gradients at Bluff State is about 6% if 9 m gradient intervals are used.

Agreement of gradients over 9 m-gradient intervals between downhole and uphole logs is also generally better than a few percent. The one exception is Datil from 305 m to 854 m where the gradients have high-amplitude, frequent variations. Small depth offsets between logs in such zones can contribute significantly to temperature-gradient differences compared over 9 m intervals.

Heat-flow estimates are typically made by averaging calculations for many gradient intervals. In clear wells, having fluids of uniform viscosity without blocks, the average of many downhole gradients measured with our system at different logging speeds between 7.6 and 15.2 m/min should contribute less than 1% or 2% error to the heat-flow estimate (Datil, San Ysidro, and Gavilon). In shut-in oil wells (Bluff State), where measurements are being made inside small tubing (∿ 5 cm diameter) that has little clearance for the probe assembly, and in fluids where blocks are to be expected, the average of many gradients might be expected to lend errors to heat-flow estimates of 5% to 6% if 9 m-gradient intervals are used and 2% or 3% if 30 m intervals are used. Uphole gradients at speeds of 30.5 m/min in gradient zones not varying greatly may also be expected to yield average gradients good enough for heat-flow estimates (typically better than a few percent, Table 1).

Comparison of Temperature Logs with Other Types of Logs

The correlation between temperature-gradient logs and other logs results from the interrelation between thermal conductivity and other rock properties. As the formation becomes more shaly or clayey and/or less competent, the thermal conductivity decreases, causing an increase in the temperature gradient. Goss and Combs (1976) have shown that it is possible to correlate thermal conductivity to logs giving rock properties. Beck (1976) has shown that a correlation exists between temperature-gradient logs and electrical-resistivity logs. Data presented in this study show a qualitative correlation between temperature-gradient logs and many other types of logs.

Figure 4a compares gamma-ray, interval-transit-time, and temperature-gradient logs in a section of the Datil well. Depths that correlate between logs are indicated by connecting lines; dashed lines indicate possible correlations. A gamma-ray increase suggests a more shaly (or clayey) formation and correlates with the temperature-gradient log at the indicated depths because of lower thermal conductivity. The interval-transit-time log may be generally related to rock competence; i.e., rocks with greater competence will have a smaller interval-transit time and a higher velocity. The interval-transit-time log correlates with the temperature-gradient log at indicated depths because more competent rocks have higher thermal conductivities. Large amplitude variations in the interval-transit-time and temperature-gradient logs are distinctly correlated over the upper part of the Datil well (Figure 3a).

Figure 4b illustrates sections of the San Ysidro well for comparison of porosity, gamma-ray, bulk-density, spontaneous-potential, resistivity, induction-conductivity logs, and temperature-gradient logs. Double dashed lines indicate zones where log trends are correlated. The line with arrow heads between 650 and 690 m indicates an almost one-to-one correlation between the adjacent logs. Hatchures indicate correlating zones having high or low gradients (hatchures down right indicate high gradients).

Generally the temperature-gradient logs qualitatively correlates best with the induction-conductivity logs. Correlations may be made because an increase in induction conductivity implies a more shaly formation that will have a lower thermal conductivity and therefore a higher temperature gradient. Less pronounced correlations are noted between the temperature-gradient logs and the gamma-ray, bulk-density, spontaneous-potential, and resistivity logs. Analysis of the logs suggests that as the formation becomes less dense or more shaly, the temperature gradient increases; as the formation becomes more dense or less shaly, and perhaps more sandy or limy, the temperature gradient decreases.

Figures 4c and 4d show sections of the Gavilon well comparing temperature-gradient logs with induction-conductivity, resistivity, and spontaneous-potential logs. In the upper depth interval (Figure 4c), the induction-conductivity log correlates with temperature-gradient logs at specific depths and over zones of 5 m to 100 m. In the bottom depth interval (Figure 4d), hatchures indicate zones of correlation between the temperature-gradient logs and the induction-conductivity, resistivity, and spontaneous-potential logs. Generally, as the spontaneous-pontential, resistivity, and induction-conductivity logs indicate shaly (or clayey) zones, the temperature gradient increases; as these logs indicate less shaly (more sandy) zones, the temperature gradient decreases.

Figure 4e and 4f illustrate sections from the Bluff State well comparing temperature-gradient logs and lithologic, spontaneous-potential, resistivity, gamma-ray, and neutron logs. In the upper section the variability in the temperature-gradient log is considerably less than in the lower section because of the relative lithologic uniformity of the upper section. In the lower section the high degree of variability in the temperature-gradient logs results from lithologic variability. The small arrow by the lithologic log indicates a zone of almost one-to-one correlation between the lithologic, gamma-ray, neutron, and temperature-gradient logs. As before, when the neutron, gamma-ray, and electric logs suggest shaly zones the temperature gradient increases; as these other logs suggest less shaly zones (sandstone or limestone) the temperature gradient decreases. The sandstone at approximately 920 m, hatchured vertically on Figure 4f, does not correlate as a unit to a low temperature gradient, although it does contain correlations between logs at specific depths within the zone.

## Summary

Temperature gradients from downhole continuous temperature logs at various logging speeds (7.6 to 15.2 m/min), averaged over many intervals, e.g. 20, 9 m intervals, should generally agree to within 1%-2% if the wellbore is clear and occupied by homogenous liquid. In small diameter shut-in wells, where blocks of high viscosity may be expected, average temperature gradients between downhole logs over many intervals may agree to only 5 or 6 percent. If longer gradient intervals are averaged, (i.e. 20, 30 m intervals) the difference between the average gradients of two logs should decrease. Consequently, errors in heat-flow data resulting from continuous temperature measurements made over a range of logging speeds in a variety of well environments should not exceed a few percent.

In general, our continuous temperature-gradient logs qualitatively correlate best with the induction-conductivity logs. The correlations are shown for a variety of sedimentary sections, in a variety of well environments, at specific depths, and over intervals of 5 m to about 100 m. The induction-conductivity log is thought to penetrate further into the formation than most other logs. The temperature gradient log therefore seems to relate well to true formation properties. This is important because the temperature gradient log may be run inside casing and tubing and therefore may be valuable in the evaluation of shut-in wells. The temperature-gradient log may also be used during field development if the

signature of the temperature-gradient log is known, because the logging can be postponed until after the casing has been set.

