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GEOTHERMAL LOW-TEMPERATURE RESERVOIR ASSESSMENT IN DONA ANA COUNTY, NEW MEXICO

Larry Icerman
Richard L. Lohse

April 1983

New Mexico Energy Research and Development Program

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Final Report

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7. ABSTRACT (A 200-word or less factual summary of the most significant information. If report includes a significant bibliography or literature survey, mention here.)

Sixty-four shallow temperature gradient holes were drilled on the Mesilla Valley East Mesa (east of Interstate Highways 10 and 25), stretching from U.S. Highway 70 north of Las Cruces to N.M. Highway 404 adjacent to Anthony, New Mexico. Using these data as part of the site selection process, Chaffee Geothermal, Ltd. of Denver, Colorado, drilled two low-temperature geothermal production wells to the immediate north and south of Tortugas Mountain and encountered a significant low-temperature reservoir, with a temperature of about 150°F and flow rates of 750 to 1,500 gallons per minute at depths from 650 to 1,250 feet. These joint exploration activities resulted in the discovery and confirmation of a 30-square-mile low-temperature geothermal anomaly just a few miles to the east of Las Cruces that has been newly named as the Las Cruces East Mesa Geothermal Field. Elevated temperature and heat flow data suggest that the thermal anomaly is fault controlled and extends southward to the Texas border covering a 100-square-mile area. With the exception of some localized perturbations, the anomaly appears to decrease in temperature from the north to the south. Deeper drilling is required in the southern part of the anomaly to confirm the existence of commercially-exploitable geothermal waters.

8. KEY WORDS (6 to 12 entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separate key words by semi-colons.)
Geothermal; Low-temperature assessment; Dona Ana County; New Mexico; Geothermal exploration data

9. AVAILABILITY
Copies of this report are available from the New Mexico Energy Research and Development Institute Information Center, University of New Mexico, 117 Richmond Drive N.E., Albuquerque, NM 87106. Tel. (505) 277-3661. Please inquire as to price.

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We thank James Gross, Senior Geologist/Exploration for Chaffee Geothermal, Ltd., who provided the data summarized in Chapter 3 and Appendix C, as well as an early draft of the text for Chapter 3; Jack Whittier, who computed the least-squares fits of the temperature data; Diane Prince, who typed many of the early drafts of the text; Arlene Starkey, who prepared the camera-ready copy; Mark Rivera, who drafted the maps in ink; and Katrina Oakeley, who reproduced the temperature-depth curves in ink.

1.0 Introduction

1.1 Background Information

Dona Ana County, New Mexico (see Figure 1), is tectonically situated within the Rio Grande Rift (stippled area in Figure 1 insert), which is a north-south trending active thermo-tectonic system that extends from northern Chihuahua, Mexico, to central Colorado and is characterized by late-Pliocene to late-Quaternary faulting and volcanic activity, high heat flow, deep sedimentary basins, and numerous geothermal areas. In this section, selected data from the literature describing the geology, geophysics, and geothermal energy potential of Dona Ana County are reviewed briefly. Some of the conclusions drawn by these earlier analyses may not be consistent with the evaluations of the data collected during the course of this project but have, nonetheless, contributed to the understanding of the geothermal energy potential of Dona Ana County.

Reiter et al. (1978), based on a limited amount of heat flow data throughout south central New Mexico, have placed Dona Ana County within an envelope of heat flow values greater than 2.5 heat flow units (HFU, one HFU = 1×10^{-6} cal cm^{-2} sec^{-1}). Seager and Morgan (1979) have placed the county within a heat flow contour of greater than 3 HFU. A heat flow study of Dona Ana County (Lohse et al., 1981) gives a modal range of about 2.5 to 3.6 HFU with a maximum value exceeding 16 HFU. Figure 2 summarizes heat flow values from above the water table throughout Dona Ana County.

Electrical resistivity data gathered by Jackson (1976) and Young (1982) in Dona Ana County show areas of low and high resistivity due to offsets in the resistive basement, which is believed to be the Paleozoic strata. Swanberg (1975) reports subsurface temperatures based on the Na-K-Ca and SiO_2 geothermometers throughout Dona Ana County (see Figures 3 and 4, respectively).

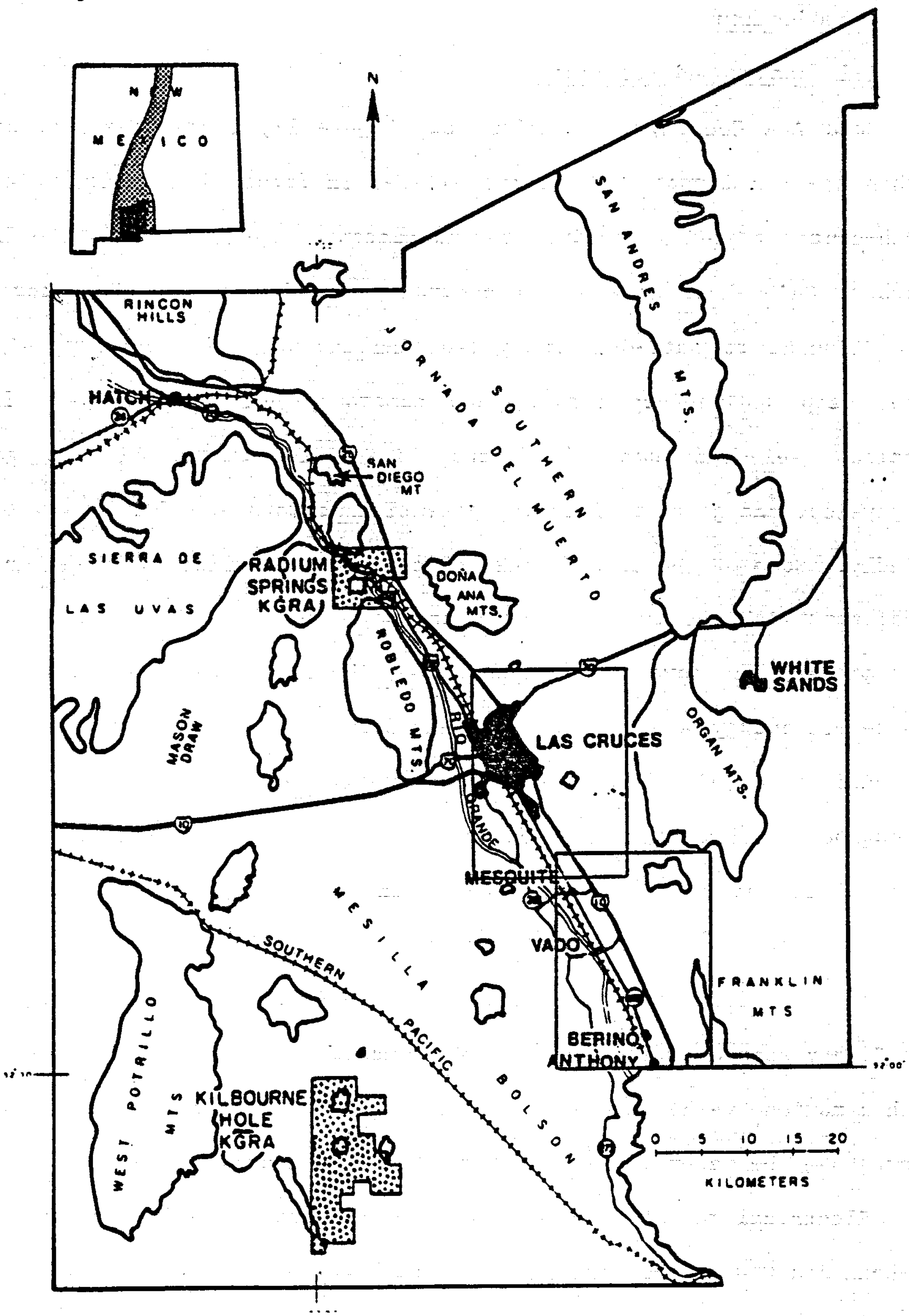


Figure 1. Location map of the study area.

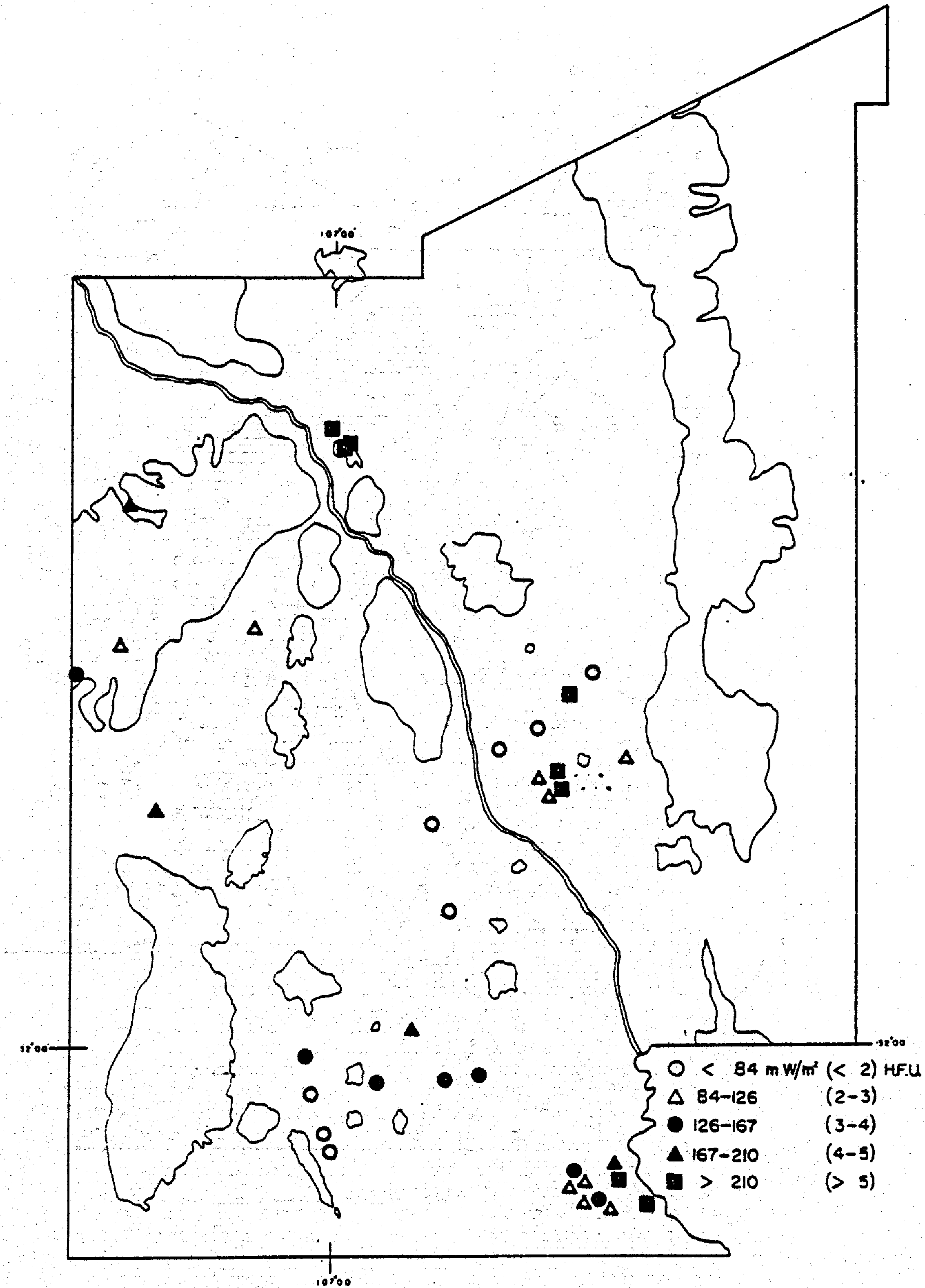


Figure 2. Heat flow values above the water table in Dona Ana County (Lohse, 1980).

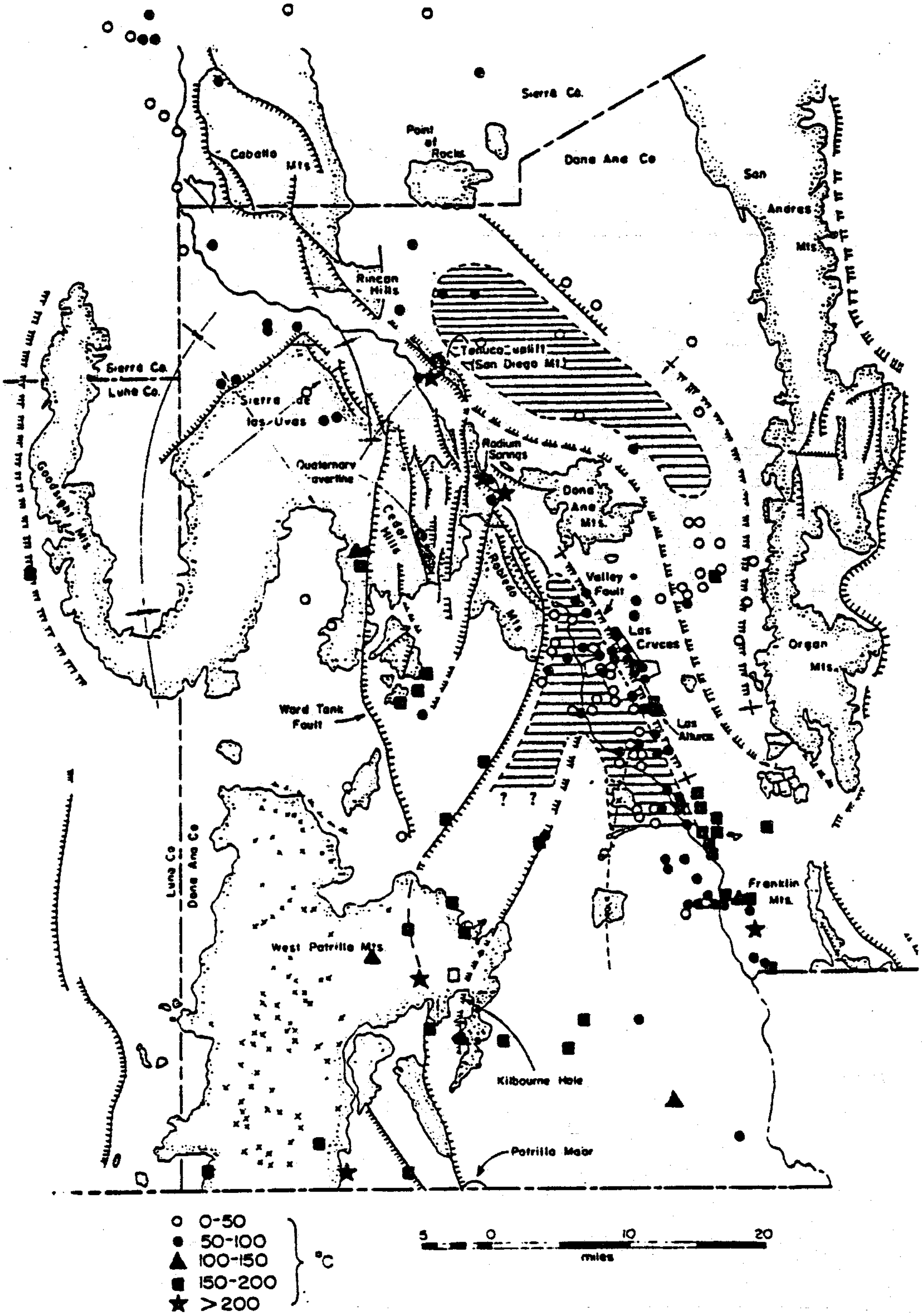


Figure 3. Temperatures estimated by Na-K-Ca geothermometry (Swanberg,1975).

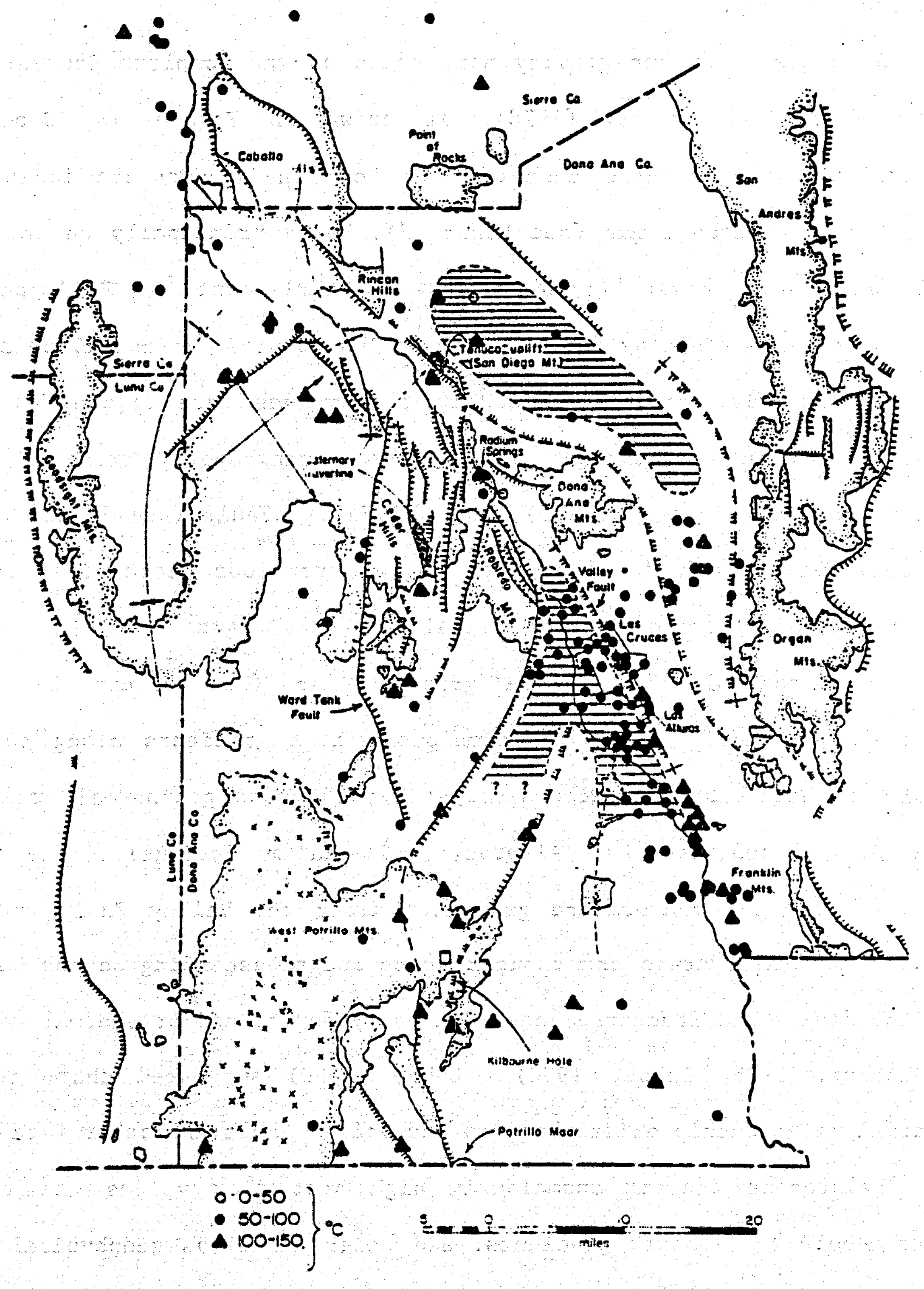


Figure 4. Temperatures estimated by SiO_2 geothermometry (Swanberg, 1975).

Updated geothermometry data have been compiled by Swanberg (1980a, 1980b) and Lohse (1982).

A complete Bouguer gravity map, based on the complete Bouguer gravity data of Cordell et al. (1978), is shown in Figure 5. Geochemical, electrical, and magnetic anomalies in Dona Ana County are identified in Figure 6. A tectonic map (see Figure 7), based principally on the data of Callendar and Seager (1980), shows late-Pliocene to Pleistocene and late-Quaternary faulting throughout Dona Ana County. A spatial relationship appears to exist between high heat flow values (see Figure 2), a steep gravity gradient associated with a north-northwesterly trending positive gravity anomaly (see Figure 5), and the Valley Fault (see Figure 7). This spatial relationship is also supported by anomalous geochemical data (see Figures 3 and 4) and other geophysical data (see Figure 6).

A bottom-hole temperature gradient map (see Figure 8) shows a north-northwesterly trend of anomalously high gradients along the Valley Fault and high gradients also associated with known geothermal areas (i.e., San Diego Mountain, Las Alturas, and Radium Springs). The elevated temperatures and temperature gradients along the Valley Fault and in the known geothermal areas are thought to be due to ascending hot or warm water up the faults and fractured zones driven by forced and/or thermal convection (Swanberg, 1975; Lohse, 1980). Lohse (1980) suggested that, because a spatial relationship exists between the Valley Fault and other late-Pliocene to Pleistocene faults; anomalously high heat flow values, temperatures, bottom-hole temperature gradients; and other anomalous geophysical data, a fault-controlled hydrothermal system is favored as the mechanism and cause of the anomalous data.