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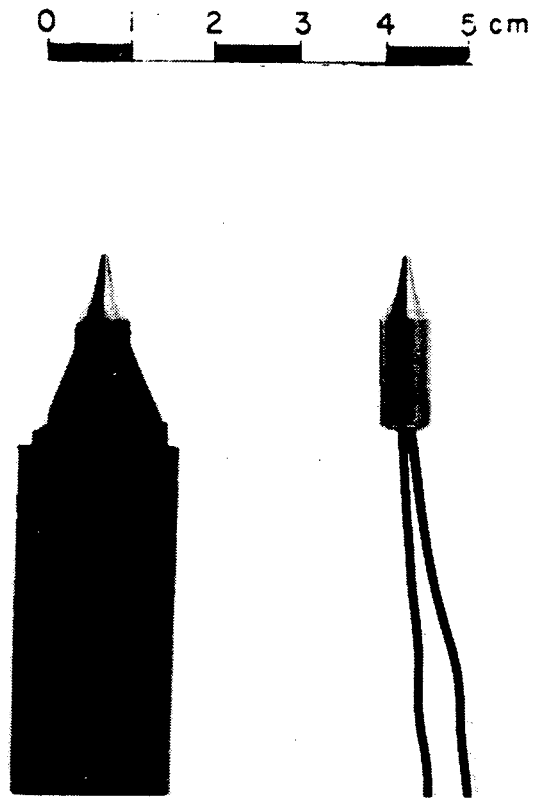


FIG. 1. Temperature probe used in the study.

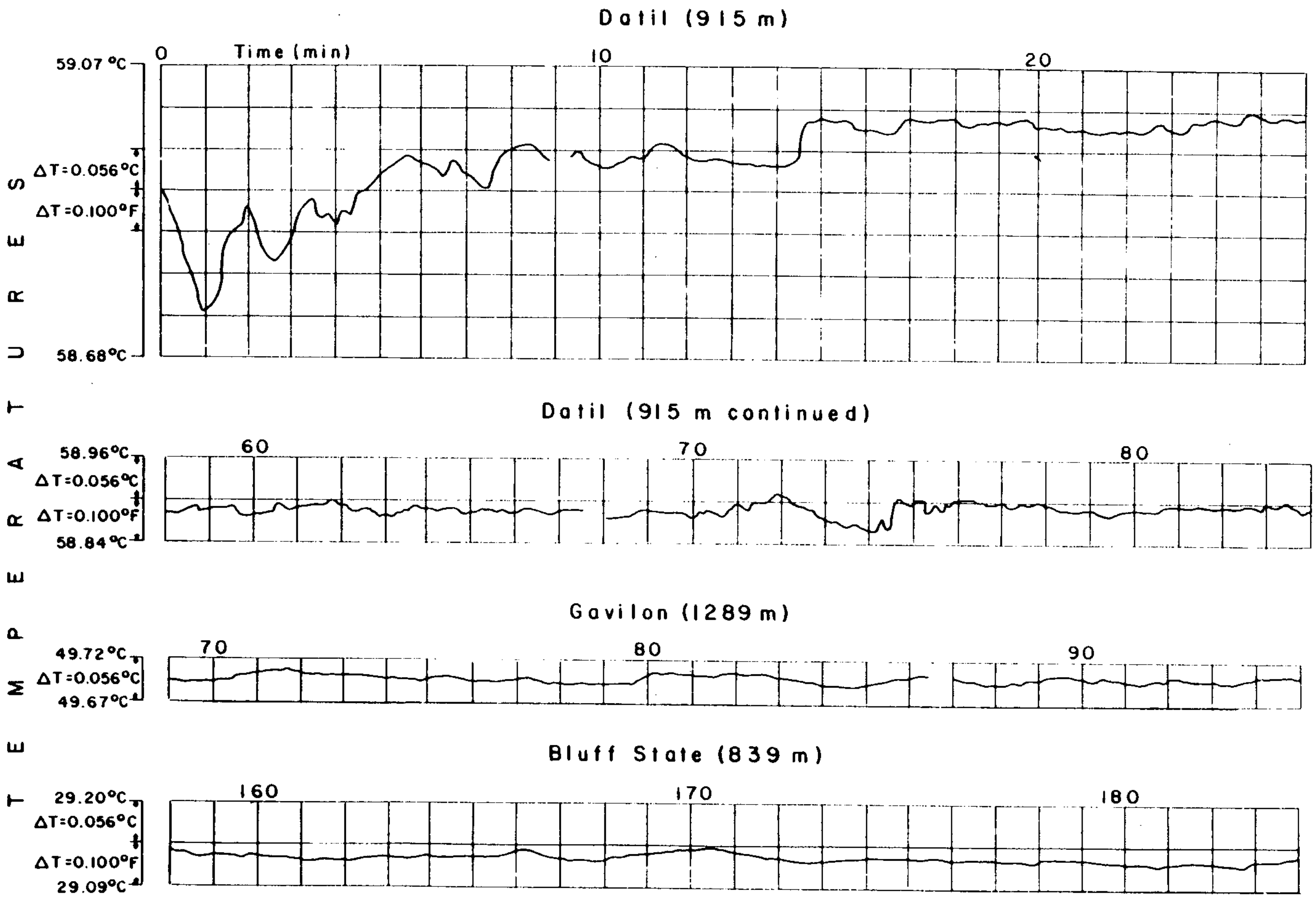


FIG. 2. Temperature fluctuations observed as a function of time at given depth stations in Datil, Gavilon, and Bluff State.

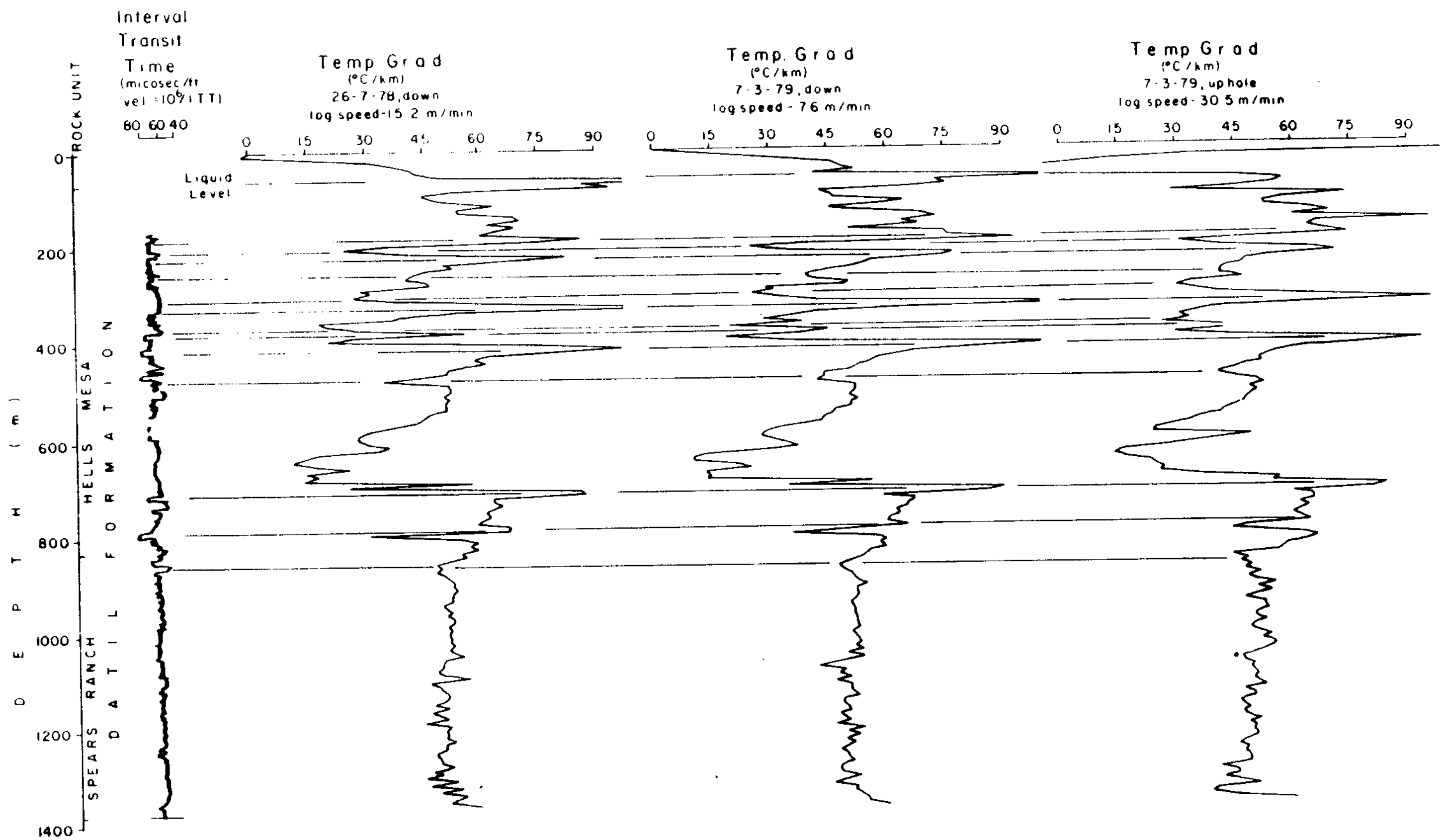


FIG. 3a. Comparison of temperature-gradient logs at Datil. Plotted interval is 7.62 m. Correlations between interval-transit time and temperature-gradient logs at depth are noted by connecting lines.