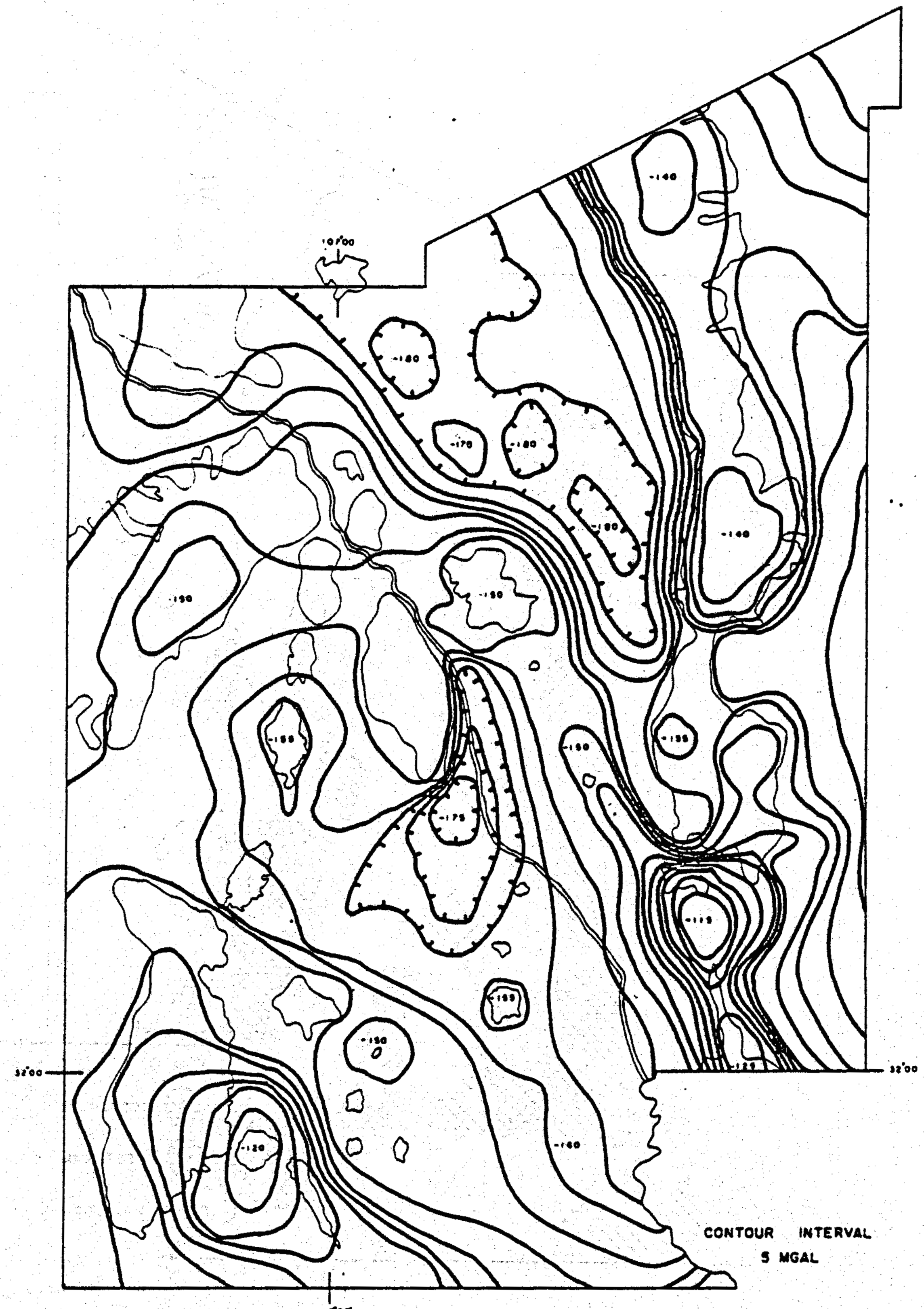


Figure 5. Complete Bouguer gravity map of Dona Ana County [after Cordell et al. (1978)].

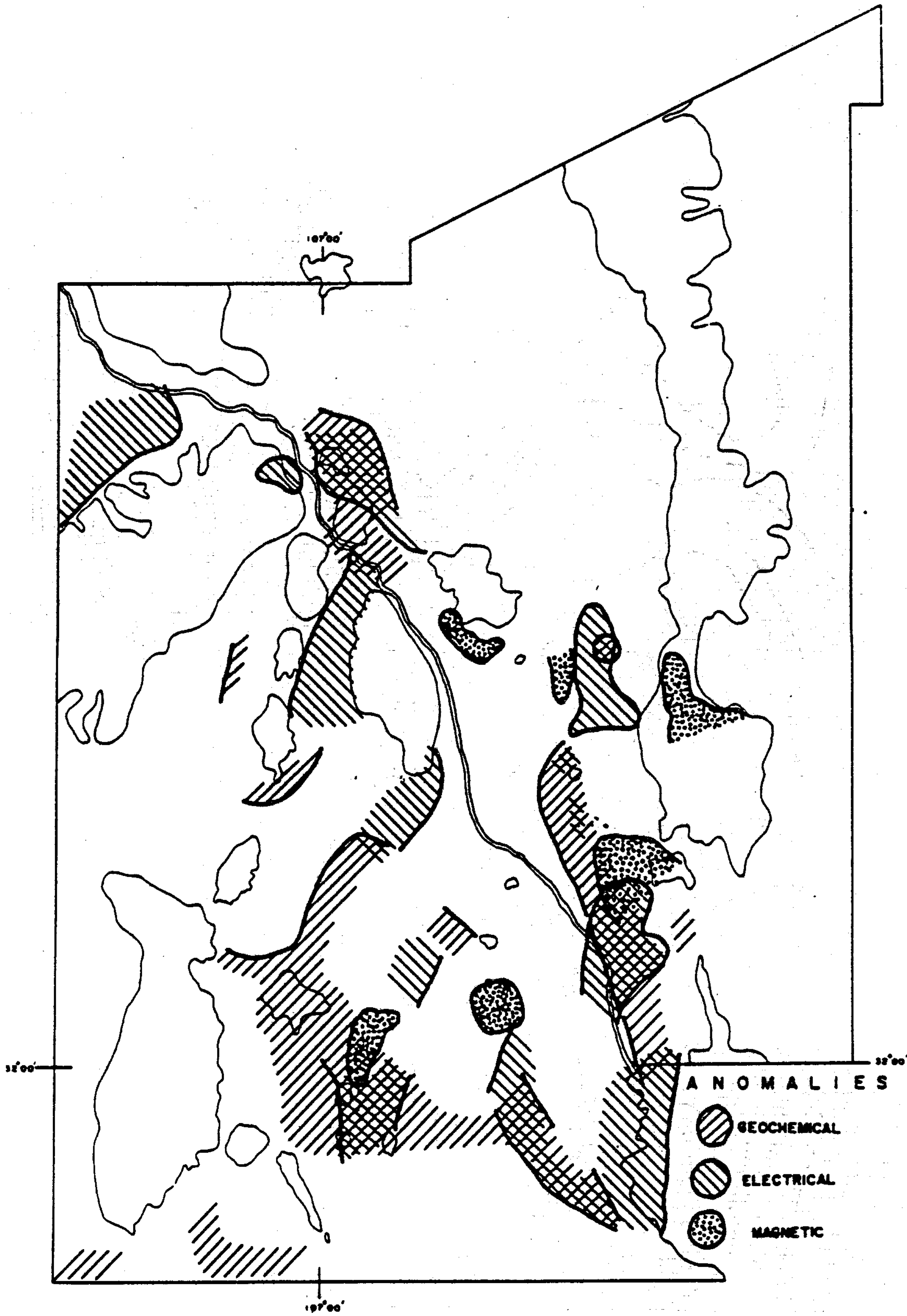


Figure 6. Geochemical, electrical, and magnetic anomalies in Dona Ana County (Lohse, 1980).

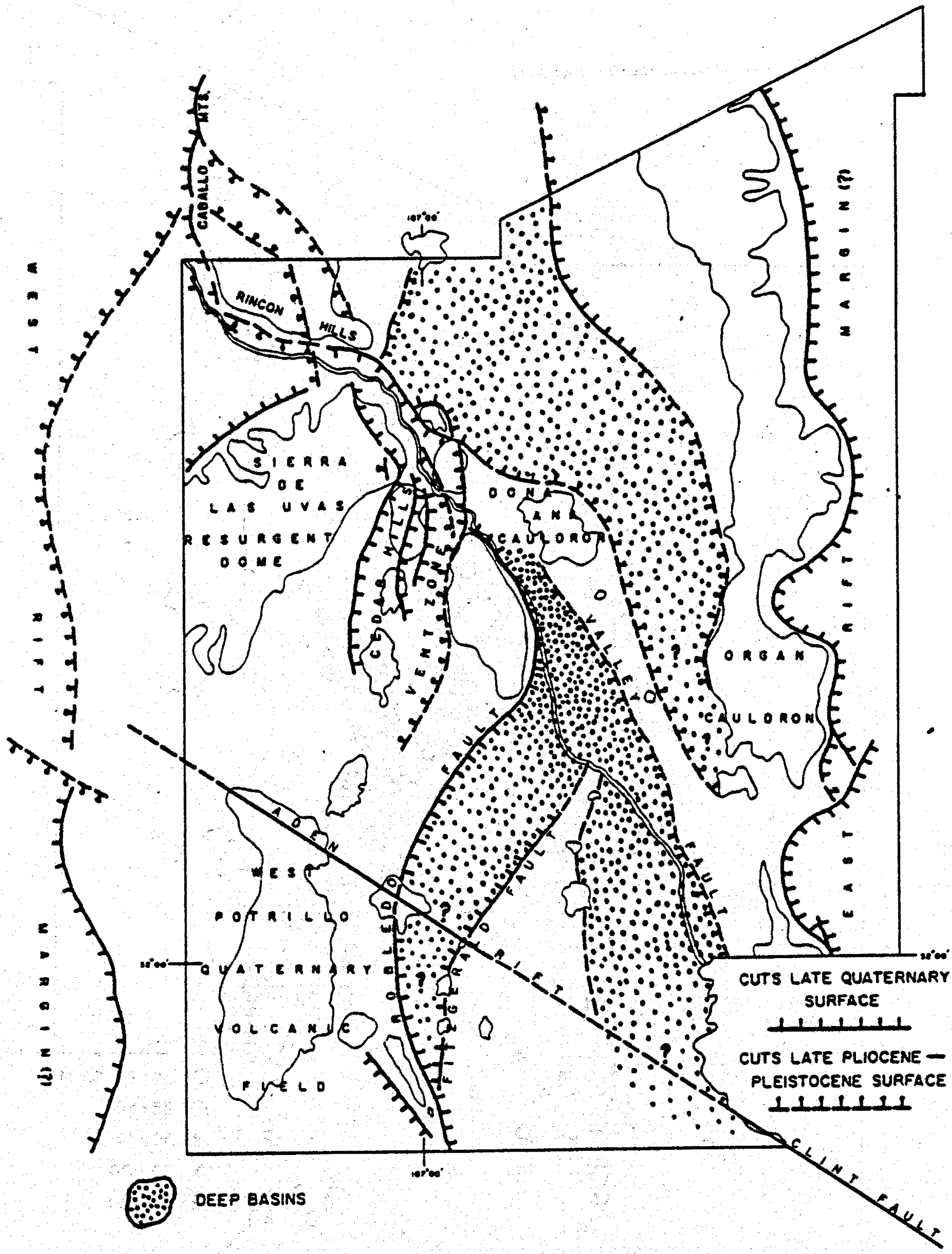


Figure 7. Tectonic map of Dona Ana County showing late-Pliocene to Pleistocene and late-Quaternary faults (Callender and Seager, 1980). Aden Rift is after Hoffer (1975).

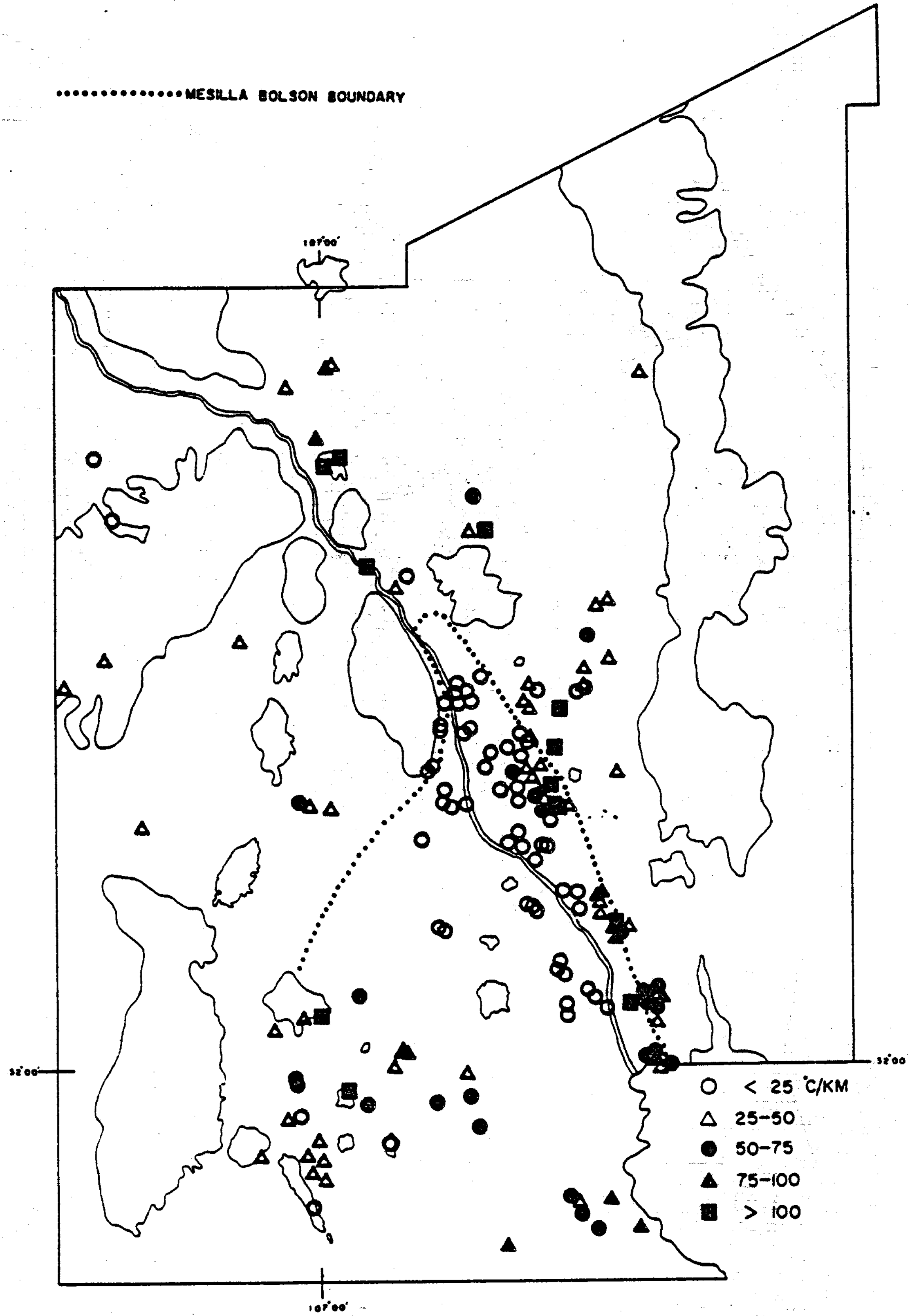


Figure 8. Bottom-hole temperature gradient map of Dona Ana County. A surface temperature of 20°C has been used and, with the exception of a few wells, most wells are less than 300 meters deep (Lohse,1980).

The (formerly named) Las Alturas Geothermal Anomaly is situated on the Valley Fault just a few miles east of Las Cruces. Morgan, Swanberg, and Lohse (1980) reported that this geothermal anomaly was believed to be due to a fault-controlled hydrothermal system. Two water wells drilled by the City of Las Cruces during 1980 located warm water to the east of Las Cruces and to the north of the Las Alturas Geothermal Anomaly. Data from both of these wells suggested that the Las Alturas Geothermal Anomaly was larger than first estimated, while data from one of the wells suggested that the anomaly was warmer than first suspected. Together, these data indicated that the Las Alturas Geothermal Anomaly was part of a much larger and hotter hydrothermal system.

Figures 9 and 10 show anomalous temperatures and geotemperatures in Dona Ana County, respectively. A composite of the data displayed in Figures 9 and 10 is shown in Figure 11. Lohse (1982) concluded that the hydrothermal systems in Dona Ana County are fault controlled, a belief stated previously by Swanberg (1975) and Lohse et al. (1981).

1.2 Project Objectives

The primary objectives of this project were to: (1) delineate the geothermal energy reservoirs, east of Interstate Highways 10 and 25, from Las Cruces to Anthony, New Mexico, and (2) provide the data needed to determine the locations of deeper (e.g., 1,500 to 2,500 feet) exploratory test holes and/or production wells. The first objective was achieved as the result of the exploration program conducted as part of this project. Based on these results, Chaffee Geothermal, Ltd. of Denver, Colorado, drilled three exploratory/production wells during the course of this project. The first two of these wells, drilled in 1981, became an integral part of this project (see Chapter 3). A third well was drilled during the fall of 1982

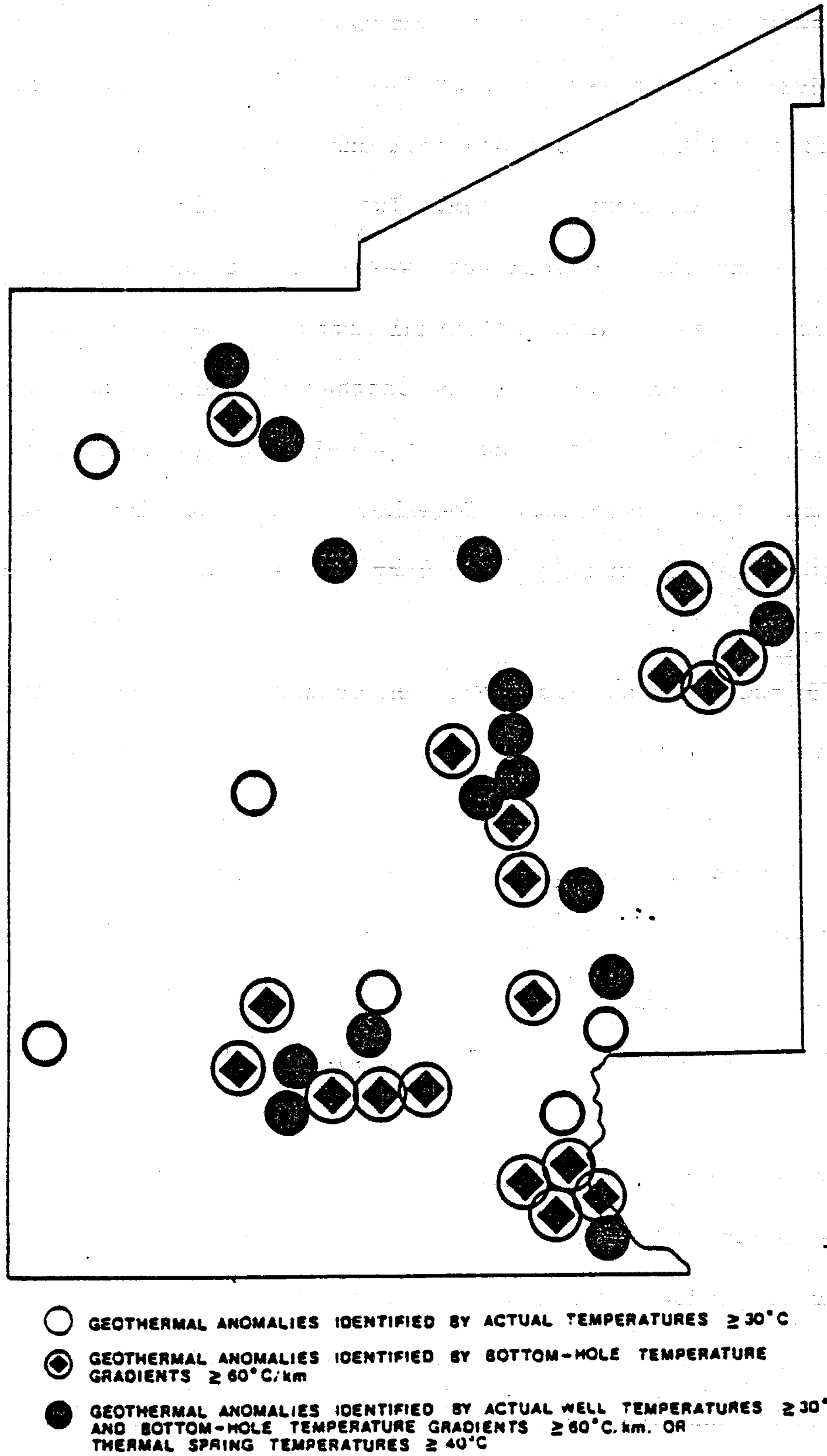


Figure 9. Sites in Dona Ana County characterized by anomalous actual temperatures ($\geq 30^{\circ}C$) of wells and springs, bottom-hole temperature gradients ($\geq 60^{\circ}C/km$) of wells, or by anomalous actual temperatures ($\geq 40^{\circ}C$) of thermal springs (Lohse, 1982).