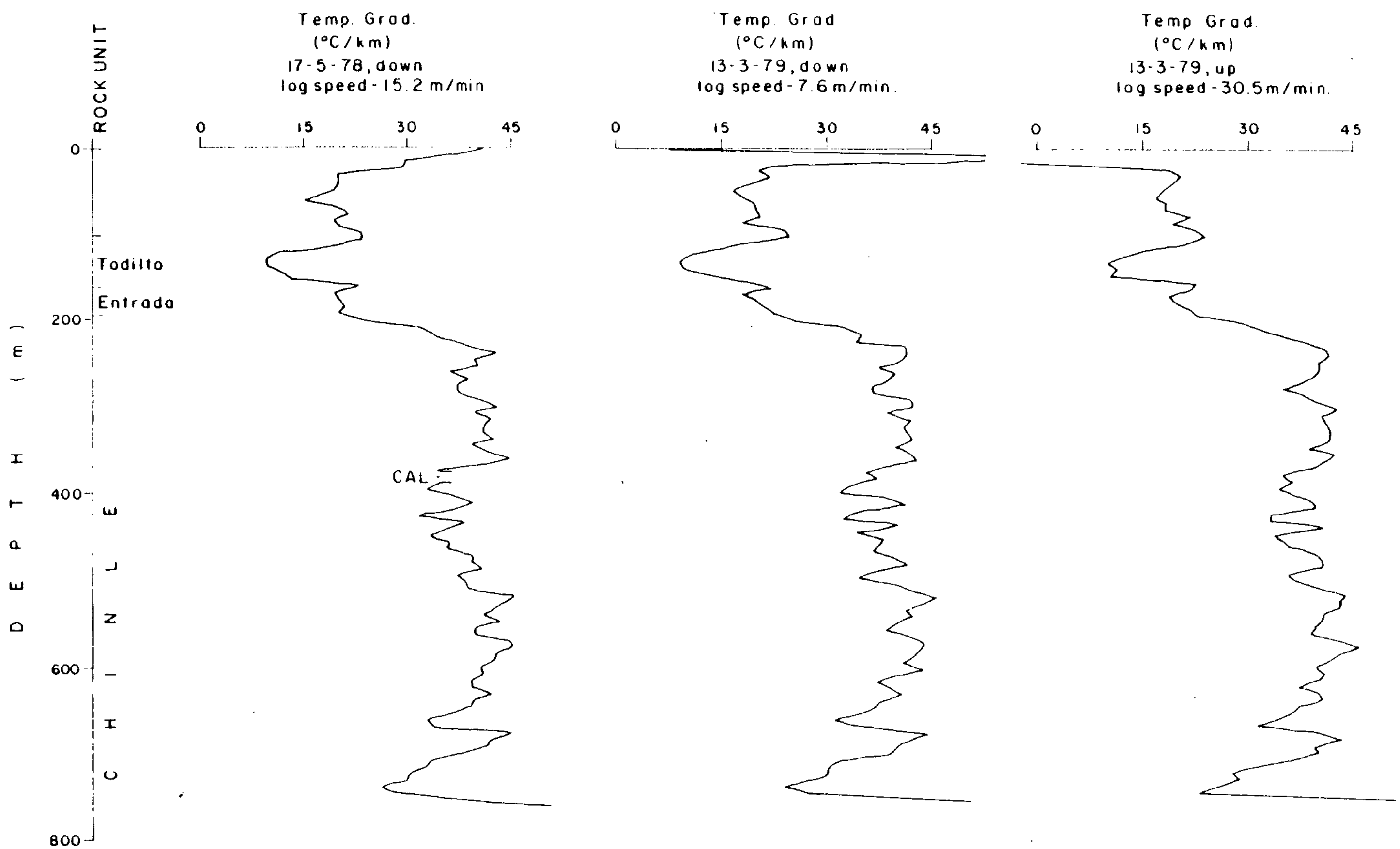


**FIG. 3b. Comparison of temperature-gradient logs at San Ysidro. Plotted interval is 7.62 m.**

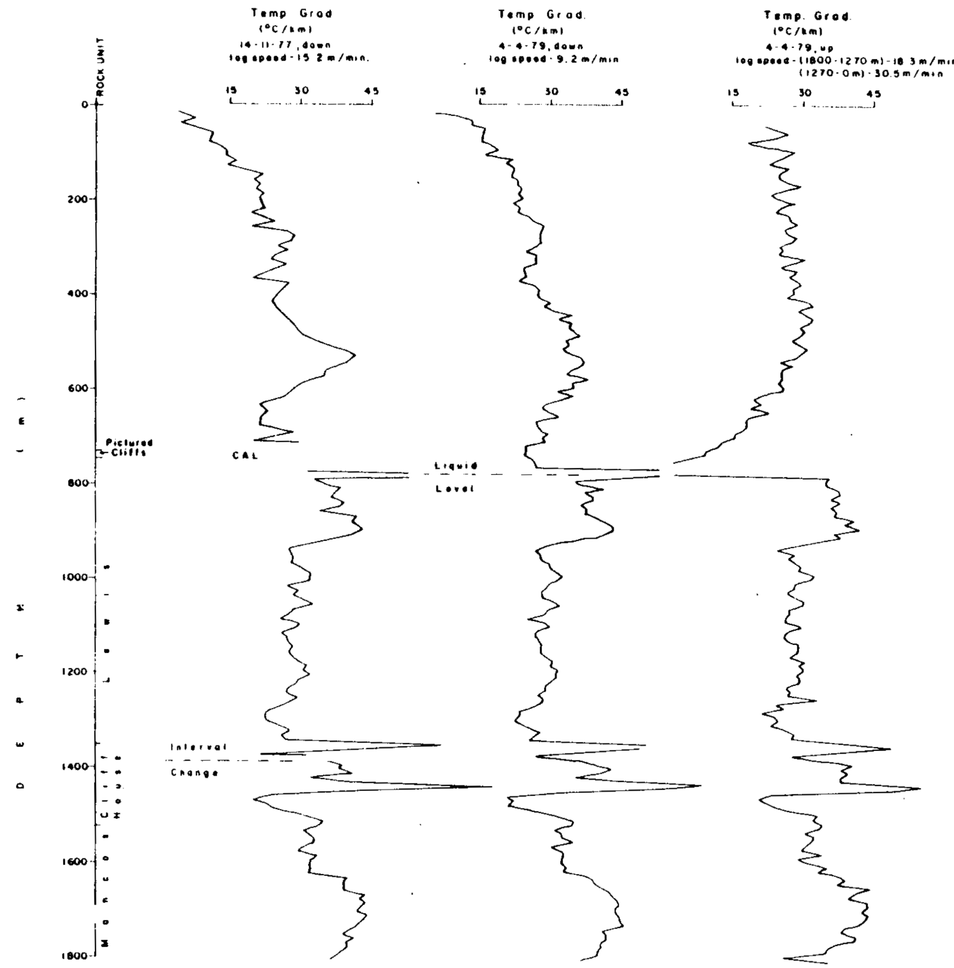


FIG. 3c. Comparison of temperature-gradient logs at Gavilon. Plotted interval is 9.14 m, except 0 to 1400 m on 4-11-77 where plotted interval is 10 m.

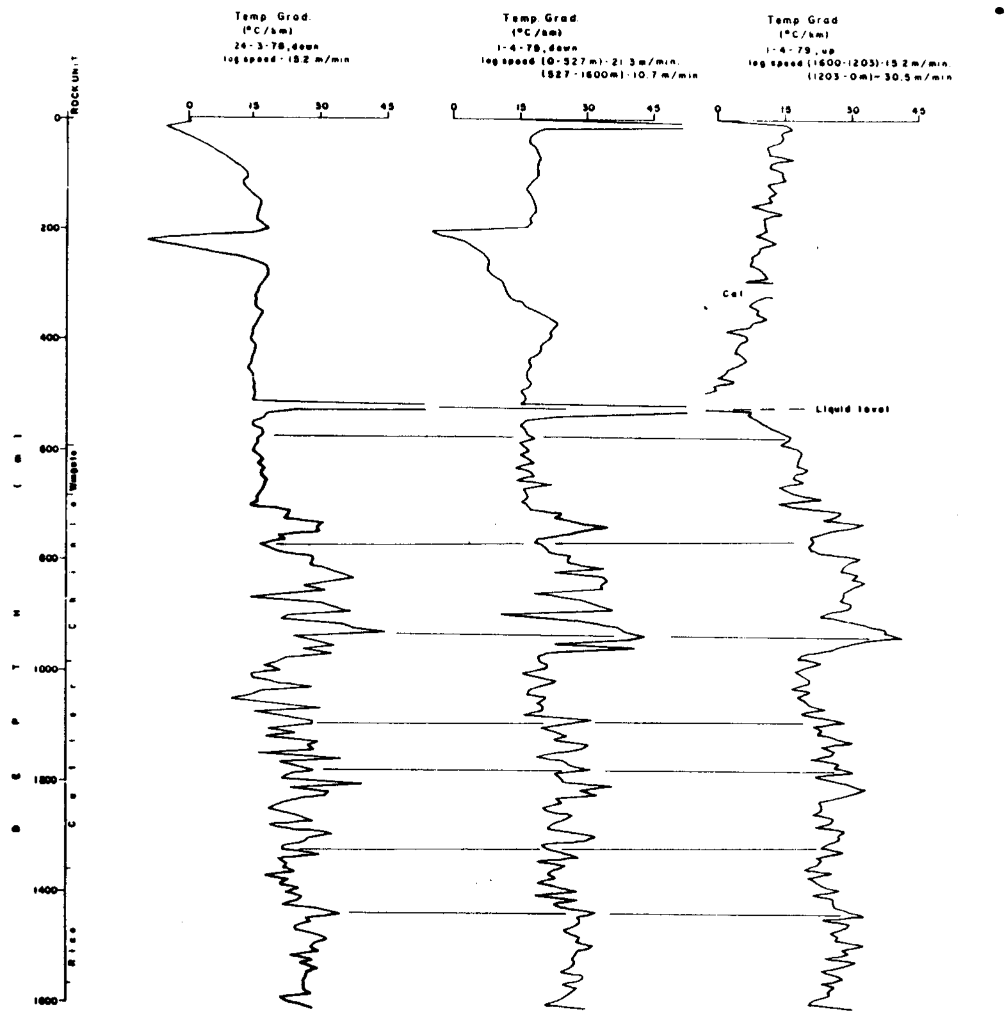


FIG. 3d. Comparison of temperature-gradient logs at Bluff State. Plotted interval is 7.62 m. Correlations between temperature-gradient logs at specific depths are noted by connecting line.

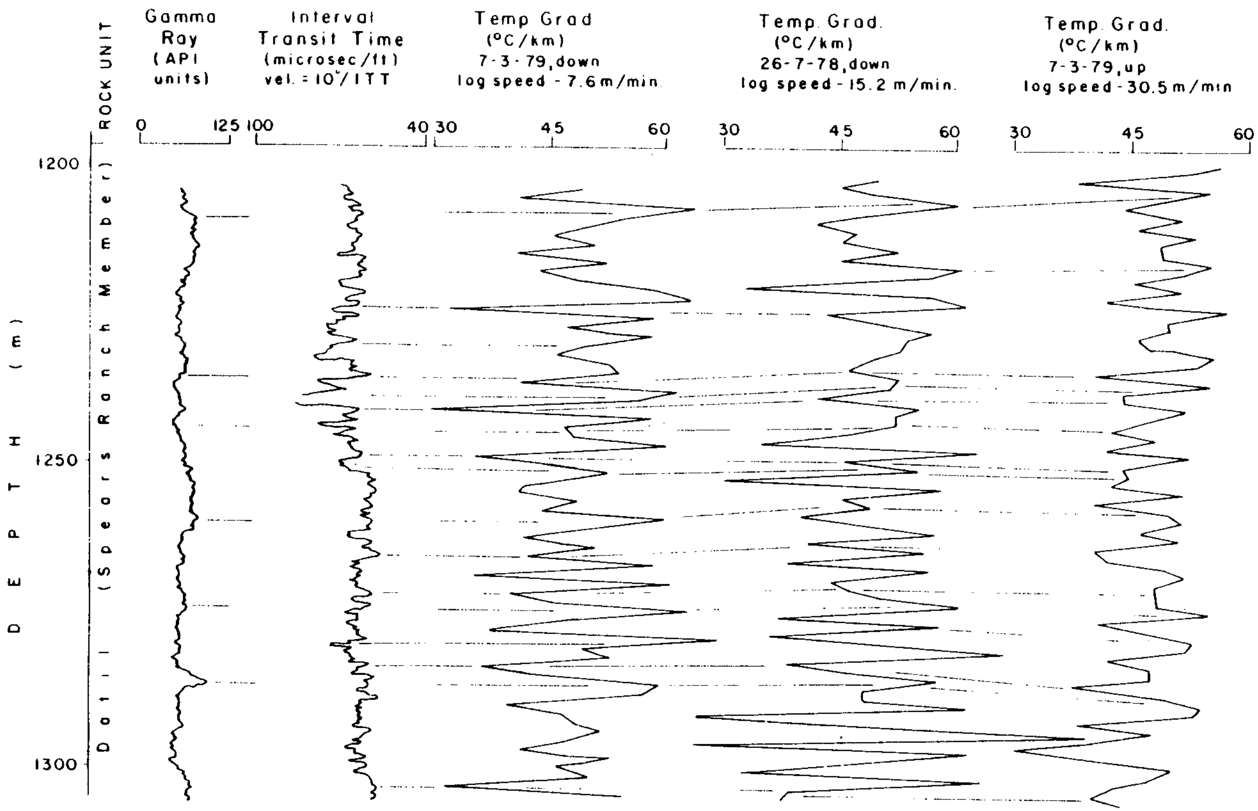


FIG. 4a. Correlation of temperature-gradient log to other logs at Datil. Plotted interval is 1.52 m (same as the data recording interval). Correlations are noted by connecting lines.

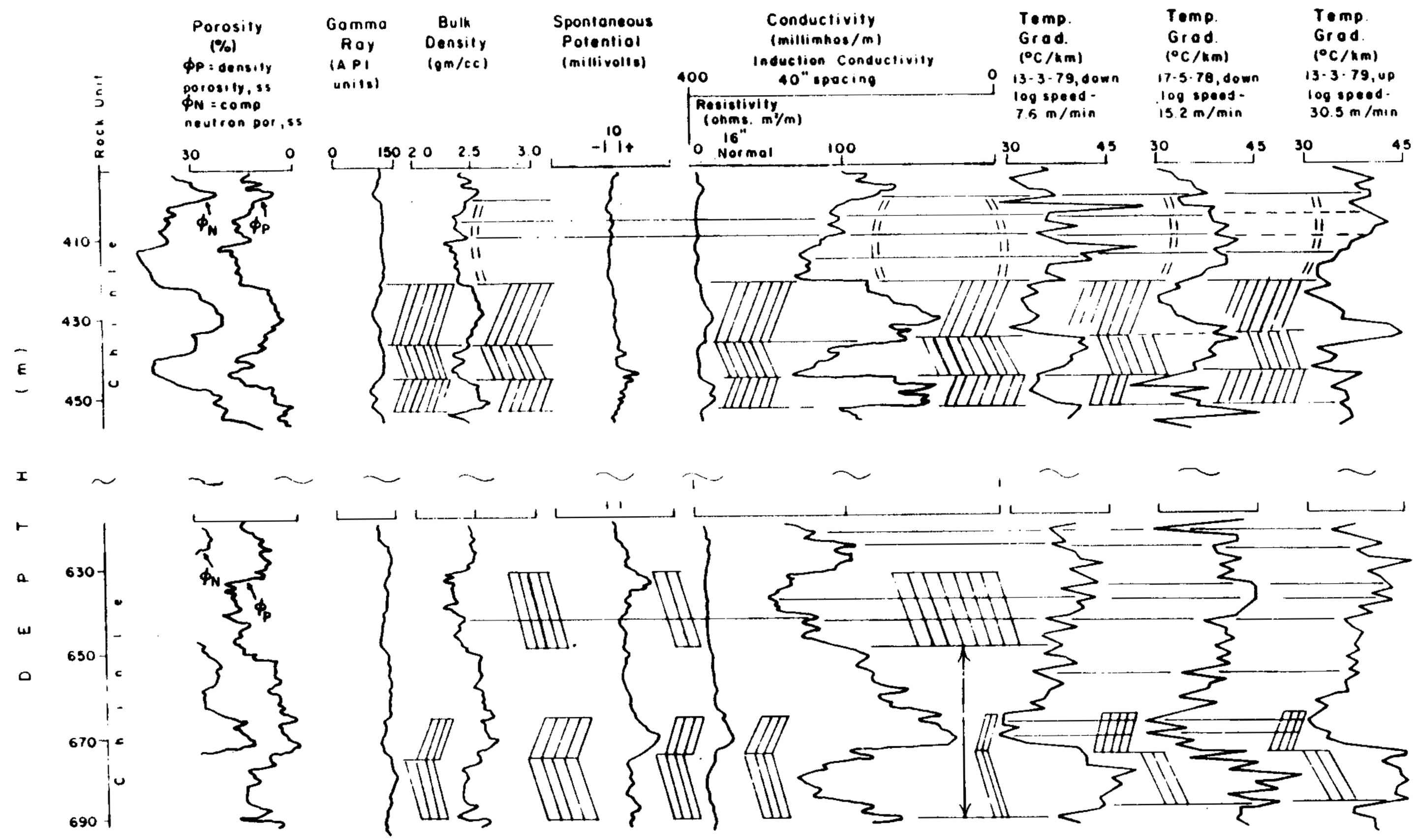


FIG. 4b. Correlation of temperature-gradient logs to other logs at San Ysidro. Zones of comparison are noted as double dashed lines beside logs being compared and hachures (for high or low gradients) between logs being compared. Arrows between logs suggest an almost one-to-one correlation of those logs. See Figure 4a for plotted interval.