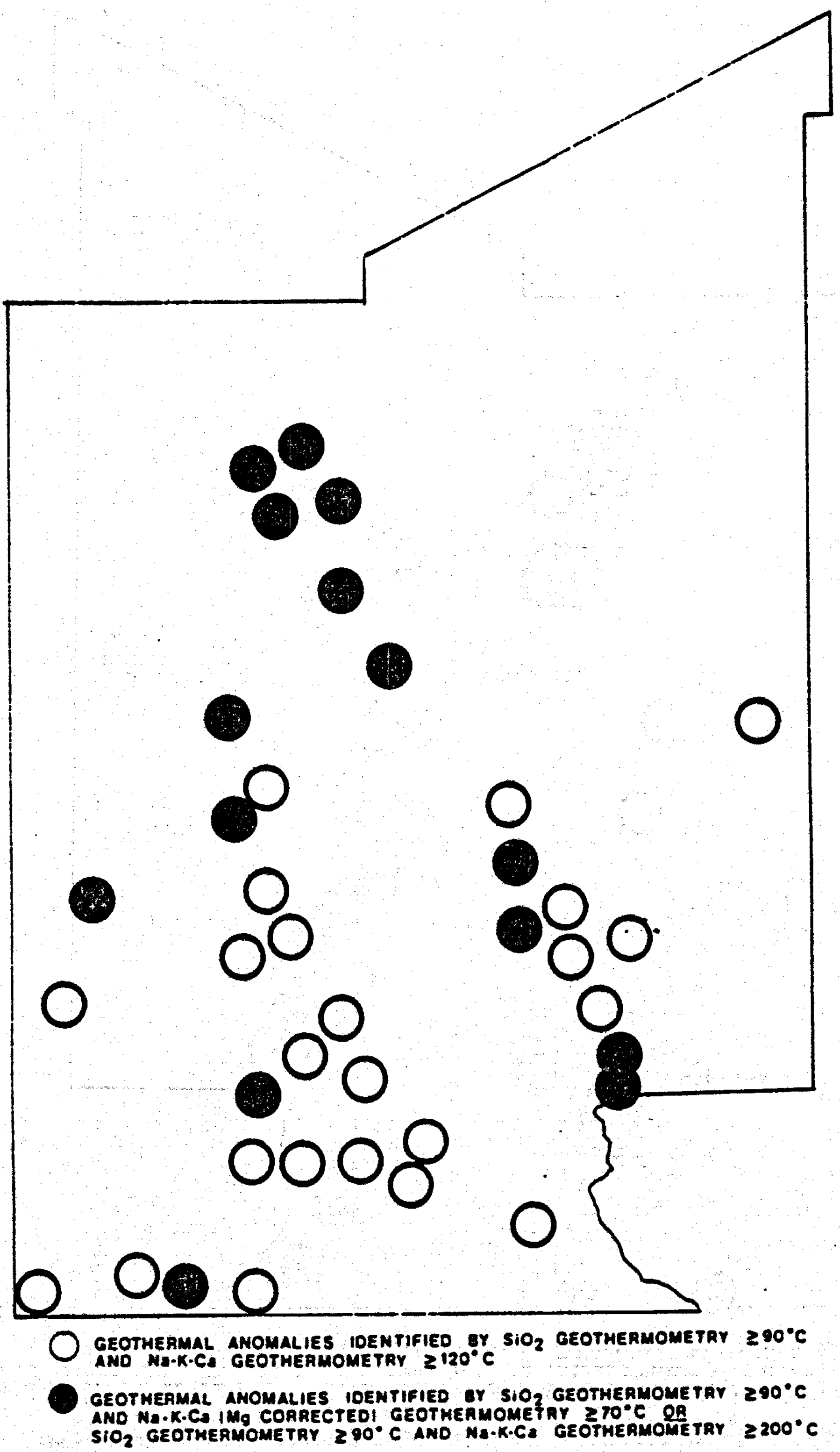


Figure 10. Sites in Dona Ana County characterized by anomalous SiO_2, Na-K-Ca, and Na-K-Ca (Mg-corrected) geotemperatures of springs and wells (Lohse, 1982).

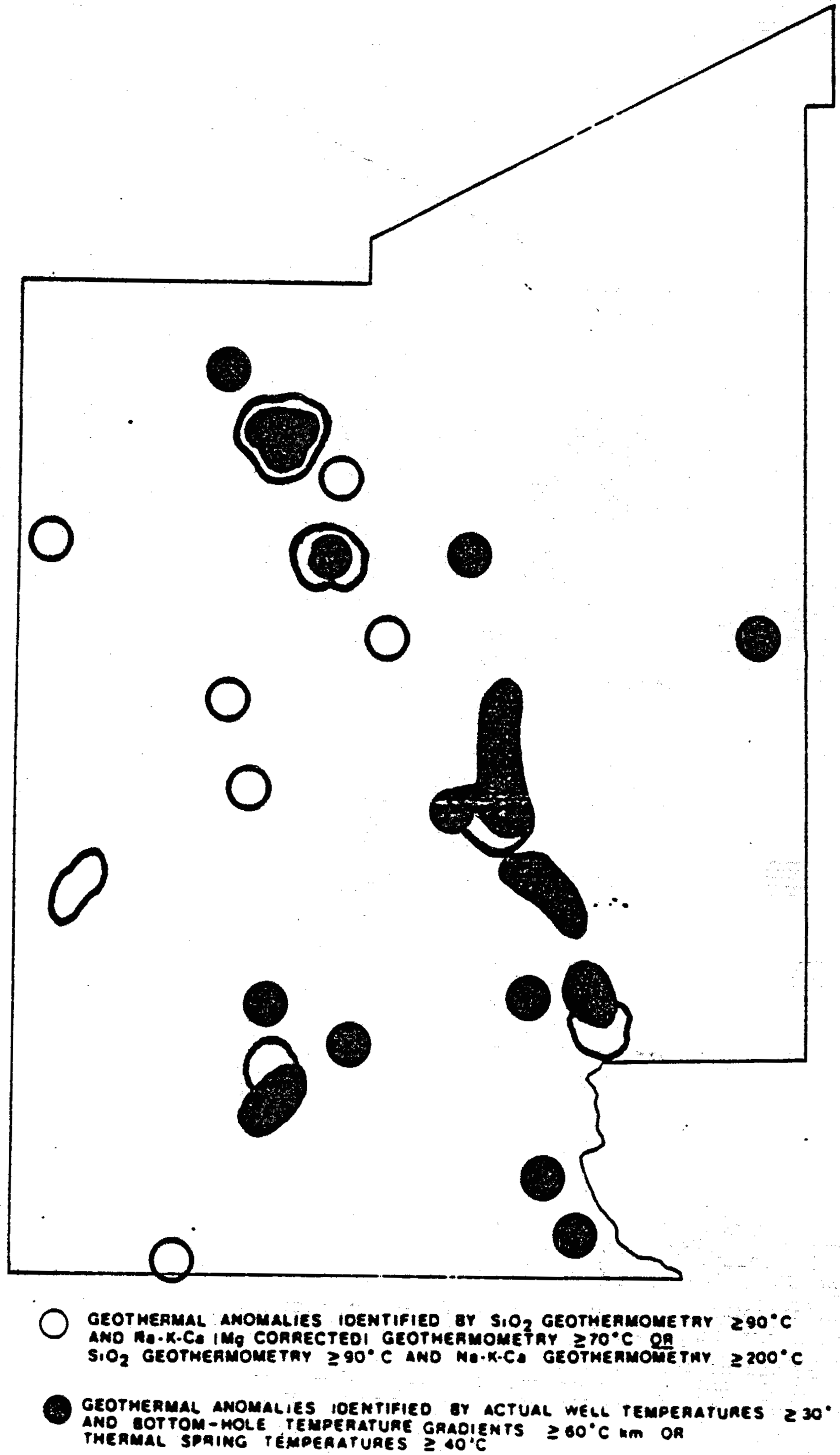


Figure 11. Sites in Dona Ana County characterized by anomalous geotemperatures, actual well temperatures, bottom-hole temperature gradients, and thermal spring temperatures (Lohse, 1982).

to a depth of approximately 2,650 ft. The data collected from this well are available from the New Mexico Energy and Minerals Department.

1.3 Project Procedure

An exploration technique of drilling and logging shallow (i.e., 100 to 300 feet) temperature gradient holes spaced roughly one mile apart was used. This technique is a proven approach to collect temperature data to complement geophysical and geological data for use in delineating geothermal energy resources. Spacing distances varied due to inaccessibility of property and topography, but the spacing was chosen so as to give maximum coverage for the drilling expenditures while at the same time maintaining the desired degree of resolution. The well location pattern was designed so that in every case the location was chosen to examine a specific geological or geophysical concept or to investigate the potential of geothermal resources located near to potential users in areas where little exploration has occurred previously.

1.4 Private Sector Participation

Most of the land targeted for exploration under this project is managed by the Bureau of Land Management (BLM). In most cases, geothermal exploration leases have been applied for by, or issued to, private resource development companies. The principal lease holders in the exploration area are Chaffee Geothermal, Ltd. of Denver, Colorado, Trans-Pacific Geothermal, Inc. of Oakland, California, and Monterey Energy Company of San Antonio, Texas. Joint exploration programs were carried out with each of these companies. Exploration activities in the area surrounding Tortugas Mountain were undertaken with the cooperation and financial assistance of Chaffee Geothermal, Ltd. The results of these activities are contained in Chapters 2 and 3. Evaluation of the geothermal energy potential east of Interstate

Highway 10 from Mesquite to Anthony, New Mexico, was conducted with the cooperation and financial assistance of Trans-Pacific Geothermal, Inc. and Monterey Energy Company. Chapter 4 summarizes the results of this exploration program. All of the temperature data collected as part of this project are reproduced in Appendices A and D.

2.0 Temperature Gradient Drilling in the Area Surrounding Tortugas Mountain

2.1 Introduction

Thirty-four shallow temperature gradient holes were drilled during 1981 in the area surrounding Tortugas Mountain on the Las Cruces east mesa in order to further delineate a geothermal anomaly which was first confirmed in the Las Alturas area in 1979. University-based researchers had previously defined the Las Alturas Geothermal Anomaly (see Figure 1) by conducting geophysical surveys and temperature gradient well drilling programs. Electrical resistivity data (Hohmann and Jiracek, 1979) were interpreted as suggesting that the anomaly was of limited extent to the north. In 1980, the City of Las Cruces drilled potable water wells north of the Las Alturas Geothermal Anomaly, which encountered warm temperatures and suggested that the anomaly was much larger and hotter than first anticipated. The results of this temperature gradient well drilling program and other recent exploration activities by Chaffee Geothermal, Ltd. (see Chapter 3) support this conjecture.

2.2 Temperature Data

The locations of the temperature gradient holes, identified by the label TG, are shown in Figure 12. Hole depths range from 35 meters to 91 meters. All of the holes encountered Quaternary deposits, ranging in compaction from unconsolidated sands and clays (with drilling rates exceeding 40 feet/hour) to well-cemented and hard sands and gravels (with drilling rates less than 3 feet/hour), except holes TG-31 and TG-32 which were drilled into limestone formations. Additional lithologic information is provided in Appendix A.

Measured bottom-hole temperature gradients range from 40 to 504 ^{o}C/km, with a temperature as high as 54^{o}C observed at 90 meters (TG-43) and

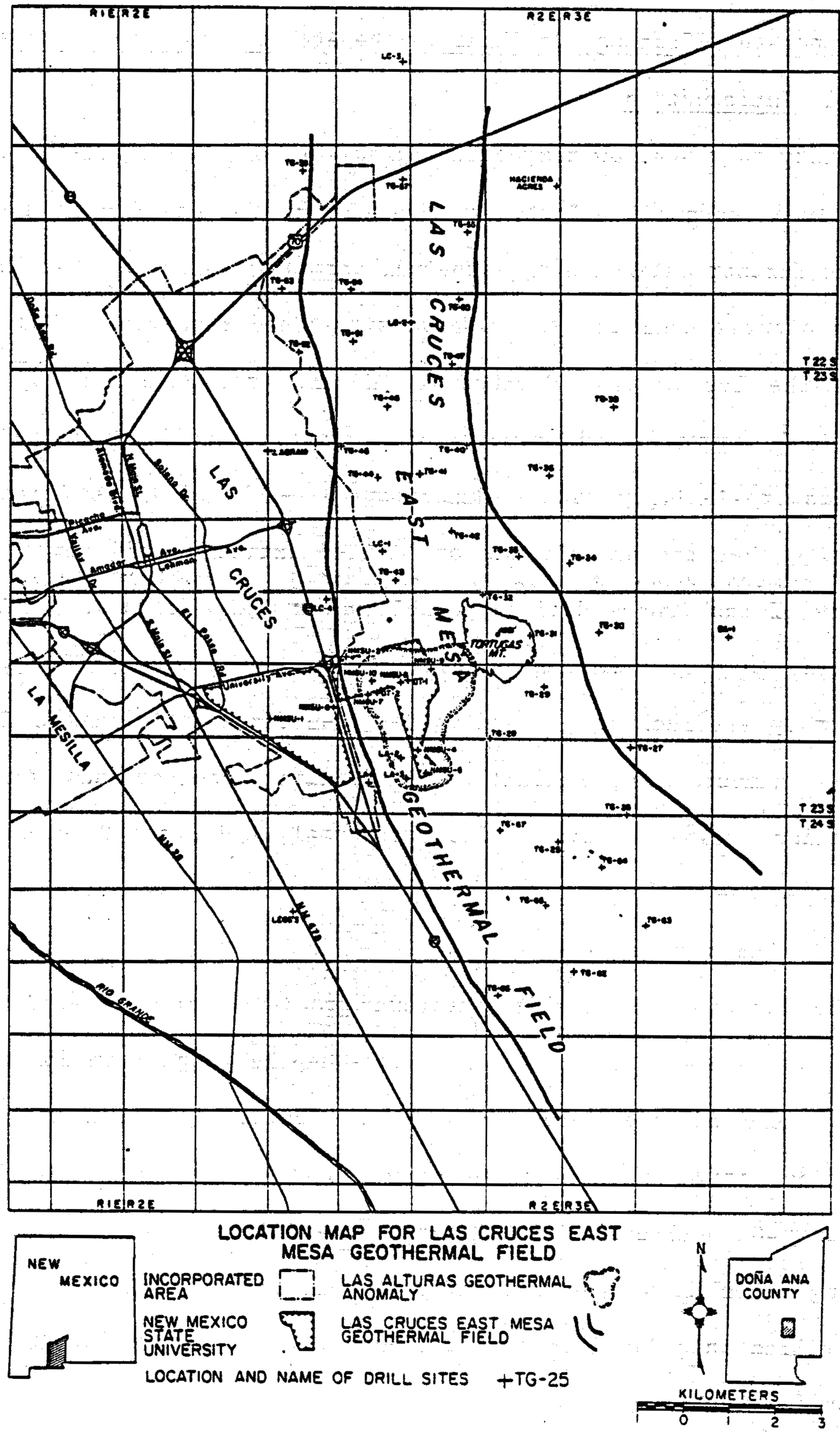


Figure 12. Location of temperature gradient holes (TG) in the area surrounding Tortugas Mountain.

a temperature of 48°C measured at a depth as shallow as 55 meters (TG-31). Examples of the temperature-depth data are given in Table 1 and Figure 13. Depth intervals for which temperature gradients are calculated have been chosen to correspond to nearly linear temperature increases with depth. Representative temperature gradients for each of these sections were computed using a least-squares fit routine. The standard error of the estimate for the temperature gradient is reported for each depth interval. A complete compilation of all the temperature data for the 34 temperature gradient holes is included in Appendix A.

Figures 14 and 15 show the hole locations and temperatures at 30 meters and 90 meters, respectively, of new and existing drill sites within the study area. Temperatures indicated in Figure 15 for those temperature gradient holes drilled to depths less than 90 meters were estimated by extrapolating the measured temperature-depth data. A linear extrapolation was used for the holes that had nearly linear measured temperature gradients, while a gradual decrease in the temperature gradient with depth was assumed for holes that were drilled into zones believed to be convection dominated. The magnitude of the assumed decrease in temperature gradient is proportional to the curvature of the actual temperature-depth profile.

The data were hand contoured at 1°C and 5°C intervals in Figures 14 and 15, respectively, using the assumption of a constant thermal gradient between data points. Contour lines for 22°C and 24°C have been added to give additional detail to the east side of the geothermal field. The 5°C contour intervals of the 30-meter data are highlighted to achieve a more balanced visual comparison with the 90-meter temperatures.

Because the 30-meter data are contoured at 1°C intervals rather than 5°C intervals, more contour lines are presented and, thus, one may be misled

Table 1. Temperature-depth data for TG-63.

Location: latitude, 32° 14.15', longitude, 106° 39.68', township & range, T24S.R3E.8.134; elevation, 1,295 meters; spudded, 10-12-81; temperature logged, 11-13-81; total depth, 91 meters; depth of 1½ inch PVC casing, 91 meters; bottom-hole temperature, 40.8°C; bottom-hole depth, 90 meters; bottom-hole temperature gradient, 231°C/km; best estimate heat flow value, 339 mW/m^2 (8.1 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mw/m^2)	Estimated Heat Flow (HFU)	Remarks
5	22.69						
10	22.08						Drilling rate was fast. Formations are unconsolidated.
15	23.39		gravel	1.4			
20	25.13	298.4 ± 8.0			418	10.0	
25	26.61						
30	27.93						Formations have a gradual decrease in grain size with depth.
35	28.98	213.0 ± 0.8	gravel and sand		320	7.7	
40	30.06						
45	31.12			1.5			
50	32.11						
55	33.01	195.6 ± 2.9	coarse sand and gravel		293	7.0	
60	34.01						
65	35.06						
70	36.23						
75	37.35						
80	38.41	228.8 ± 2.3	coarse sand	1.4	320	7.7	
85	39.68						
90	40.84						
91	40.96						

* Estimated thermal conductivity values.

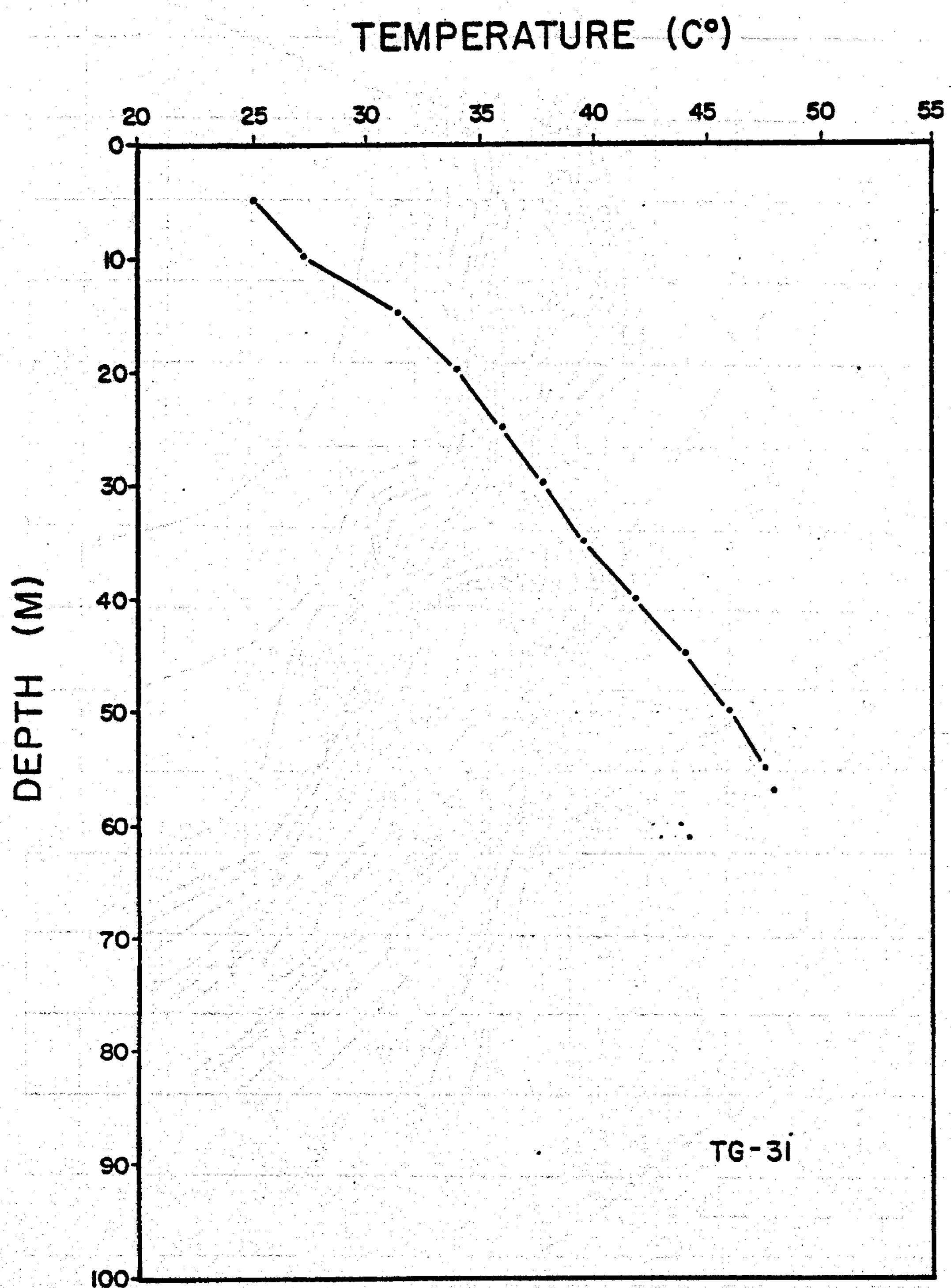


Figure 13. Temperature-depth curve for TG-31.