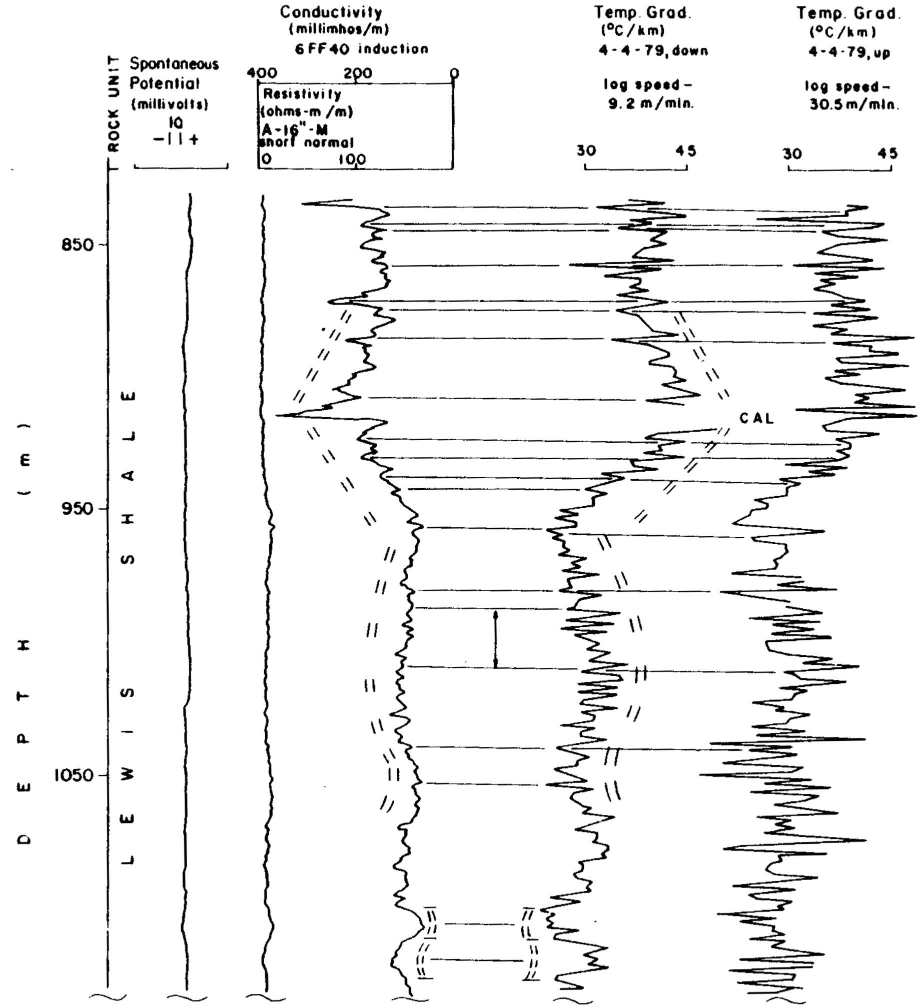


FIG. 4c. Correlation of temperature-gradient logs to other types of logs at Gavilon, upper section. See Figures 4a and 4b for plotted interval and ledger.

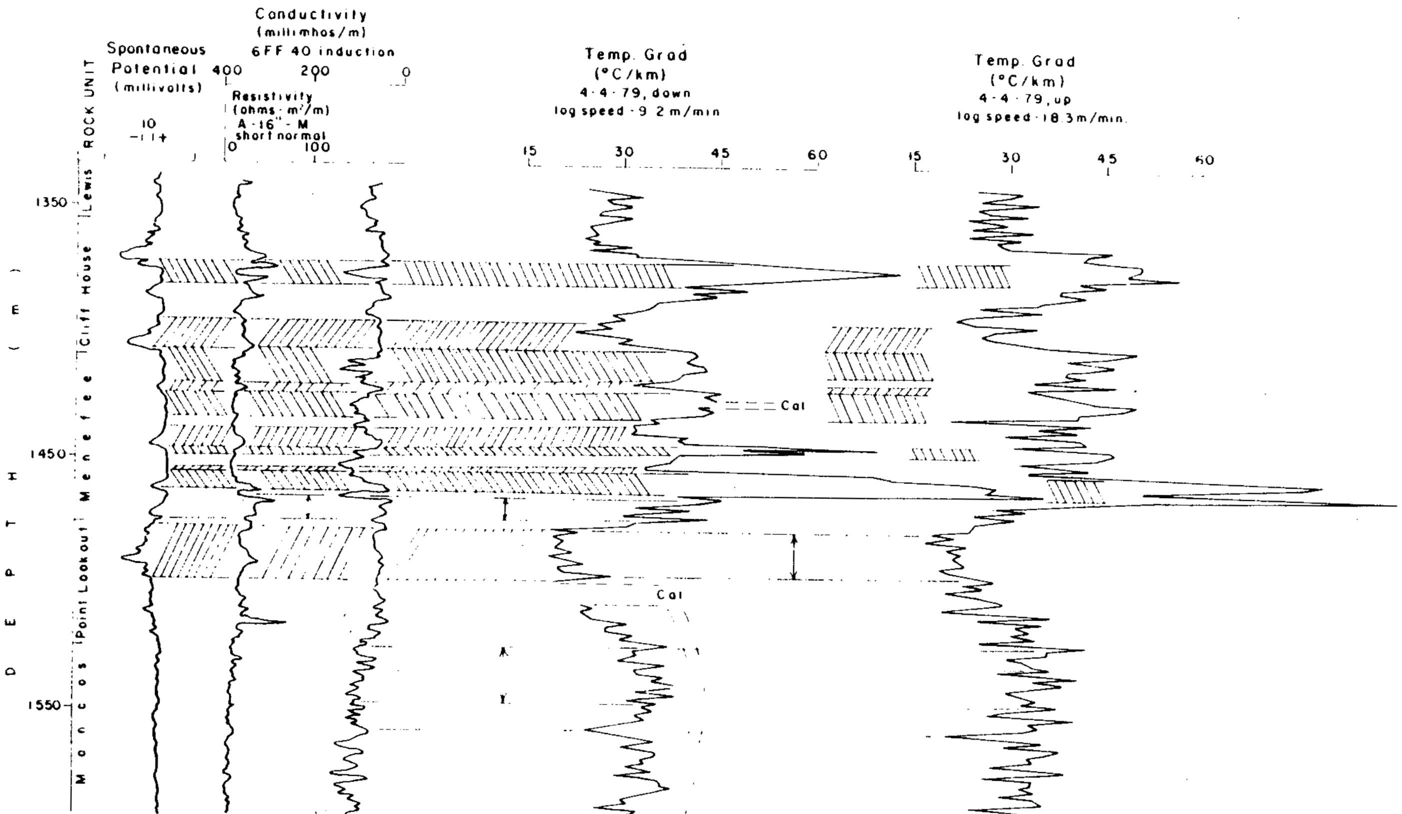


FIG. 4d. Correlation of temperature-gradient logs to other types of logs at Gavilon, lower section. See Figures 4a and 4b for plotted interval and ledger.

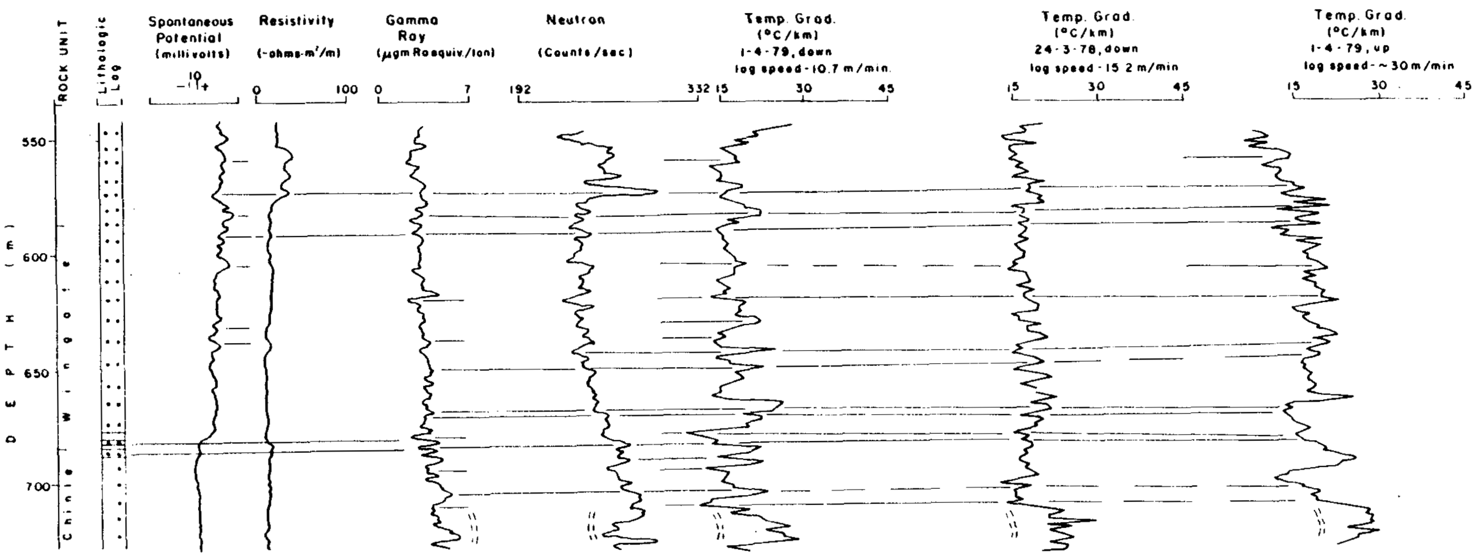


FIG. 4e. Correlation of temperature-gradient logs to other types of logs at Bluff State, upper section. See Figures 4a and 4b for plotted interval and ledger. Lithologic description as follows: two dots indicate sandstone, one dot indicates siltstone, blank space indicates shale.