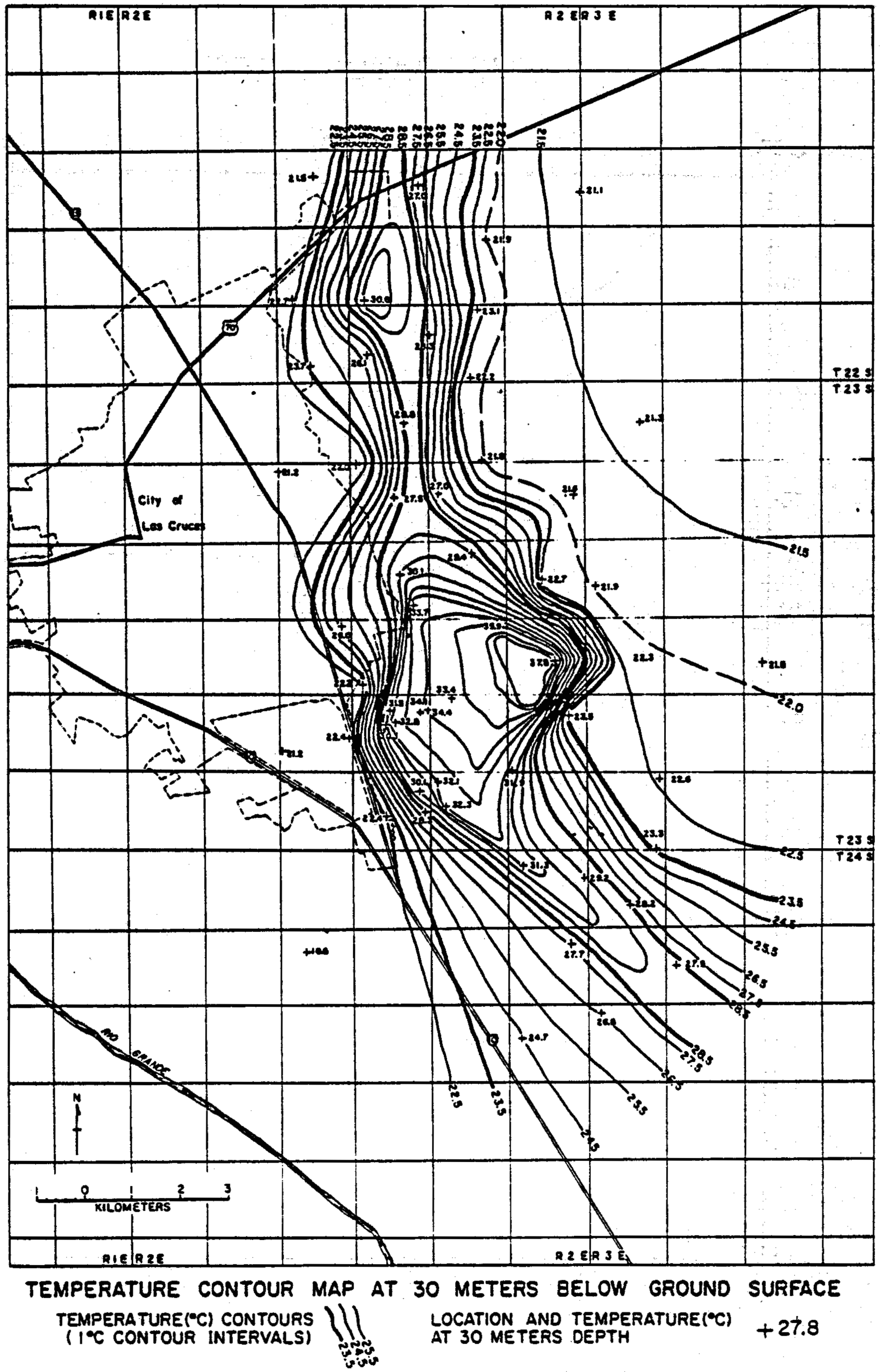


Figure 14. Temperature contours at a 30-meter depth in the area surrounding Tortugas Mountain.

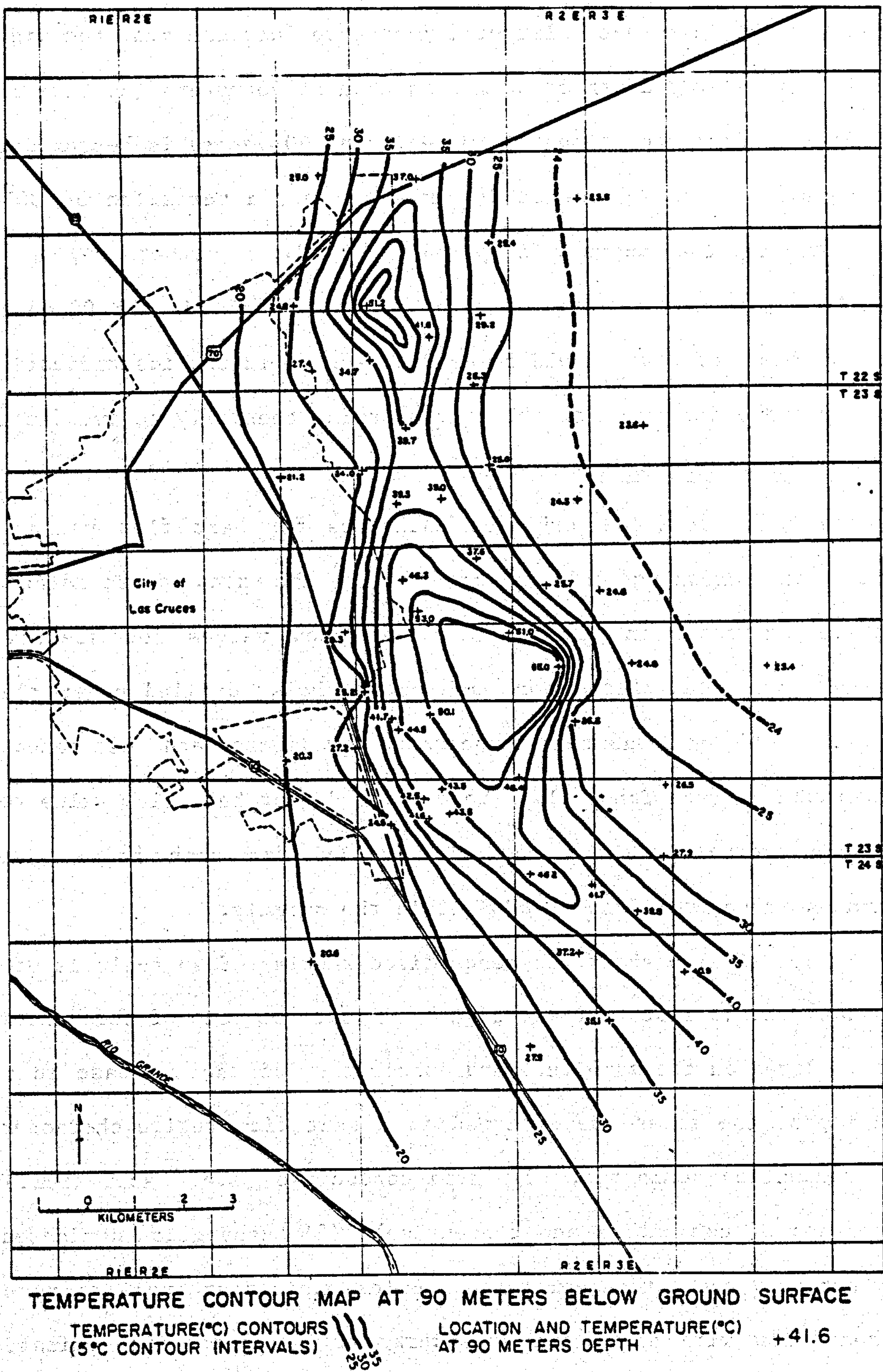


Figure 15. Temperature contours at a 90-meter depth in the area surrounding Tortugas Mountain.

visually to believe that a larger temperature increase over the width of the anomaly exists at a depth of 30 meters than at 90 meters (compare Figures 14 and 15). In fact, the temperature regime at 90 meters is better defined and more detailed than the one at 30 meters (i.e., a variation of 30°C across the width of the anomaly compared to 17°C). Furthermore, because the hydrothermal system is believed to be fault controlled, the 90-meter rather than the 30-meter data should be used to assist in the identification of the location and orientation of the corresponding thermally-active fault system.

2.3 Heat Flow Data

The hole locations and best estimates for heat flow values for the current and existing drill sites within the area surrounding Tortugas Mountain are shown in Figure 16. Heat flow values for specified depth intervals were calculated for each of the holes drilled under the current program based on measured temperature gradients and estimated thermal conductivities (see Table 2). The estimated best heat flow value represents a simple average of the heat flow values for each hole. These best estimates range from 2 to 19 HFU within the anomaly.

Figure 16 also shows the generalized results of an analysis of the heat flow data versus depth for all of the current and some of the existing drill sites. Based on the magnitude and consistency of the decrease in heat flow with depth, the sites are assigned to a heat flow regime characterized as: (1) conduction dominated; (2) semi-conductive (i.e., approximately equal components of conduction and convection); (3) convection dominated; or (4) very strongly convection dominated. Holes exhibiting small or no decreases in heat flow with depth are considered to be conduction dominated, while holes with large decreases are labeled very strongly convection dominated. Although a strong convective area lies adjacent to a conductive area in

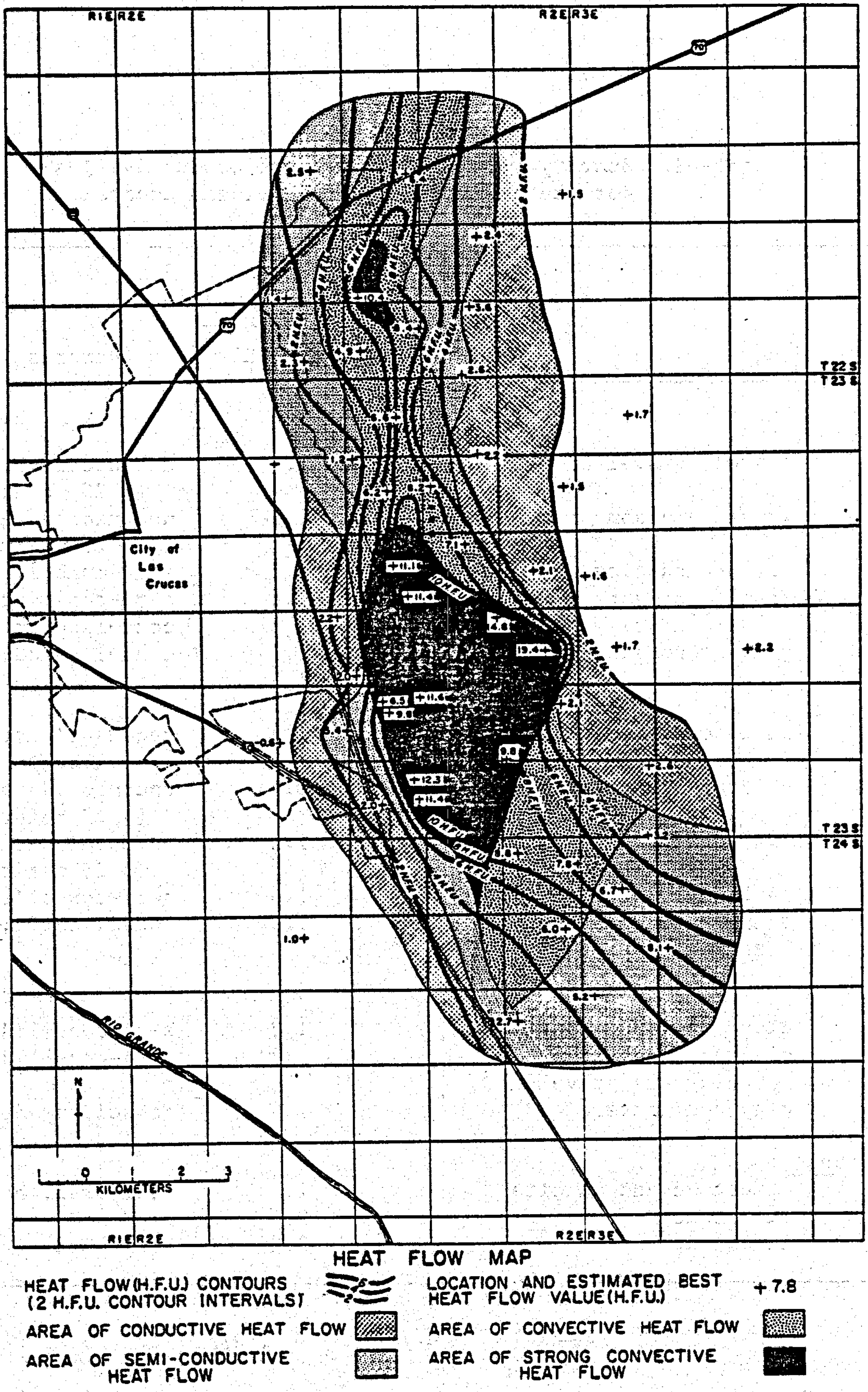


Figure 16. Heat flow map of the area surrounding Tortugas Mountain.

Table 2. Summary of estimated thermal conductivities for the area surrounding Tortugas Mountain.

Lithology	Estimated Thermal Conductivity (W/m-^{o}K)	Remarks
<u>gravels</u>		
gravel; gravel and sand	1.4	unconsolidated (< 25 meters)
gravel and sand	1.5	unconsolidated (> 25 meters)
gravel and clay	1.5	semi-consolidated
gravel and sand	1.6	semi-consolidated
gravel and clay	1.8	consolidated, hard
gravel and sand	1.9	consolidated, hard
<u>sands</u>		
sand (coarse, medium, and fine); sand and clay	1.4	unconsolidated to semi-consolidated
sand and gravel	1.4	unconsolidated (< 25 meters)
sand and gravel	1.5	unconsolidated (> 25 meters)
sand and gravel	1.6	semi-consolidated
sand (well-cemented); sand and gravel	1.9	consolidated, hard
<u>clays</u>		
clay; clay and calcite	1.3	semi-consolidated
clay and sand; clay and gravel	1.4	semi-consolidated
clay and gravel	1.5	consolidated, hard
<u>limestones</u>		
limestone and calcite	1.7	fractured, hard
limestone	2.1	hard
limestone	2.2	very hard

Figure 16, this condition should not be interpreted as a strict physical model but instead as a measure of the contrast between the heat flow character of the two adjacent drill sites.

2.4 Geological and Geophysical Data

2.4.1 Tectonic Features

Several miles to the east of the area surrounding Tortugas Mountain, Seager (1981) has mapped pre-late-Quaternary faults which trend in a NW-SE direction. The Massey Tank Fault zone and the Pena Blanca Fault in the southern part of the Organ Mountains, approximately 10 kilometers to the southeast of Tortugas Mountain, are on line with the NW-SE trending northern boundary fault of Tortugas Mountain. These faults are also shown on a geologic map of the area (Kottlowski, 1960). An area in the Organ Mountains near Squaw Mountain, approximately 8 kilometers to the north of the Massey Tank Fault zone and the Pena Blanca Fault, shows some NW-SE structural control (Seager, 1981) and lies on a line with a suspected NW-SE trend in the northern part of the area surrounding Tortugas Mountain evident in Figures 14 through 16.

Seager et al. (1981) show late-Quaternary N-S faulting throughout Dona Ana County. This observation is supported by geologic cross sections developed by Wilson et al. (1981), which are based on electrical resistivity data collected by Jackson (1976) and on lithologies of existing drill holes.

2.4.2 Lineament Data

A lineament study of New Mexico (Lepley, 1982) and LANDSAT and SKYLAB satellite imagery clearly show a NW-SE fracture zone extending from the northern boundary of Tortugas Mountain to the northwest across Dona Ana County. Two main trends of structural weakness in NW-SE and N-S directions are believed to intersect in Dona Ana County (Lepley, 1982; Lohse, 1982).

2.4.3 Aeromagnetic and Gravity Data

The aeromagnetic data of Keller (1979) show NW-SE and N-S structural trends (see Figure 17). These trends, defined by large magnetic gradients, are predominately NW-SE and N-S in the southern and northern parts of the area surrounding Tortugas Mountain, respectively, and may identify the positions of basement faults. Because of a limited density, the discrete fault structure is not easily recognized in Figure 18, which shows the residual Bouguer gravity data of Aiken et al. (1978).

2.4.4 Electrical Resistivity Data

Electrical resistivity data obtained by Schlumberger depth sounding techniques in the area surrounding Tortugas Mountain have been collected by Jackson (1976) and Young (1982). The electrical resistivity sites where these data were collected and the profile lines used for the current analysis are shown in Figure 19. Jackson (1976), Wilson et al. (1981), using the data of Jackson (1976), and Young (1982) have modeled electrical resistivity data in the area of Tortugas Mountain in the form of resistivity layers, for which the thickness, resistivity, and depth of emplacement are specified for each layer.

2.4.5 Subsurface Structure

In order to postulate the subsurface structure of the area surrounding Tortugas Mountain, electrical resistivity layers were correlated to determine cross sections along profile lines from one depth sounding to another. The cross section for the profile line C1-C10 is shown in Figure 20. A complete set of cross sections is included in Appendix B.

These correlations are based on: (1) relative and systematic changes between alternate or sequential high and/or low resistivity values; (2) similar thicknesses and depths of layers with comparable resistivity values; and (3) order of magnitude changes in resistivity values.

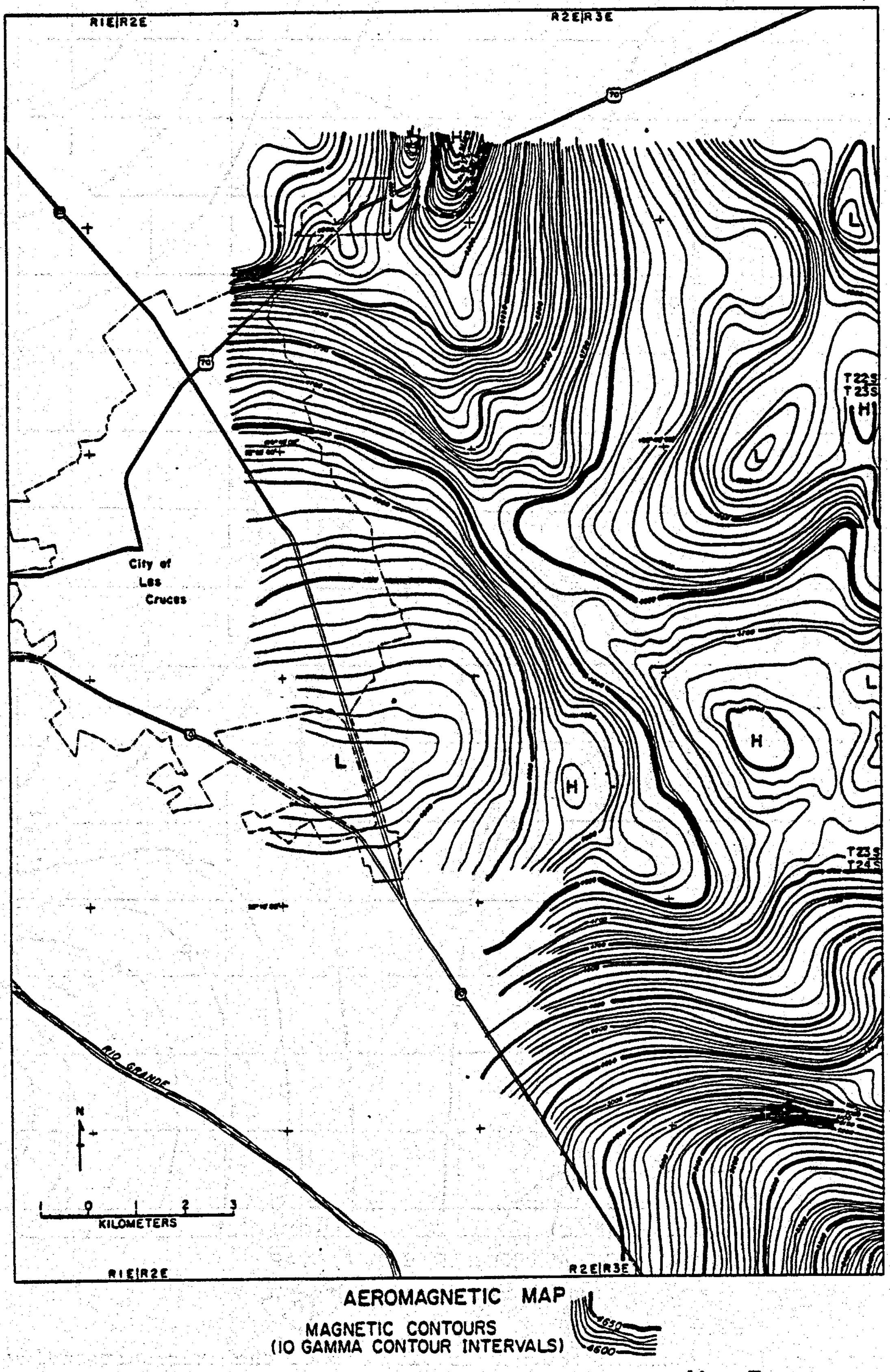


Figure 17. Aeromagnetic map of the area surrounding Tortugas Mountain [after Keller (1979)].

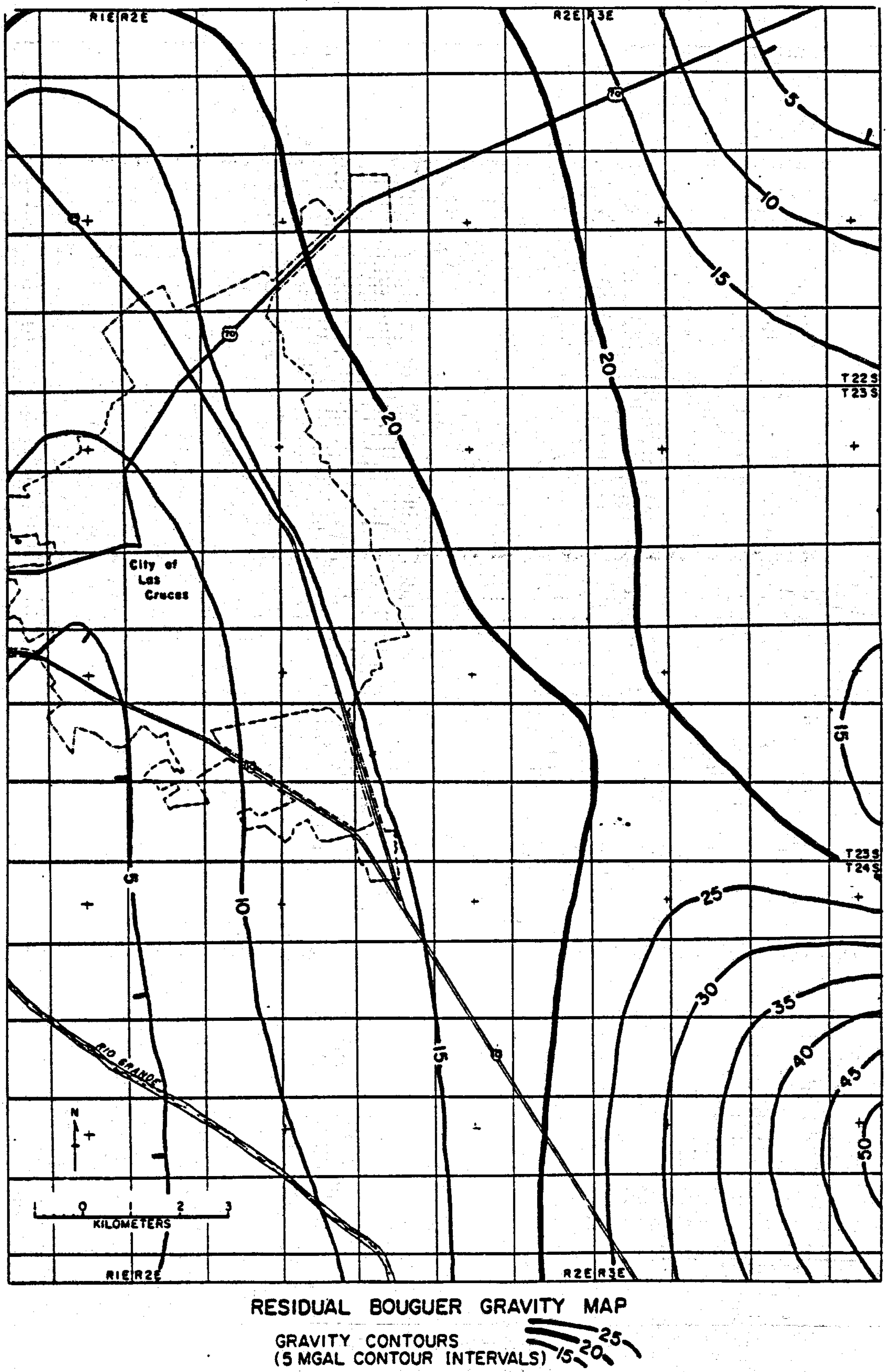
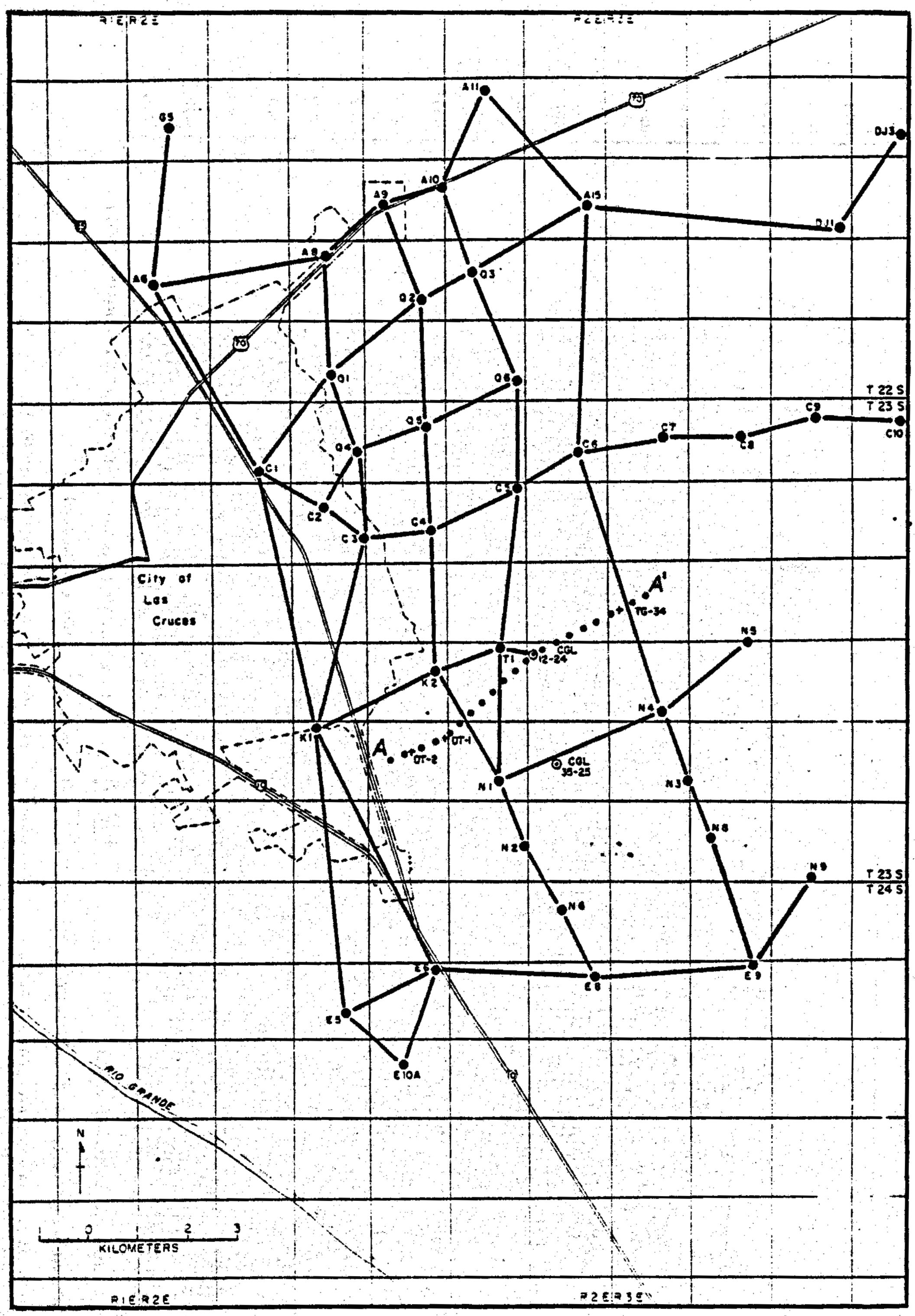


Figure 18. Residual Bouguer gravity map of the area surrounding Tortugas Mountain [after Aiken et al. (1978)].



LOCATION MAP FOR ELECTRICAL RESISTIVITY SITES AND PROFILE LINES

LOCATION AND NAME OF ELECTRICAL RESISTIVITY SITE ●A9 — POSITION AND NAME OF PROFILE LINE (A9 — A10 — A11)

CHAFFEE GEOTHERMAL, LTD. DEEP TEST WELL ◎ 12-24

Figure 19. Electric resistivity sites and profile lines for the area surrounding Tortugas Mountain. The data are taken from Jackson (1976) and Young (1982). The profile line A-A' is discussed in Section 3.3.2.

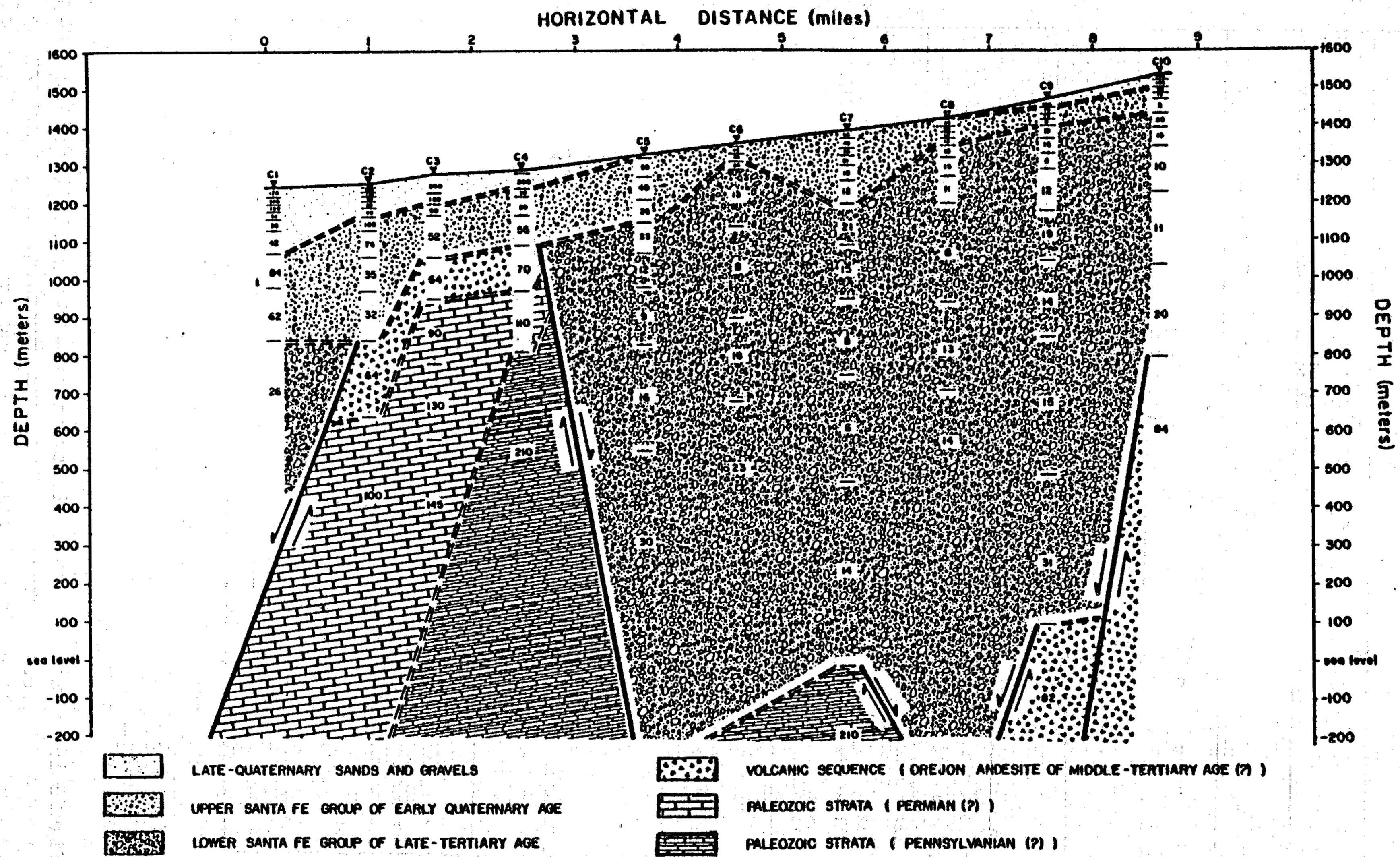


Figure 20. Lithologic cross section for line C1-C10. The resistivity data are given in units of ohm-meters.

Three distinct subsurface formations are identifiable from these correlations, namely, three layers of sediments, one volcanic sequence, and three divisions of Paleozoic strata. In order of increasing depth, the sedimentary layers are interpreted to be: (1) late-Quaternary sands and gravels; (2) the Upper Santa Fe group of early-Quaternary age; and (3) the Lower Santa Fe group of late-Tertiary age. The Orejon Andesite of late-Eocene of early-Oligocene (middle-Tertiary) age is believed to comprise the volcanic sequence. The three divisions of Paleozoic strata are defined by large increases in resistivity values and are interpreted to be increasingly deep and dense layers of the Permo-Penn, or possibly Mississippian or Devonian, age.

The cross sections corresponding to the profile lines shown in Figure 19 are synthesized into a subsurface fault map reproduced in Figure 21. Estimated depths to bedrock, interpreted as the Paleozoic strata, are also shown in Figure 21. The subsurface faults are inferred primarily from offsets in the correlated resistivity layers. However, surface faults and geology by Kottowski (1960), King and Kelley (1980), Seager (1981), and Seager et al. (1981); lineament data from Lepley (1982); aeromagnetic data by Keller (1979); residual Bouguer gravity data of Aiken el al. (1978); satellite imagery and aerial photography; and temperature and heat flow data compiled from the temperature gradient holes also contributed to the placement of the subsurface faults. Estimated depths to and dip directions of the bedrock are taken from the lithologic cross sections and local geology. The magnitude of the dip is inferred from the observed dip of exposed Paleozoic outcrops at Tortugas Mountain and in the Bishop Cap area of the Organ Mountains, located approximately 12 kilometers to the southeast.

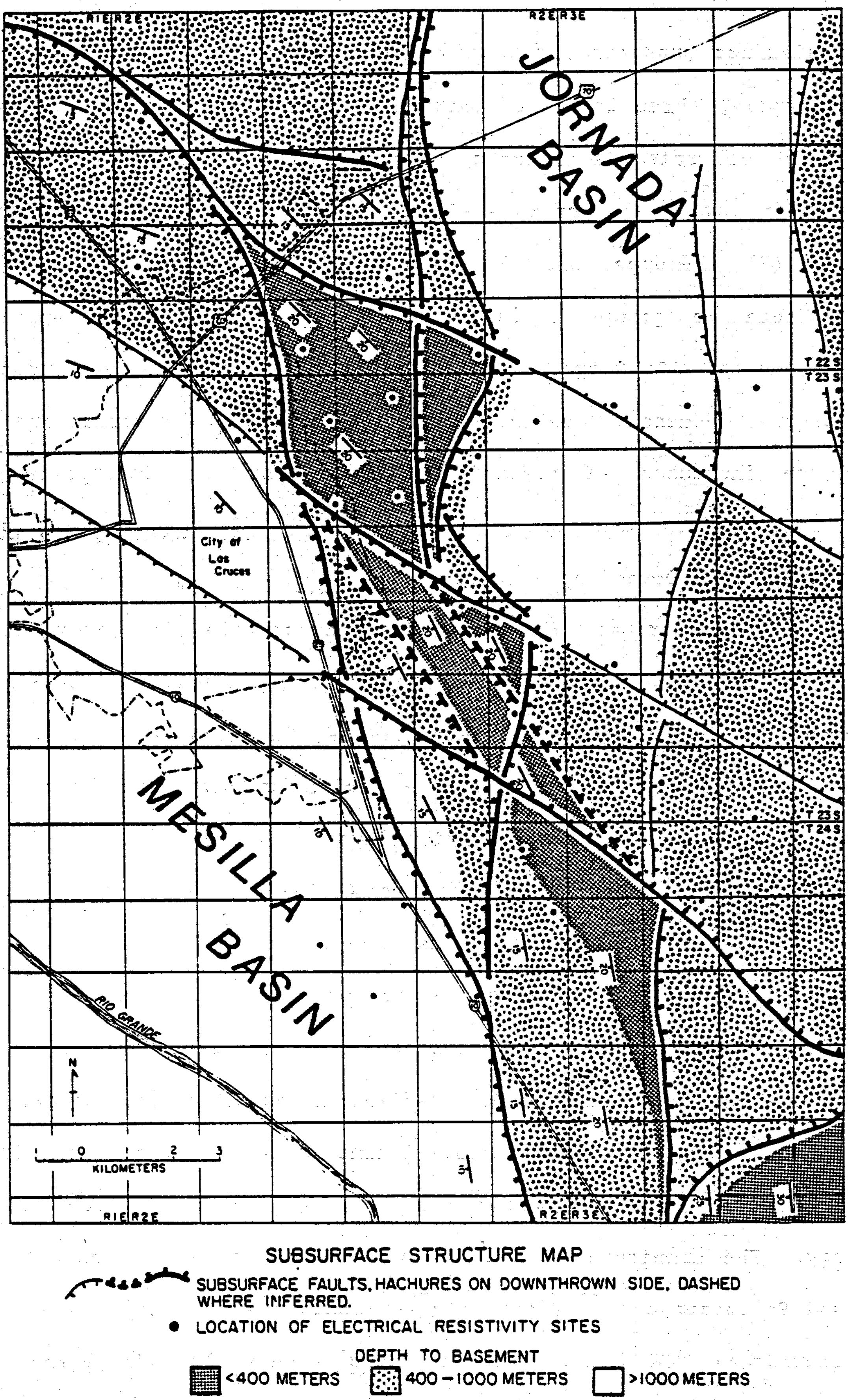


Figure 21. Subsurface structure of the area surrounding Tortugas Mountain. The numbered values indicate the dip of the strata in degrees.

2.5 Discussion

Both the temperature and heat flow data (see Figures 14 through 16) show a similar pattern for the thermal anomaly. Sharp contrasts in bottom-hole temperatures (i.e., 20 to 54°C), heat flow values (i.e., 2 to 19 HFU), and in the character of the heat flow (i.e., conductive to strongly convective) over distances on the order of 1 kilometer within the area surrounding Tortugas Mountain indicate the existence of a near-surface, fault-controlled hydrothermal system.

Where the contrast is not so sharp, the fault-controlled hydrothermal system is probably somewhat deeper, hidden below the Quaternary sediments. Because the sharpest contrast occurs where the electrical basement (Permo-Penn) is well exposed (Tortugas Mountain), the basement fault structure may well control the hydrothermal system. However, because large lateral hot water flows lead to high heat flow values, are of a convective nature, and probably occur following the ascent of the geothermal fluids through the basement (Permo-Penn) and into the overlying Quaternary sediments, there may be significant deviations between actual fault positions and the positions inferred from sharp contrasts in temperatures, heat flow values, and modes of heat transfer. In particular, this condition may be true for the high heat flow area west of Tortugas Mountain (see Figure 16). This strongly convective zone may be caused by: (1) hot water flowing in a southerly direction following its ascent up the NW-SE trending northern boundary fault of Tortugas Mountain or (2) vertical flow of hot water up through an extremely fractured basement caprock overlying a very large convective system and geothermal reservoir.

The subsurface structure map (see Figure 21) suggests that the fault-controlled hydrothermal system is composed of NW-SE and N-S components, which give the system an apparent NNW-SE trend. There is also a strong spatial correlation between the apparent NNW-SSE trending thermal anomaly and the deep structural control defined by gravity and aeromagnetic maxima. These maxima and the thermal anomaly closely coincide in the northwest and southeast portions of the area surrounding Tortugas Mountain, while the gravity and aeromagnetic maxima trend slightly to the east of the thermal anomaly in the central portion of the area. Both the gravity and aeromagnetic data show very large maxima in the southeast portion of the area surrounding Tortugas Mountain, where analyses of temperature gradient and heat flow data show an increase in the temperature gradient with depth and suggest a semi-conductive to conductive mode of heat transfer, respectively.

Temperature gradient and heat flow values in the southeast part of the area surrounding Tortugas Mountain are as high as 200°C/km and 7 to 8 HFU, respectively, with bottom-hole temperatures of 41°C at 90 meters. If temperature gradients of this magnitude persist with depth, temperatures of 100°C could exist at depths as shallow as 400 meters.

3.0 Deep Test Production Well Drilling in the Area Surrounding Tortugas Mountain

3.1 Introduction

Chaffee Geothermal, Ltd. is a small, independent geothermal production company located in Denver, Colorado, which holds federal and state geothermal leases for approximately 16,000 acres of land east of Las Cruces, New Mexico. In addition to this lease acreage, Chaffee is pursuing an interest in another 10,000 acres of lease applications. Both the leased land and the land under lease application are contained in an area of interest that is 14 miles long and 2.5 miles wide. This oblong area of interest is oriented north by northwest and is situated approximately 5 miles east of downtown Las Cruces.

Work began on the Chaffee Geothermal, Ltd. Las Cruces deep test production well drilling project in 1981 when farm-out agreements with Southland Royalty Company were completed. Subsequent lease acreage was acquired by Chaffee Geothermal, Ltd. in 1981 and 1982 through direct federal and state leasing programs.

A shallow temperature gradient survey (see Chapter 2) along with other published information suggested that a forced convective system with hot water ascending along deep and steep faults bordering the Jornada Basin was present beneath the lands under lease. The reservoir was envisioned to consist of fractured Paleozoic rocks, primarily limestone, in a north by northwest trending horst complex that stood between the Jornada Basin to the east and the Rio Grande Basin to the west. This model predicted water flow up along the Jornada Fault zone and descending again to the west along bedding planes in the Paleozoic rocks, eventually finding its way into the sediments of the Rio Grande Basin. The congruence of the surface temperature anomaly with the boundaries of the horst block, the parallelism of isotherms with known and inferred faults, and the abrupt transition from background to anomalous surface temperatures all suggested a fault-controlled system.

3.2 Exploration Program Initiated in 1981 by Chaffee Geothermal, Ltd.

The production test well locations were selected by considering three principal criteria: (1) proximity to important faults controlling the ascent of the geothermal water; (2) access from existing roads to minimize environmental impact, permitting time, and road building expenses; and (3) a reasonable pipeline distance to L'Eggs Products, Inc. (Hanes Corporation) and Sandyland Nursery. Five locations were originally chosen and permitted; however, only two wells were drilled. The location of these wells, Chaffee-Las Cruces 35-25 and 12-24, are shown in Figure 19. Drilling activities were conducted during late 1981 and early 1982, with a target temperature of 200°F.

Schlumberger depth soundings indicated that the depth to reservoir rock (limestone) did not exceed 1,500 feet at the chosen well locations, so 2,000 feet was selected as the maximum anticipated drilling depth. All of the proposed wells were permitted to 2,000 feet. The selection of a drilling contractor and the well construction was based on this depth.

Billings Drilling Company of Salt Lake City, Utah, was chosen as the drilling contractor because their equipment was in excellent condition and the company had a proven record of drilling similarly designed geothermal wells successfully. Billings operates a Chicago-Pneumatic RT 1800 with a mast capacity of 60,000 pounds. The rig is outfitted with a Gardner-Denver 5-1/2 inch x 8 inch mud pump, rated at 220 gallons per minute at 338 pounds per square inch, and an air compressor, rated to deliver 825 cubic feet per minute at 250 pounds per square inch. Billings was awarded a daywork contract that provided operating rig time at $160 per hour and standby time at $125 per hour, including all support equipment and personnel.