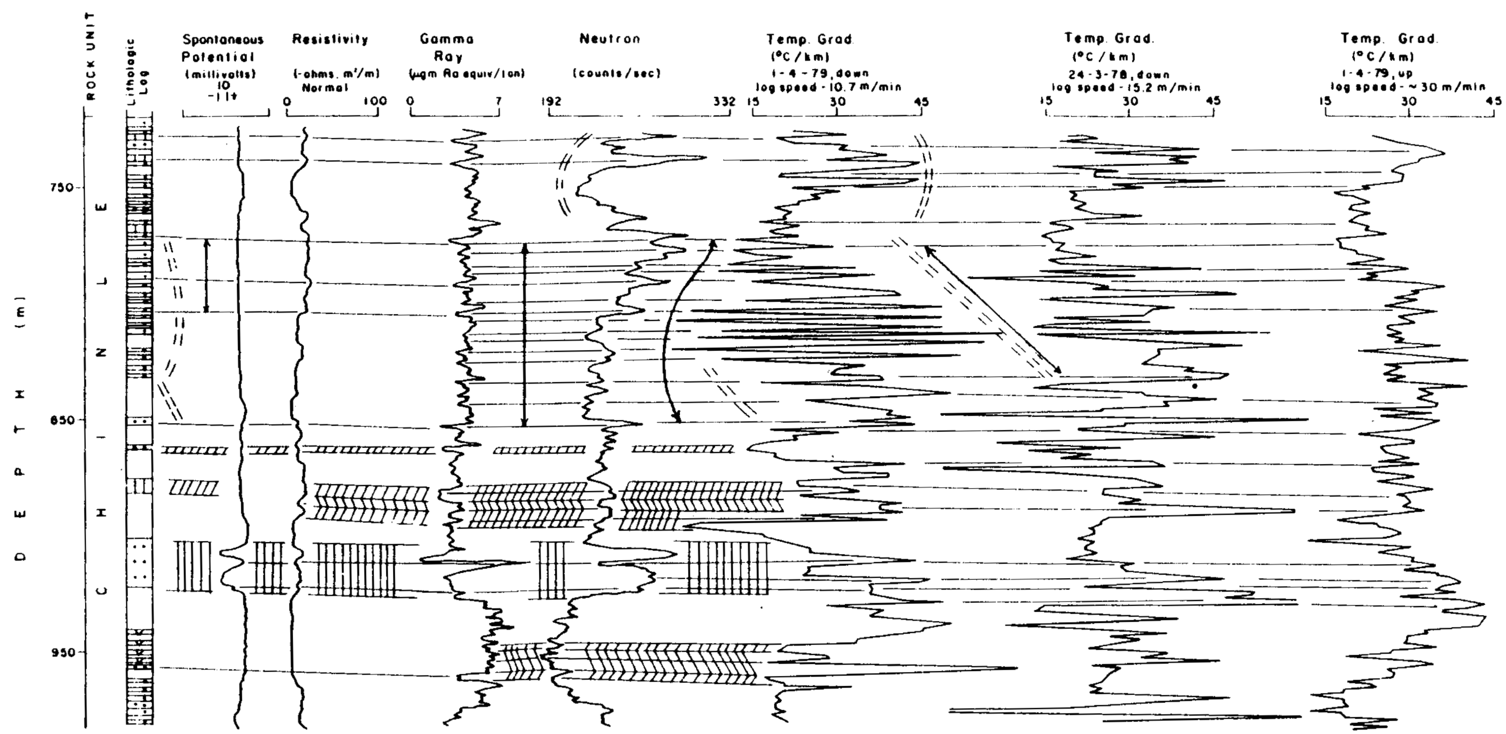


FIG. 4f. Correlation of temperature-gradient logs to other types of logs at Bluff State, lower section. See Figures 4a and 4b for plotted interval and ledger. Lithologic description as follows: two dots indicate sandstone, one dot indicates siltstone, blank space indicates shale, two vertical lines indicate limestone, and a V indicates mudstone.

Table 1. Comparison of temperature data and temperature-gradient data for different logs in Datil, San Ysidro, Gavilon, and Bluff State. Logs are identified by the logging run date; and (d) indicating the log was performed as the probe was going down the well, or (u) indicating the log was performed as the probe was coming up the well.

| Site | Logging Runs | | Temperature Comparisons | | | | | Temperature Gradient Comparisons | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Run 1<br>Run I.D.-Speed (m/min) | Run 2<br>Run I.D.-Speed (m/min) | Total Depth Interval (m) | No. Of Depth Stations Compared | Dist. Between Stations Compared (m) | Mean Of Temp. Diffs. (°C) | Mean Of Absolute Temp. Diffs. (°C) | Total Depth Interval (m) | No. Of Equally Spaced Grad. Zones | Length Of Grad. Zone (m) | Mean Of Percentage Differences Of Grads. | Mean Of Absolute-Percentage Differences Of Grads. |
| Datil | 26-7-78(d)-15.2 | 7-3-79(d)-7.6 | 152-1584 | 40 | 30.5 | ~.03 | .03±.02 | 153-854 | 22 | 9.15 | 2 | 7±9 |
| | " " | " " | | | | | | 854-1352 | 17 | 9.15 | 1 | 3±4 |
| | 7-3-79(d)-7.6 | 7-3-79(u)-30.5 | 152-1584 | 40 | 30.5 | .83±.20 | (u) always greater | 305-854 | 16 | 9.15 | * | * |
| | " " | " " | | | | | | 854-1309 | 15 | 9.15 | 2 | 4±4 |
| San Ysidro | 17-5-78(d)-15.2 | 13-3-79(d)-7.6 | 40-741 | 24 | 30.5 | .01 | .04±.03 | 92-732 | 21 | 9.15 | 1 | 5±4 |
| | 13-3-79(d)-7.6 | 13-3-79(u)-30.5 | 40-741 | 24 | 30.5 | .11±.04 | (u) always greater | 92-732 | 21 | 9.15 | 0.4 | 6±4 |
| Gavilon | 14-11-77(d)-15.2 | 4-4-79(d)-9.2 | 920-1418 | 17 | 30.5 | .03±.02 | 4-4-79(d) always higher | 920-1814 | 30 | 9.15 | 1 | 4±5 |
| | " " | " " | 1448-1814 | 13 | 30.5 | .15±.04 | 4-4-79(d) always higher | | | | | |
| | 4-4-79(d)-9.2 | 4-4-79(u)-** | 920-1814 | 30 | 30.5 | .36±.06 | (u) always higher | 920-1814 | 30 | 9.15 | 3 | 6±7 |
| Bluff State | 2 -3-78(d)-15.2 | 1-4-79(d)-10.7 | 610-1130 | 17 | 30.5 | .14±.04 | 24-3-78(d) always higher | 550-1587 | 35 | 9.15 | 6 | 12±10 |
| | " " | " " | 1130-1586 | 16 | 30.5 | .30±.09 | 24-3-78(d) always higher | | | | | |
| | 1-4-79(d)-10.7 | 1-4-79(u)-*** | 610-1586 | 33 | 30.5 | .29±.05 | 1-4-79(u) always higher | 550-1587 | 35 | 7.62 | 3 | 7±8 |

*percentage difference in grads. is 2%-60%
**4-4-79(u)-logging speed-18.3 (1800-1270 m), 30.5 (1270-0 m)
***1-4-79(u)-logging speed-15.2 (1600-1203 m), 30.5 (1203-0 m)

**Table 2. Location and description of wells used in the present study.**

| Site | Location | Well description |
|---|---|---|
| Datil | 29-3S-9W, Catron Co., NM. (34°01′N lat, 107°49′W long) | (1) 24.5 cm casing only, unperforated; (2) no surface pressure on valve; (3) logs all taken with same probe; (4) observed wellbore temperature fluctuations .04–.05°C; (5) water level ~70 m, test well filled with water; (6) recording interval 1.52 m. |
| San Ysidro | 19-15N-1E, Sandoval Co., NM (35°32′N lat, 106°59′W long) | (1) 21.9 cm surface casing to 206 m, 14 cm casing to bottom, 5.1 cm tubing to bottom, perforated at bottom; (2) 92 psi water pressure on wellhead valve maintained while logging; (3) logs on different days made with different probes; (4) wellbore fluctuations ~.005°C; (5) water level (pressure on wellhead valve), observation well; (6) recording interval 1.52 m. |
| Gavilon | 23-25N-1W, Rio Arriba Co., NM (36°22′N lat, 106°54′W long) | (1) 34 cm surface casing to 98 m, 19.4 cm casing to bottom, perforated at bottom; (2) 70 psi (4-11-77) and 100 psi (4-4-79) methane maintained while logging; (3) logs on different days taken with different probes; (4) wellbore temperature fluctuations ~.02°C; (5) oil level ~780 m, hole filled with crude oil, observation well; (6) recording interval: 4-11-79, 0 m to 1400 m − 10 m, 1400 m to 1800 m − 3.05 m; 4-4-79, 1.52 m. |
| Bluff State | 32-39S-23E, San Juan Co., UT (37°22′N lat, 109°22′W long) | (1) 14 cm casing to bottom, 7.3 cm tubing to bottom, bottom perforated; (2) less than 1 psi methane on wellhead valve; (3) logs on different days made with different probes; (4) wellbore temperature fluctuations about .02°C; (5) liquid level ~520 m, shut in oil well; (6) recording interval 1.52 m. |