Energy Services, Inc. of Idaho Falls, Idaho, was chosen to engineer the wells and supervise the drilling operations. Energy Services has been involved with many shallow, low-temperature geothermal well drilling activities throughout the western United States.

3.2.1 Well Design

The original well designs for Chaffee-Las Cruces 35-25 and Chaffee-Las Cruces 12-24 were identical. A 7-7/8 inch pilot hole would be drilled with mud through the alluvium and into the limestone bedrock. This hole would be opened to 16 inches to set and cement 12-3/4 inch OD, 33.38 pounds per foot casing into the bedrock, at a depth expected to be 500 to 600 feet.

After setting and drilling out the surface casing, the well would continue with a 12-1/4 inch bit through the production zone or to 2,000 feet, whichever occurred first. This stage of drilling was planned to use an air circulation system with foam or stiff foam to control loss of circulation.

An 8-5/8 inch, 22.36 pounds per foot casing with slotted intervals as needed was planned as the production casing string. The weight of 2,000 feet of this pipe approached the hoisting capability of the drilling rig, so it was hoped that less than 2,000 feet of production casing would be necessary.

If conductor casing was needed to case out cool water or lost circulation zones, then drilling would proceed below this second string of casing with a 7-7/8 inch bit. This option was possible since 6 inch drill collars would be used throughout the drilling process. A 6-5/8 inch liner could then be hung from the conductor casing if conditions warranted.

3.2.2 Well 35-25 History

The daily progress of drilling operations for Well 35-25 is given in Table 3. Well construction departed from the initial design early in the drilling process. Since this well was the first drilled into the limestone reservoir, safety considerations changed the casing points because there was a possibility of intercepting an over-pressured or artesian system that could not be controlled without surface casing.

A profile for Well 35-25 is shown in Figure 22. The 12-3/4 inch casing was set at 260 feet to ensure well control. The 8-5/8 inch casing was set at 560 feet, the depth at which limestone was encountered. This string of casing was intended to penetrate through the limestone contact to ensure an adequate cement seal, but wall caving from the unconsolidated alluvium above filled the hole from the drilled depth of 582 feet back to 560 feet.

Drilling with mud circulation continued to the first significant lost circulation zone at 642 feet. This zone was capable of producing 250 gallons per minute of 150°F water. Drilling continued below this zone with air circulation provided by the rig-mounted compressor. A 7-7/8 inch hole was drilled to 950 feet before air line pressures equaled the capability of the rig compressor. Several more production zones had been encountered by this time, and the pumped capacity of the well was probably up to 1,000 gallons per minute. Because of inadequate lifting capability, there was no circulation to the surface from depths below 755 feet.

The well was temperature logged to 950 feet and cement operations were undertaken to seal out water from the wellbore, since production temperatures were still 50°F below the target temperature of 200°F. The

Table 3. Well history for Chaffee-Las Cruces 35-25.

Date	Activity
11-10-81	Drilling rig and equipment arrive in Las Cruces.
11-11-81	Drill pad construction and road work.
11-12-81	Excavate mud pits, set blocks for rig base, rig-up, haul water, and mix mud.
11-13-81	Start 24 hour per day operation. Spud in at 8:00 am. Drill 8-3/4" hole to 260'. Open at 16" to 220'. Drilling and opening with mud.
11-14-81	Open at 16" to 260'. Run 12-3/4" OD casing to 260'. Cement 12" casing with 258 ft^3 class G cement. WOC.
11-15-81	WOC. Drill out cement with 11" bit. Drill 7-7/8" hole to 520' with mud.
11-16-81	Drill 7-7/8" hole to 642'. Open at 11" to 530' with mud. Open at
11-17-81	11" to 582'. Run 8-5/8" OD casing to 560'. Cement 8" casing with 250 ft^3 class G cement. WOC.
11-18-81	WOC. Drill out cement with 7-7/8" bit.
11-19-81	Drill with mud to 642'. Lost circulation at 642'. Pull out and install well control equipment. Switch to air. Drill 7-7/8" hole to 665'.
11-20-81	Drill 7-7/8" hole to 806'. Pull out to change bit. Temperature log hole. Trip back to bottom with new 7-7/8" bit.
11-21-81	Drill 7-7/8" hole to 950'. Run short term air-lift tests at 548', 608', and 668'. Trip out of hole. Run temperature log. Pour cement down hole to seal lost circulation zones. WOC.
11-22-81	Drill out cement with 7-7/8" bit. Continued lost circulation. Order 3-1/2" OD pipe to pump additional cement. Run 840' of 3-1/2" pipe into hole.
11-23-81	Pump 400 ft^3 class G cement in five stages. Attempt to pull 3-1/2" pipe from 630'; stuck. Pull 45,000 lb on 3-1/2" pipe, but cannot free it. Suspend operations at 7:00 pm.
11-24 to 12-1-81	Suspend operations.
12-2-81	Run into hole with 3" hammer. Attempt to drill down beside 3-1/2" pipe. Hammer torques up and is damaged. Back off 3-1/2" pipe and pull out 31' of 3-1/2" pipe. Rig down and move equipment to Chaffee-Las Cruces 12-24.
12-3-81	Clean up site and shut in well.

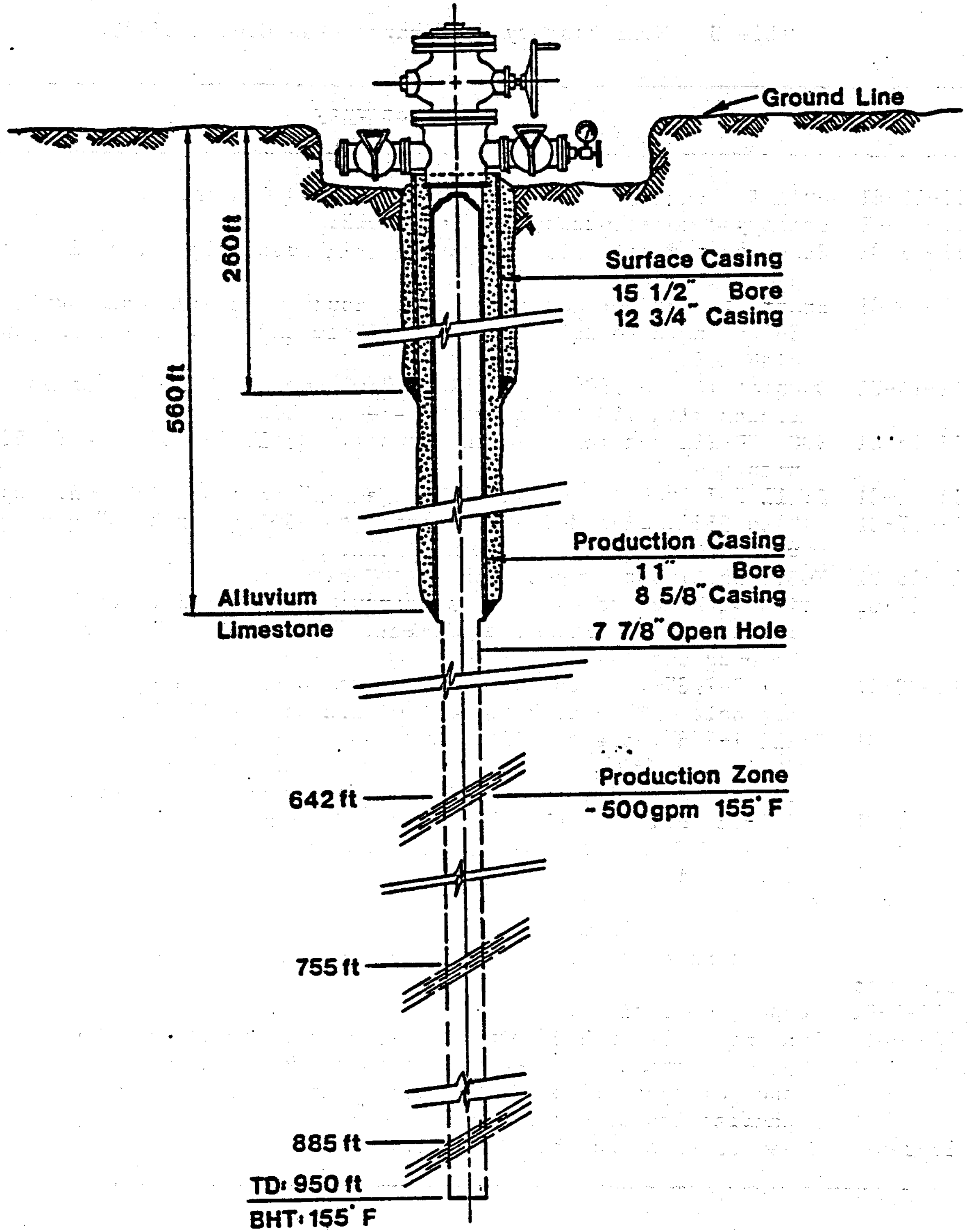


Figure 22. Profile for Well 35-25.

cementing option was taken rather than employing additional air compressors and boosters because this strategy seemed to stand a reasonable chance of success at a much lower cost. Approximately 160 cubic feet of cement was poured from the surface in the first attempt to seal the water zones. This technique succeeded only in sealing the lowest zone at 885 feet, and the cement level was tagged with drill pipe at 880 feet. Then, 840 feet of 3-1/2 inch OD pipe was run into the well to pump cement directly into the water zones. Forty cubic feet of cement was pumped at this depth, and the pipe was then pulled up to 798 feet. Another 40 cubic feet of cement was pumped at 756 feet, and again at 630 feet. This staged operation brought the cement level to 640 feet. Although another 80 cubic feet of cement was pumped down the hole, the cement level did not rise above 640 feet. The zone at 640 feet seemed to be quite cavernous, and so another 80 cubic feet of cement was pumped down the hole. Only 14 cubic feet of this last volume of cement went into and filled up the zone at 640 feet. The remaining 66 cubic feet rose up the hole and into the casing to the 450-foot level.

Apparently, the 180 feet of 3-1/2 inch pipe that was buried in cement provided a greater frictional resistance to pulling than the maximum lift of the rig because 45,000 pounds of pull was registered on the weight indicator without moving the pipe more than one inch. It is also possible that the cement was setting very quickly since the borehole temperature was at least 150°F, and possibly hotter as the result of the exothermic setting of such a large quantity of cement in the hole. Consequently, the 3-1/2 inch pipe became cemented into the well. An unsuccessful attempt was made to salvage the well several days later by drilling alongside the 3-1/2 inch pipe. The current status for this well is plugged and abandoned. A cement plug is in the well from 450 to 950 feet of depth. No further attempts are planned to salvage this well.

3.2.3 Well 12-24 History

The daily progress of drilling operations for Well 12-24 is given in Table 4. Well construction design changed from the original plan before the well was spudded, namely, the first two strings of casing became 16 inch OD and 12-3/4 inch OD in order to accommodate a larger pump in the completed well.

A profile for Well 12-24 is shown in Figure 23. The 16 inch casing was set at 468 feet in an 18-3/4 inch hole. This hole was initially drilled as a 7-7/8 inch pilot hole, then opened to 15-1/2 inches, and finally opened to 18-3/4 inches. Mud circulation was used to the lost circulation zone at 435 feet and water circulation was used below this zone. The 16 inch string cased out 400 feet of alluvium and the large cavity in the limestone at 435 feet.

Drilling was able to continue with mud for 96 feet below the 16 inch casing when lost circulation was encountered again. All drilling below 564 feet was accomplished with an air-foam circulation system. The drilling continued to a production zone at 889 feet, at which time too much water was flowing into the well to be lifted with the rig-mounted compressor. Opening to 15-1/2 inches was then begun so that 12-3/4 inch pipe could be used to case out the 889-foot zone. However, plans were changed and the hole was opened only to 886 feet, when auxiliary air compressors were acquired in order to regain circulation.

An 850 cubic feet per minute Quincy primary compressor and a 1,500 pounds per square inch Joy two-stage booster provided adequate circulation capability for deepening the 7-7/8 inch hole to 1,315 feet, the total depth

Table 4. Well history for Chaffee-Las Cruces 12-24.

Date	Activity
12-2-81	Begin moving rig and equipment onto site.
12-3-81	Finish moving onto site. Rig-up. Haul water and mix mud. Spud in with 8-3/4" bit at 11:50 pm.
12-4-81	Drill 8-3/4" hole to 15'. Pull out and make up 7-7/8" bit onto drill collar. Drill to 158'. Trip out to change bit. Drill 7-7/8" hole with mud to 285'.
12-5-81	Drill 7-7/8" hole to 412". Trip out to change bit. Drill 7-7/8" hole with mud to 435'. Total lost circulation at 435'. Pull out of hole to ream to 16". Pick up 16" opener. Open at 16" to 22'.
12-6-81	Open hole at 16" to 180'. Shut down for repairs to mud pump.
12-7-81	Shut down for repairs to mud pump. Open hole at 16" to 200'.
12-8-81	Open hole at 16" to 370'.
12-9-81	Open hole at 16" to 435". Trip out of hole with plugged bit.
12-10-81	Make up 7-7/8" bit to investigate depth of void at 435'. Touch bottom of void at 450'. Drill 7-7/8" hole with water to 463'. Trip out of hole and make up 18-3/4" opener. Open hole at 18-3/4" to 160' with mud.
12-11-81	Open hole at 18-3/4" to 351'. Twist 7-7/8" pilot off at 6:30 pm. Wait on fishing tools.
12-12-81	Wait on fishing tools. Fishing.
12-13-81	Fishing. Wait for replacement crossover sub to arrive.
12-14-81	Open hole at 18-3/4" to 431' with mud. Total lost circulation at 431'. Open hole at 18-3/4" to 453' with water.
12-15-81	Open hole at 18-3/4" to 462' with water. Trip out to inspect hole openers. Open at 18-3/4" to 470' with water.
12-16-81	Open at 18/3/4" to 477' with water. Run 16" OD casing to 468'. Cement 16" casing with 560 ft^3 of class G cement. WOC.
12-17-81	WOC. Trip into hole with 7-7/8" pilot and 15-1/4" opener to drill out cement. Drill out cement and casing shoe with water. Pull out of hole. Assemble well control equipment and stack. Trip into hole with 7-7/8" hammer.
12-18-81	Soft fill in hole prevents use of hammer. Trip hammer out of hole. Trip in with 7-7/8" bit. Drill 7-7/8" hole to 535' with mud.
12-19-81	Drill 7-7/8" hole to 560' with mud. Twist off 120' above bit at noon. Wait on fishing tools. Fishing.
12-20-81	Fishing. Drill 7-7/8" hole to 564' with mud. Lost circulation at 564'. Pull out of hole. Set up to drill with stiff foam.
12-21-81	Drill 7-7/8" hole to 785" with stiff foam.
12-22-81	Trip out of hole. Run temperature log. Rig down and secure equipment for Christmas break.
12-23-81 to 1/5/82	Suspend operations.
1-5-82	Repair front jack. Trip out of hole to change bit. Drill 7-7/8" hole to 815' with stiff foam.

Table 4. (continued).

Date	Activity
1-6-82	Drill 7-7/8" hole to 880' with stiff foam. Lose stiff foam circulation to surface at 889'. Run short term air-lift tests. Trip out of hole. Run temperature log. Trip into hole with 15-1/4" opener.
1-7-82	Open hole at 15-1/4" to 500' with stiff foam. Shut down for repairs. Open hole at 15-1/4" to 510'.
1-8-82	Open hole at 15-1/4" to 540'. Twist off at 3:00 pm. Wait on fishing tools. Fishing.
1-9-82	Lay down and remove defective 4-1/2" pipe. Pick up and stack replacement 3-1/2" drill pipe. Open hole at 15-1/4" to 600' with foam.
1-10-82	Shut down for repairs to injection pump. Open hole at 15-1/4" to 700'.
1-11-82	Open hole at 15-1/4" to 808'. Shut down for repairs to clutch.
1-12-82	Shut down for repairs to clutch.
1-13-82	Shut down for repairs to clutch. Thaw out frozen pumps, lines, and equipment.
1-14-82	Open hole at 15-1/4" to 860' with foam.
1-15-82	Open hole at 15-1/4" to 893' with foam. Wait on auxiliary compressor and booster. Rig up equipment for high pressure drilling.
1-16-82	Rig up equipment for high pressure drilling. Drill 7-7/8" hole with foam to 905'.
1-17-82	Drill 7-7/8" hole to 1,025' with foam.
1-18-82	Drill 7-7/8" hole to 1,055' with foam. Trip out to change bit. Drill 7-7/8" hole to 1,150' with foam.
1-19-82	Drill 7-7/8" hole to 1,215' with foam. Trip out of hole to change bit. Temperature log hole. Trip into hole.
1-20-82	Drill 7-7/8" hole to 1,286' with foam.
1-21-82	Drill 7-7/8" hole to 1,315'. Run logs: natural gamma, sonic, temperature. Begin running 12-3/4" OD casing into hole.
1-22-82	Run 12-3/4" casing to 876'. Prepare to drill out float plug and casing shoe.
1-23-82	Drill out float plug and casing shoe. Cement bottom of casing with 70 ft^3 of class G cement. Trip into hole. WOC.
1-24-82	WOC. Shut down for repairs to hydraulic system. Drill out cement in 12" casing with 11" bit. Trip out of hole.
1-25-82	Trip into hole with 7-7/8" bit to check that hole is open to bottom. Encounter obstruction at 905'. Trip out of hole to put on collars. Trip into hole with collars. Finish cementing 12-3/4" casing with 280 ft^3 of class G cement. WOC. Push obstruction to 1,085'.
1-26-82	Trip out of hole to remove check valves from string for air-lift/hydrologic test. Run air-lift test. Air lift water to clean out cuttings from well.
1-27-82	Continue air lifting water to remove drill cuttings. Trip to bottom of hole for final bottom confirmation: 1,078'. Trip out of hole. Release rig.
1-28-82	Rig down and load equipment for departure.

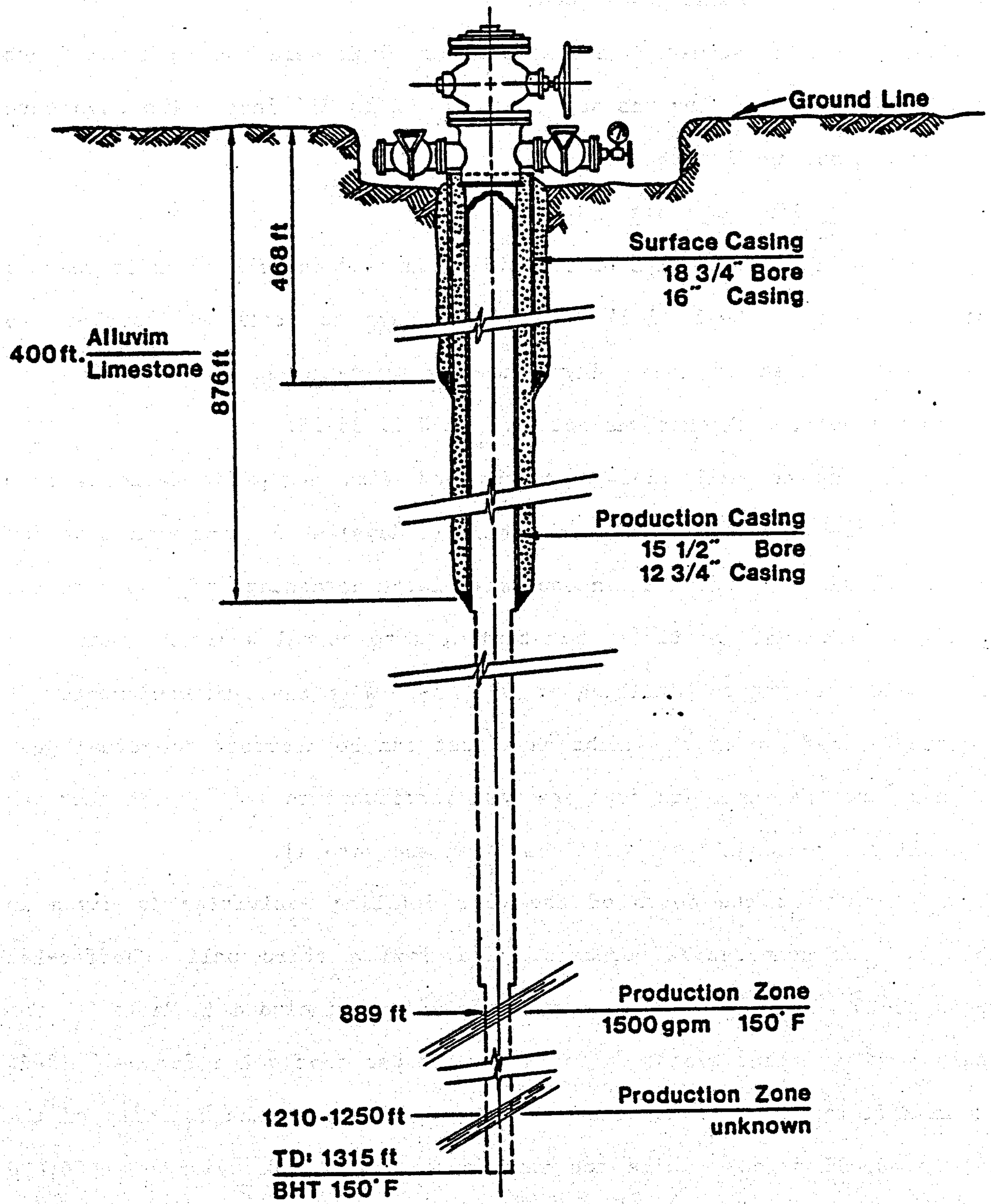


Figure 23. Profile for Well 12-24.

achieved in this well. Returns were intermittent towards the lower part of the well, but hole cleaning was good.

Natural gamma, acoustic, and temperature logs were run to total depth and the 12-3/4 inch casing was set and cemented at 876 feet. Two days were used to test and develop the well.

3.2.4 Drilling Analysis

Whereas only eleven days of rig time were used on Well 35-25 to reach a depth of 950 feet, Well 12-24 required 42 days to drill and complete to 1,315 feet. Three of these days, however, were used to log, test, and develop the well, work that was not done on Well 35-25.

Operations on Well 12-24 were plagued with equipment failures from start to finish. A total of 190-1/2 hours (8 days) were spent shut down for repairs and fishing, which is an unusually large percentage of down time for any rig and can only partially be attributed to normal wear and tear. No time was lost during the drilling of Well 35-25 with the same equipment. It is probable that two of the eight days lost can be ascribed to normal wear and tear, but the other six days are best attributed to using a rig that was too small for the drilling conditions being encountered.

A summary of the costs of the 1981 drilling activities is given in Table 5. For comparative purposes, data from a third well, Chaffee-Las Cruces 55-25, drilled during the fall of 1982 are included in Table 5. The single most important factor in the high cost per foot value for Well 12-24 was insufficient weight capacity of the rig. The derrick capacity of the rig was 60,000 pounds, while the maximum possible hook weight was 45,000 pounds. A total of 7,800 pounds of drill collars were initially brought to the job, and additional collars obtained during the drilling process boosted

Table 5. Summary of well drilling costs.

Item	Well		
	35-25	12-24	55-25
Total well depth, feet	950	1,315	2,645
Total well cost, dollars	92,649	245,500	460,000
Average cost, dollars/foot	97.52	186.69	173.91
Drilling time (spud to rig release), days	11	42	24
Average drilling rate, feet/day	86	31	110

this value to 13,000 pounds. This weight was still only approximately one-third the bit weight needed for optimum penetration rates.

Drilling records for Well 55-25, drilled in 1982, show that the best penetration rates while drilling a 12-1/4 inch hole in limestone were achieved with 40,000 to 50,000 pounds of weight on the bit. Since a 12-1/4 inch hole cuts a 118 square inch area and the hole opening process from 7-7/8 inch to 15-1/2 inch that was used in 1981 cuts 140 square inches, the optimum penetration for opening would probably have been obtained with more than 50,000 pounds of weight.

Two of the three fishing operations that occurred during the drilling of Well 12-24 can also be attributed to insufficient weight capacity. Safe drilling practice requires that the neutral point in a drilling string (no tension or compression) be in the collars. Drill pipe is intended to be run in tension, not compression. The rig needed all of the collar weight on the bit to get any penetration at all, which allowed the lowest pieces of drill pipe to undergo compression. Both of these pipe failures occurred at or right above the drill collars. In retrospect, the rig was a very cost effective rig for the amount of work performed at Well 35-25, but a poor choice for Well 12-24.

3.3 Reservoir Geology and Interpretation

3.3.1 Well 35-25

A lithologic log, temperature log, and water analysis for Well 35-25 are included in Appendix C. No flow test data are available for Well 35-25 because the well was lost before completion. However, the temperature log to 950 feet identified two more production zones, at 755 and 885 feet, below the known production zone at 642 feet. The 755-foot zone was recognized during drilling as a lost circulation zone. There was no circulation return to the surface deeper than the 755-foot zone and, probably, cuttings from below were circulated into this zone.

The zone at 642 feet was estimated to produce 250 gallons per minute during air lifting. If each of the three production zones at 642, 755, and 885 feet in the well would have yielded equal flow, then the well should have been capable of producing 750 gallons per minute. This estimate is conservative because a pumped well ordinarily produces more flow than an air-lifted well and because smaller production zones below 755 feet may have been penetrated but not recognized.

The temperature log indicates that the temperatures of all three zones are equal, which suggests that the zones are interconnected. The low productivity of the first zone at 642 feet, compared with production zones encountered in Wells 12-24 and 55-25, suggests that no major fault was intercepted. In addition, no fault gouge nor mineralization was seen at the 642 foot zone.

The highest temperature measured in Well 35-25 was 154.4°F. This temperature probably could have been produced if the well had been pumped. The maximum surface temperature measured at the blooie line during drilling was 150°F, but this value is affected by the injection of cooler, ambient surface temperature water during foam drilling. This cooling effect is observable downhole and is more pronounced in the vicinity of a production zone because the foam has been circulated into the production zone. The temperature log for Well 35-25 shows this cooling effect at 755 and 885 feet (see Appendix C).

It is difficult to predict what temperature might have been achieved had the well been completed at the target depth of 2,000 feet. No temperature reversals were recorded on the temperature log; however, the well was isothermal for the entire section of the limestone. There is some evidence from the drilling of Well 55-25 in 1982 that the 155°F water zone is comprised of mixed water, that is, partly cooler, shallower water and partly deeper hotter water.

The depth to bedrock in Well 35-25 confirmed the interpretation from the gravity map of Brown (1977) that the Tortugas Mountain horst continues to the south. One-half mile to the southwest of Well 35-25, the depth to bedrock in the Clary-Ruther oil and gas wildcat well has been reported to be 520 feet. This well is located near the center of the gravity high reported by Brown (1977). Data from Well 35-25 suggest a minimum width of one mile for the highest part of the buried horst block just south of Tortugas Mountain, which is very nearly the maximum width of the exposed outcrop of Tortugas Mountain, measured in a northeasterly direction.

The northwest trending photo lineament just 0.3 mile northeast of Well 35-25 is interpreted as a fault with significant dip slip. If the horst block has bilateral symmetry about the Clary-Ruther well as the gravity data suggest, then this fault establishes a maximum half-width for the horst of 0.75 mile measured from the fault to the Clary-Ruther Well and a corresponding maximum width of 1.5 miles for the buried horst block. Wells designed to produce 155°F fluids can probably be completed at depths shallower than Well 35-25 within this span of the horst.

3.3.2 Well 12-24

A lithologic log, temperature log, and water analysis for Well 12-24 are included in Appendix C. The temperature-depth curve for Well 12-24 is reproduced in Figure 24. Flow data for Well 12-24 are available from a two-hour, air-lift test run on January 26, 1982. This short test gathered information for the planning of a long-term pump test. The calculated specific capacity of 9.6 gallons per minute per foot of drawdown indicates

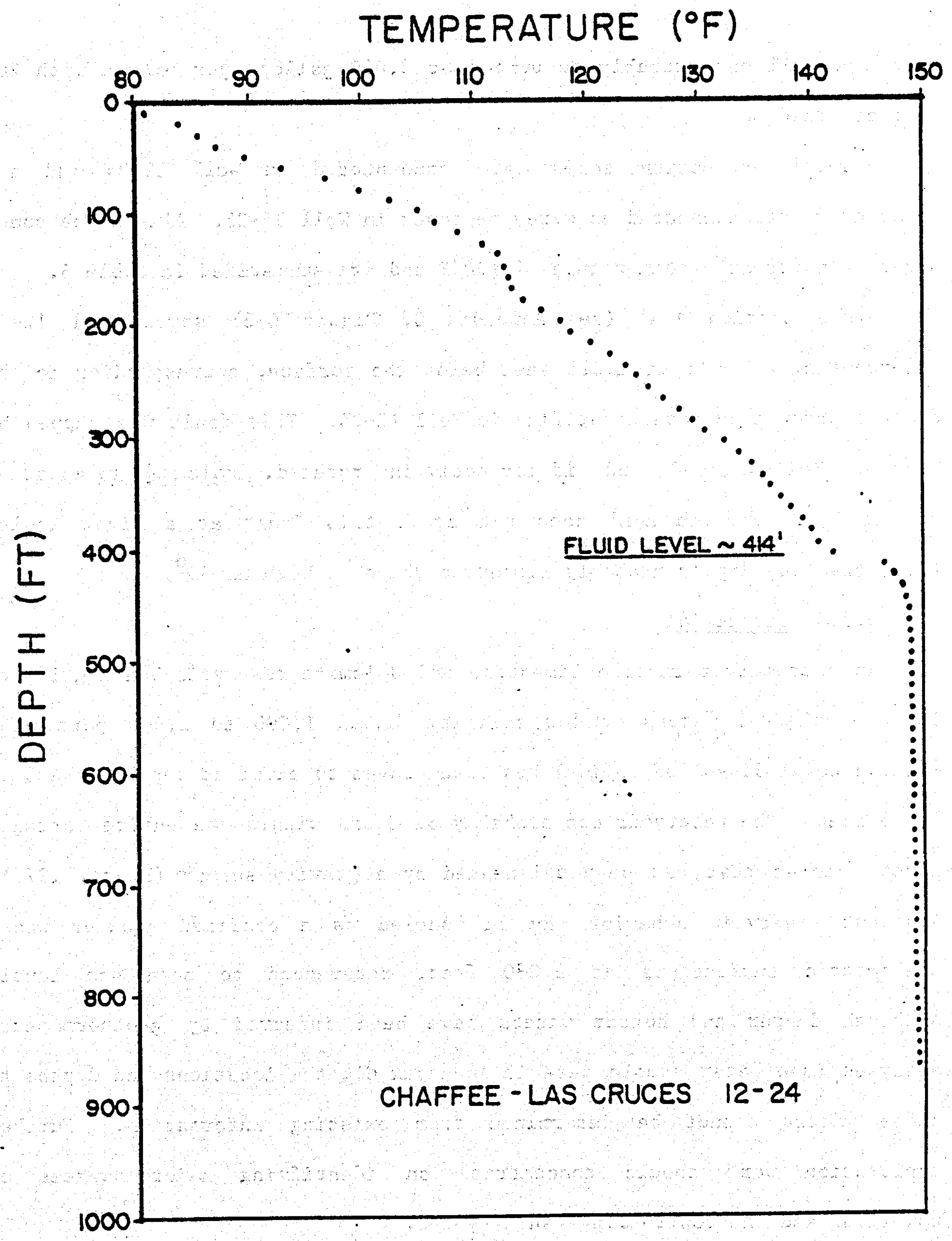


Figure 24. Temperature-depth curve for Well 12-24. The data were collected on February 1, 1982, five days after terminating air lifting. The total depth of the well is 1,315 feet.

that the well can probably be pumped at 2,000 gallons per minute with 200 feet of drawdown.

Several production zones were encountered in Well 12-24 and are apparently interconnected as were the zones in Well 35-25. All of the zones produced water at a temperature of 150°F and are summarized in Table 6.

Cross section A-A' (see Appendix C, Figure C-3) shows Well 12-24 intercepting a fault at 1,215 feet below the surface, corresponding to the deepest production zone identified in Well 12-24. This fault was mapped by King and Kelley (1980) and, if correctly interpreted, indicates an apparent dip of 52°. Section A-A' does not cross this fault at a right angle, thus, the true dip is probably larger, perhaps as high as 60°.

3.3.3 Discussion

An extremely permeable limestone and dolomite reservoir bearing 150 to 155°F geothermal waters of low salinity (i.e., 1,600 to 2,000 parts per million total dissolved solids) has been proven to exist at depths of 435 to 1,315 feet. The reservoir can probably be found within the entire Tortugas horst complex that has been delineated by a gravity survey (Brown, 1977). Apparent reservoir behavior may be modeled as a confined aquifer whose piezometric surface is at 3,880 feet, referenced to mean sea level. Although deeper and hotter waters have been inferred by geothermometry analyses (see water sample data in Appendix C), the locations and depths to those waters cannot be determined from existing information. Further exploration work should concentrate on identifying major sources of upwelling and the controlling fault system.

Table 6. Production zones encountered in Well 12-24.

Zone Depth (ft)	Comments
435 to 450	cavern, known production, cased out by 16 inch pipe
564	lost circulation zone, minor production, cased out by 12-3/4 inch pipe
595	fractured rock, increased water volume to surface during drilling, minor production zone, cased out by 12-3/4 inch pipe
800	fractured rock, increased water volume to surface during drilling, minor production zone, cased out by 12-3/4 inch pipe
889	lost circulation zone, known production, probably 50% or more of current total well production capability
1,210 to 1,250	interval identified by acoustic log, associated with known lost circulation zone at 1,245 to 1,255 feet, unknown contribution to production

4.0 Temperature Gradient Drilling in the Mesquite-Anthony Area

4.1 Introduction

Thirty shallow temperature gradient holes were drilled during 1982 on the mesa east of Interstate Highway 10 from Mesquite to Anthony, New Mexico (see Figure 1), to further delineate the Las Cruces East Mesa Geothermal Field (Lohse and Iceman, 1982). The northern boundary of this area is approximately 6 kilometers south of the southern extent of the area surrounding Tortugas Mountain that was delineated in 1981 (see Chapters 2 and 3). As the result of these two exploration programs, detailed temperature data have been collected over an area of about 250 square kilometers ($\sim$100 square miles) in Dona Ana County.

4.2 Temperature Data

The locations of the temperature gradient holes, identified by the label TG, are shown in Figure 25. Twenty-eight of the holes had target depths of 150 feet ($\sim$45 meters). Twenty-six of these holes reached the target depth, with two holes, TG-72 and TG-91, being terminated prematurely as the result of encountering hard strata at 133 feet and loss of circulation at 29 feet, respectively. Two of the thirty holes were drilled to a total depth of 315 feet ($\sim$ 95 meters). All of the holes bottomed out in Quaternary sediments, ranging from unconsolidated gravels and sands to semi-consolidated clays. Additional lithologic information is provided in Appendix D. Measured bottom-hole temperature gradients range from 37 to 177^{o}C/km. The highest temperature recorded at 45 meters was 28^{o}C observed in hole TG-68.

Examples of the temperature-depth data are given in Table 7 and Figure 26. Temperatures were recorded at one-meter intervals for the first ten meters and at five-meter intervals from ten meters to the total depth.

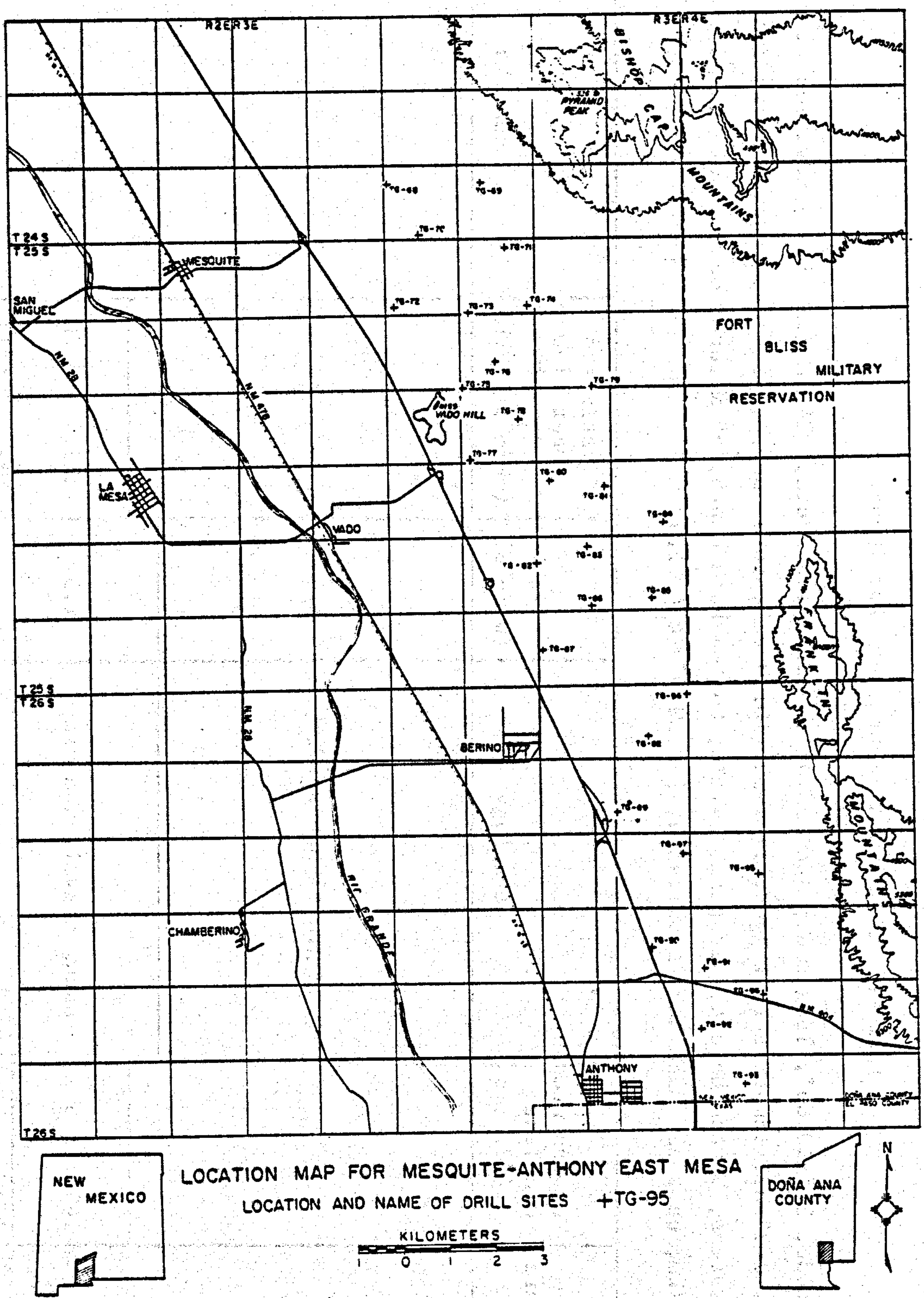


Figure 25. Location of temperature gradient holes (TG) in the Mesquite-Anthony area.

Table 7. Temperature-depth data for TG-68.

Location: latitude, 32° 10.86', longitude, 106° 38.88', township & range, T24S.R3E.33.113; elevation, 1,274 meters; spudded, 7-23-82; temperature logged, 11-1-82 (10:30 am); total depth, 95 meters; depth of 1½ inch PVC casing, 95 meters; bottom-hole temperature, 34.1°C; bottom-hole depth, 95 meters; bottom-hole temperature gradient, 149°C/km; best estimate heat flow value, 184 mW/m^2 (4.4 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mW/m^2)	Estimated Heat Flow (HFU)	Remarks
1	22.06						
2	23.55						
3	24.28						
4	24.36						
5	23.72						
6	23.24		gravel and sand	1.4			
7	23.05						
8	23.11						
9	23.18						
10	23.36						
15	24.22						
20	24.92						
25	25.63						
30	26.28	144.8 ± 5.2	sand, gravel, and clay	1.5	217	5.20	
35	27.19						
40	27.76						
45	28.49	115.2 ± 0.8			173	4.13	
50	29.01		sand and clay	1.4	161	3.86	

* Estimated thermal conductivity values.

Table 7. (continued).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow		Remarks
					(mW/m^2)	(HFU)	
55	29.58						
60	30.19						
65	30.74						
70	31.31						
75	31.93	115.2 ± 0.8	sand and clay	1.4	161	3.86	
80	32.49						
85	33.08						
90	33.59						
95	34.12						

*Estimated thermal conductivity values.

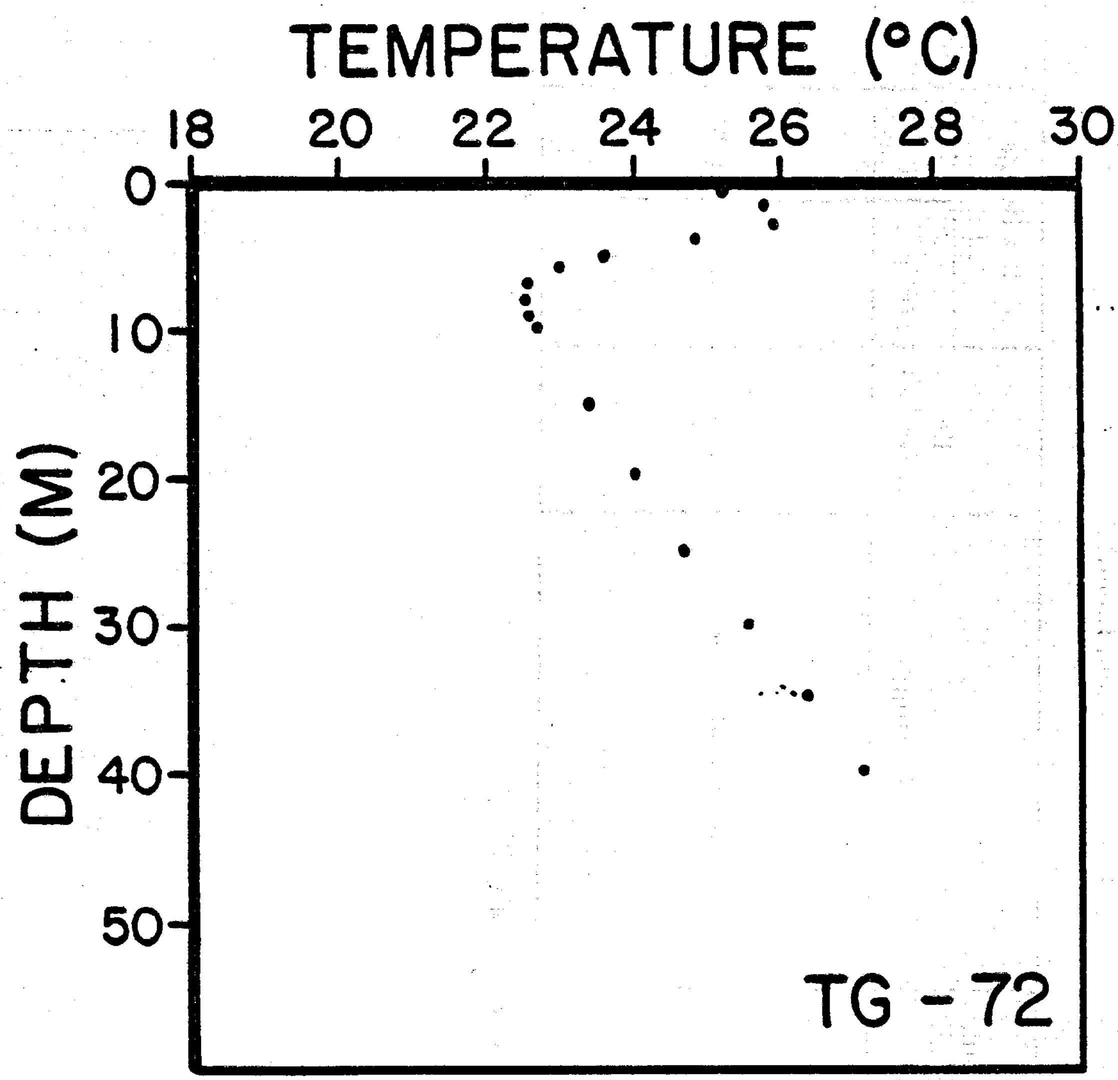


Figure 26. Temperature-depth curve for TG-72.

Depth intervals for which temperature gradients are calculated are given in Appendix D. Representative temperature gradients for each of these intervals were computed using a least-squares fit routine. The standard error of the estimate for the temperature gradient is also reported for each depth interval. Temperature gradients were not calculated for temperature data above 20 meters in order to avoid diurnal and annual temperature disturbances. A complete compilation of all of the temperature data for the 30 temperature gradient holes is included in Appendix D.

Figure 27 shows the hole locations and temperatures at 30 meters. The temperature data are hand-contoured at 1°C intervals. In general, temperatures decrease from north to south and from west to east, although a small increase in temperature appears to occur near the Texas border.

4.3 <u>Heat Flow</u>

Heat flow values for specified depth intervals were calculated for each of the holes based on measured temperature gradients and estimated thermal conductivities (see Table 8). When heat flow values have been calculated for more than one interval in a given hole, the best estimate heat flow value represents a simple average of the heat flow values. The hole locations, best estimates for heat flow values for the individual drill sites, and heat flow contours for the Mesquite-Anthony area are shown in Figure 28. The heat flow data are hand-contoured at 1 HFU intervals. These best estimates range from 1.6 to 5.3 HFU. In general, heat flow values decrease from north to south with a small rise in heat flow occurring near the Texas border. In an east to west direction, heat flow values exhibit a somewhat cyclic pattern from highs to lows to highs in the northern part of the Mesquite – Anthony area.

Table 8. Summary of estimated thermal conductivities for the Mesquite-Anthony area.

Lithology	Estimated Thermal Conductivity (W/m-^{o}K)	Remarks
gravels and sands		
gravel and sand	1.4	
sand and gravel	1.5	semi-consolidated
gravel, sand, and clay	1.5	
sand, gravel, and clay	1.5	
sands and clays		
sand and clay	1.4	
sand and clay, alternating layers	1.4	
sand, clay, and gravel	1.5	semi-consolidated
clays		
clay	1.3	semi-consolidated
clay	1.4	consolidated, hard
clay and sand	1.4	semi-consolidated
clay and sand	1.5	consolidated, hard

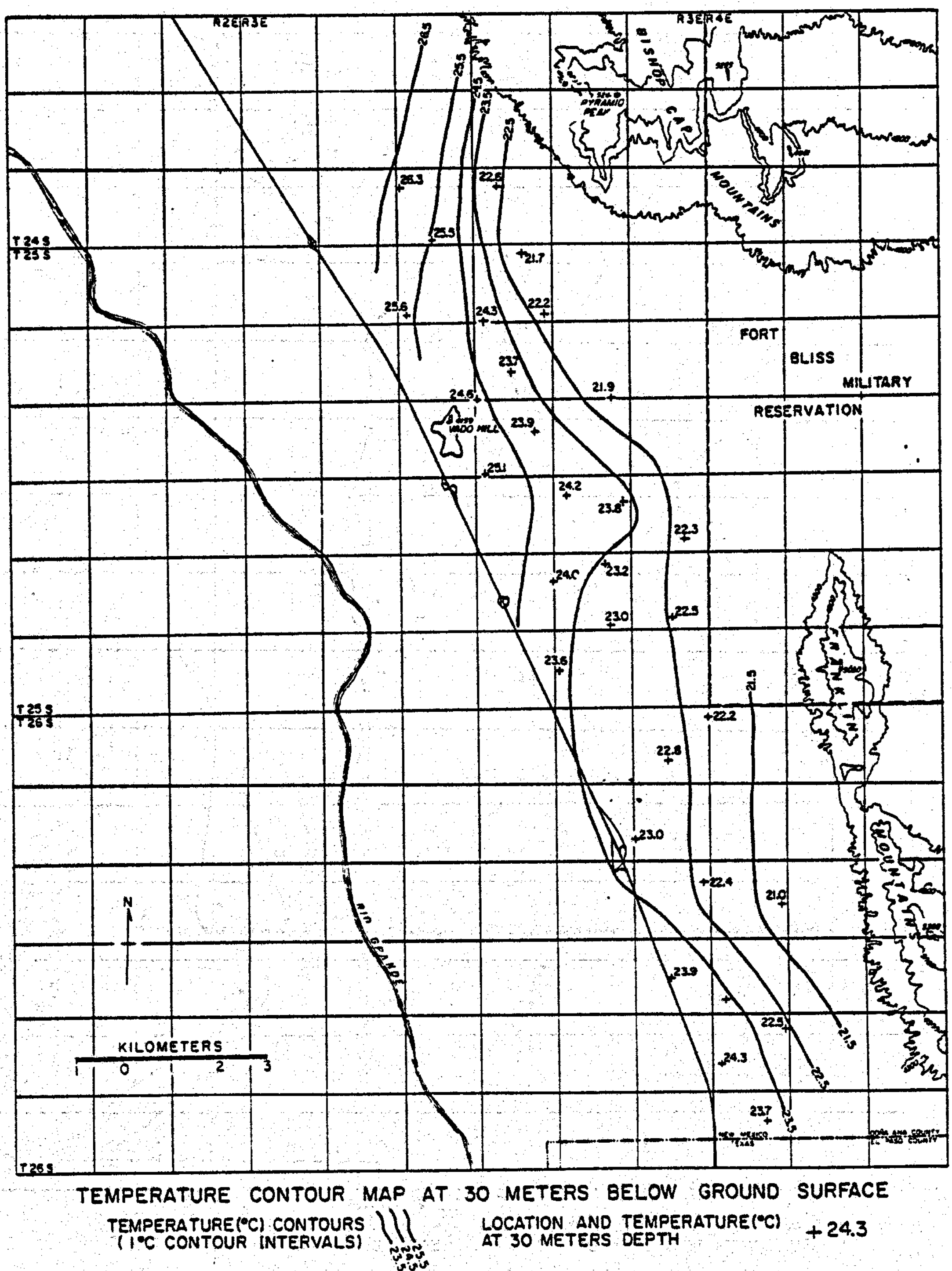


Figure 27. Temperature contours at a 30-meter depth in the Mesquite-Anthony area.

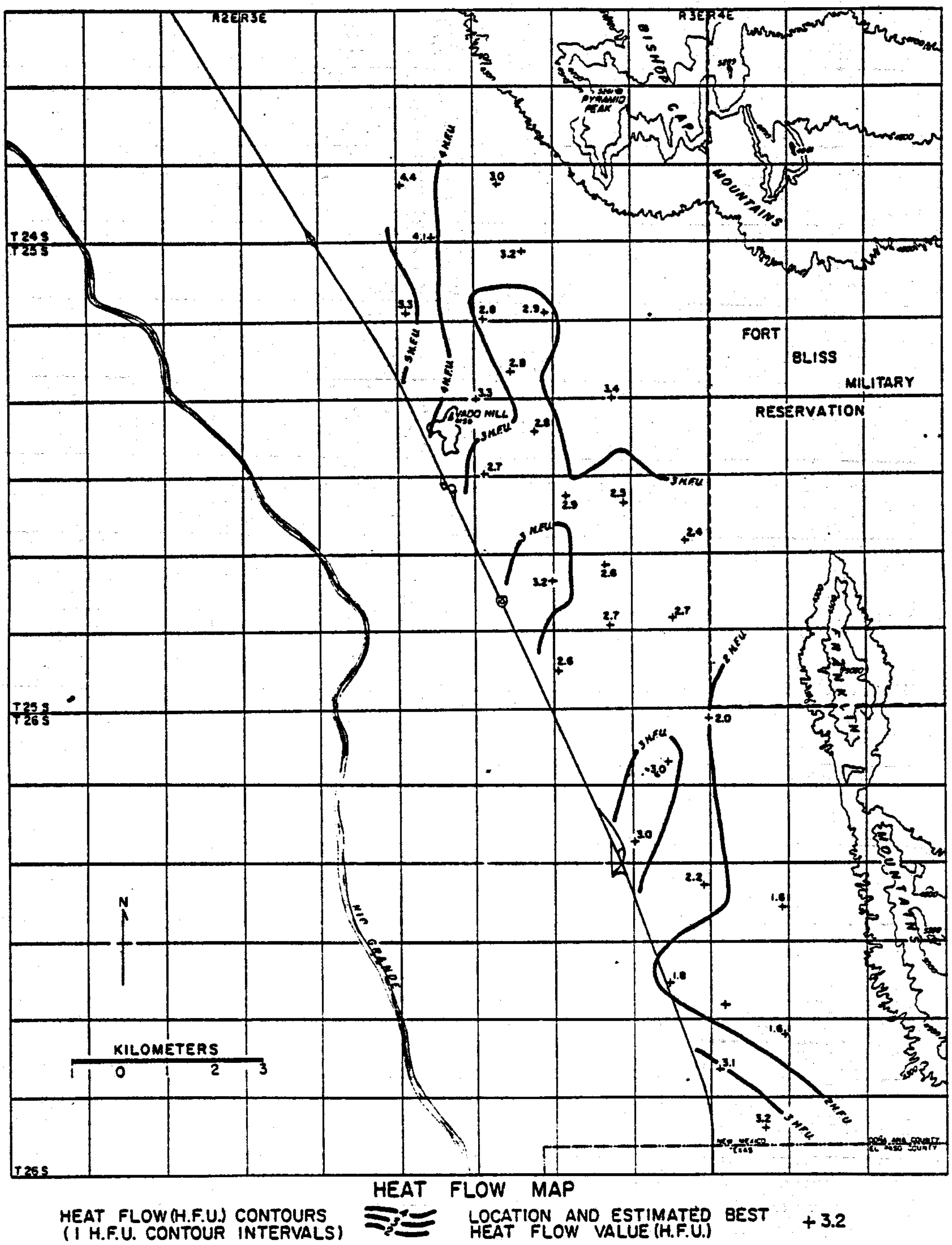


Figure 28. Heat flow map of the Mesquite-Anthony area.

4.4 Geological and Geophysical Data

4.4.1 Tectonic Features

Surface faults have been mapped by Seager (1981) in the Bishop Cap area of the Organ Mountains (also known locally as the Bishop Cap Mountains) and by Kottlowski (1960) in the Franklin Mountains. Surface faults in the Bishop Cap area generally trend in both NNW-SSE and ENE-WSW directions, with some minor faults trending in a NNE-SSW direction. In the Franklin Mountains, the surface faults trend in a NW-SE direction. The Bishop Cap area is composed of Paleozoic strata ranging in age from Pennsylvanian to Ordovician. The dip of the strata ranges approximately from 20 to 45° WSW and the strike is generally in a NNW-SSE direction with some strata striking in a NNE-SSW direction. Paleozoic strata of similar age are also found in the Franklin Mountains, while here the dip is a little larger generally ranging from 35 to 45° SW. The northern portion of the Franklin Mountains within the Mesquite-Anthony area generally strike in a N-S direction, while the southern portion generally strikes in a NNW-SSE direction.

Paleozoic strata of the Permian Epoch is exposed approximately 8 kilometers to the north of the Mesquite-Anthony area at Tortugas Mountain (see Chapter 2), which is structurally formed by a NW-SE trending fault to the north and a NNE-SSW trending fault to the east. King and Kelley (1980) report that the dip of the strata ranges from 15 to 25° SW and the average strike is in a NNW-SSE direction. Vado Hill, also located within the Mesquite-Anthony area, is an andesite or latite flow of early-Tertiary age (Kottlowski, 1960), which includes the Orejon Andesite of Dunham (1935) found in the Organ Mountains (see Section 2.4.5).

4.4.2 Lineament Data

A lineament study of New Mexico (Lepley, 1982) and LANDSAT and SKYLAB satellite imagery suggest that there are three major regional trends which intersect in the study area: (1) NW-SE, (2) NE-SW, and (3) N-S. Close inspection suggests that most of the N-S trends are composed of local NNW-SSE and NNE-SSW components, which, when connected end to end, result in a regional N-S trend.

4.4.3 Gravity and Aeromagnetic Data

The residual Bouguer gravity data of Aiken et al. (1978) show three principal features in the Mesquite-Anthony area (see Figure 29). A regional gravity maximum and a local increase in gravity to the northeast are apparent. Thirdly, a high gravity gradient trends in a NNW-SSE direction through the center of the Mesquite-Anthony area, except in the extreme northwest corner of the area where the gravity gradient trends in a N-S direction. The aeromagnetic data of Keller (1979) extends only a few miles into the northern end of the Mesquite-Anthony area. However, these data suggest the existence of a magnetic maximum in the north central portion of the area (see Figure 17).

4.4.4 Electrical Resistivity Data

Electrical resistivity data obtained by Schlumberger depth sounding techniques in the Mesquite-Anthony area have been collected by Jackson (1976). The electrical resistivity sites where these data were collected and the profile lines used for the current analysis are shown in Figure 30. Jackson (1976) has modeled the electrical resistivity data in the form of resistivity layers, for which the thickness, resistivity, and depth of emplacement are specified for each layer.

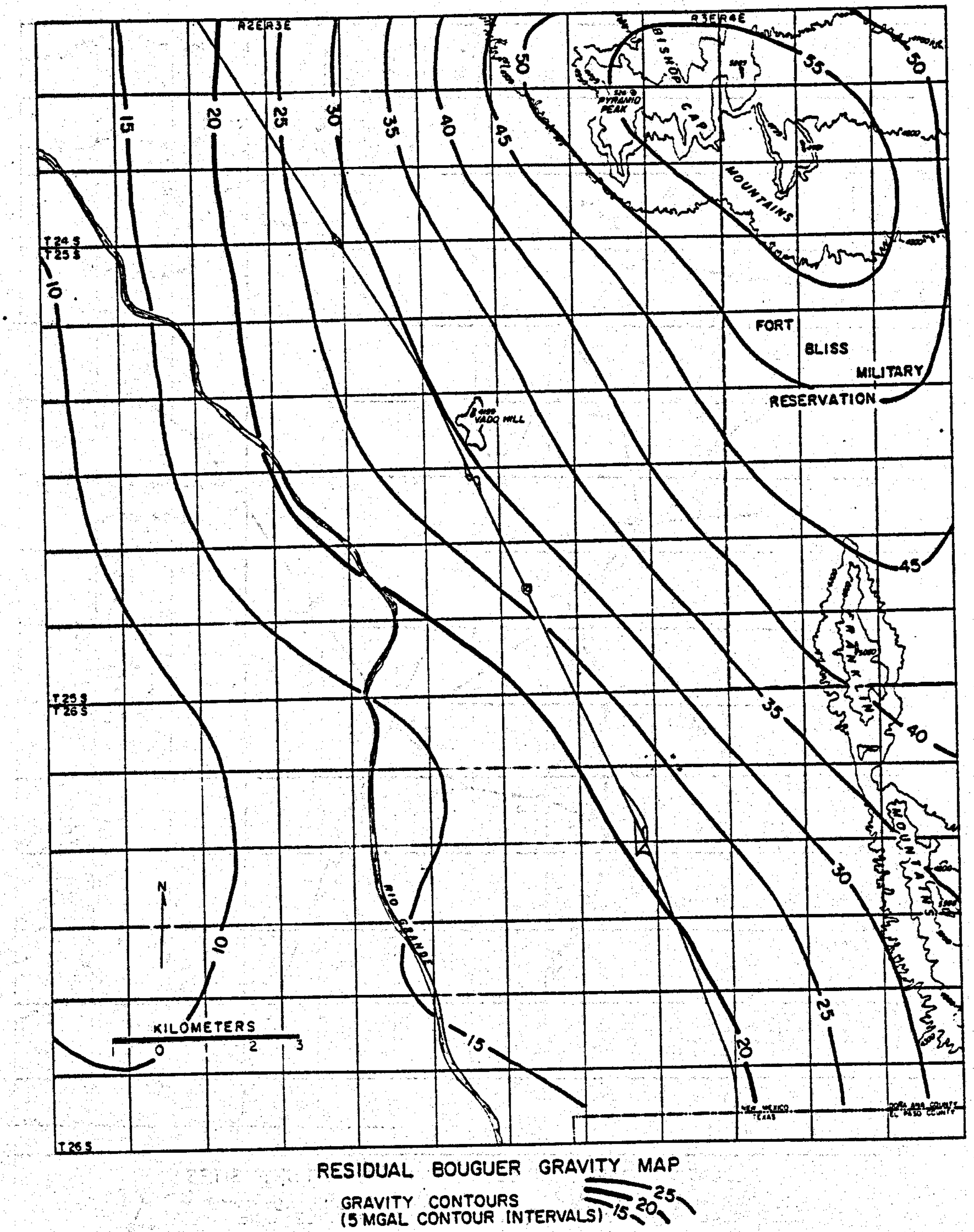


Figure 29. Residual Bouguer gravity map of the Mesquite-Anthony area [after Aiken et al. (1978)].

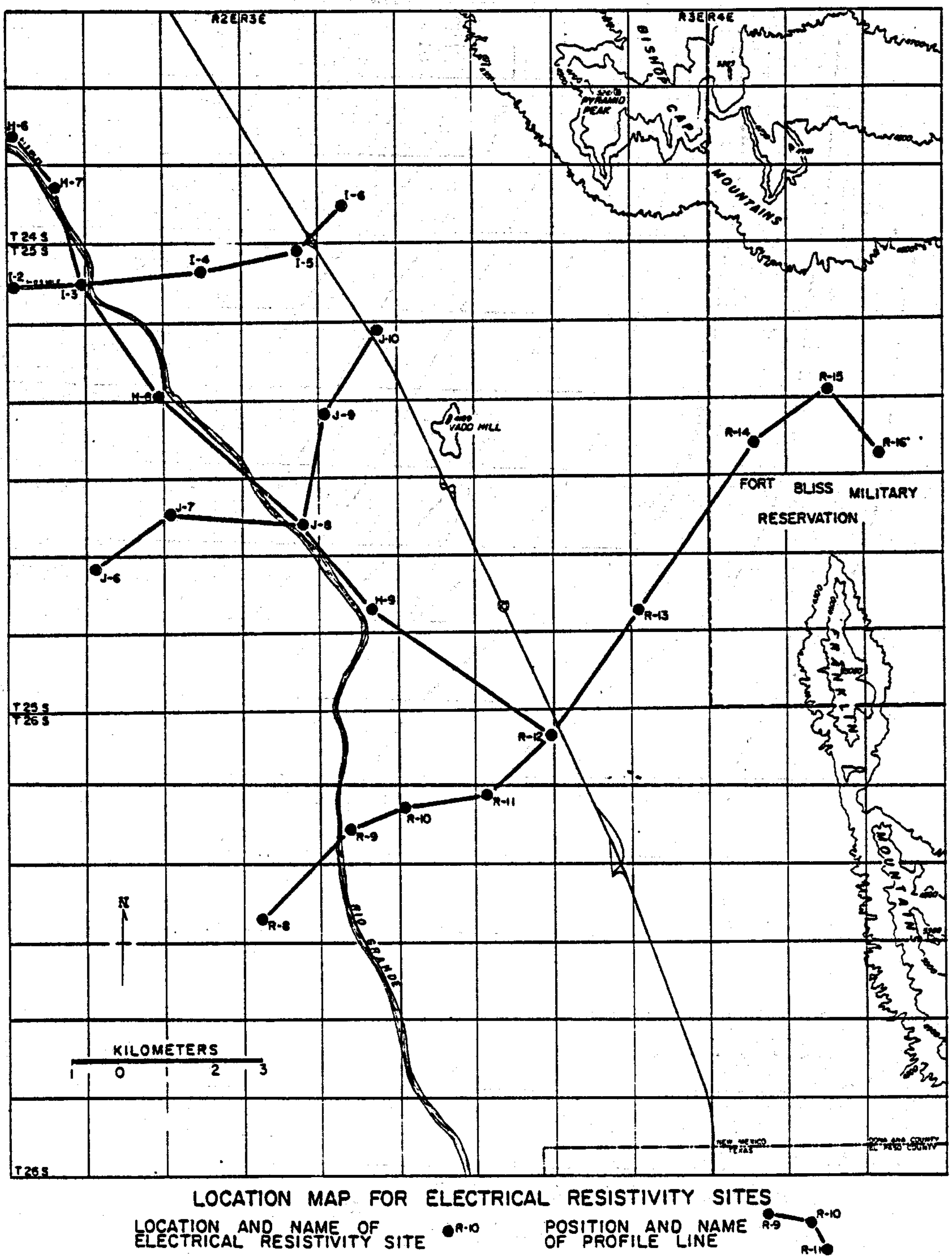


Figure 30. Electrical resistivity sites and profile lines for the Mesquite-Anthony area. The data are taken from Jackson (1976).

4.4.5 Subsurface Structure

The electrical resistivity layers were correlated to determine cross sections along profile lines from one depth sounding site to another in the Mesquite-Anthony area. The cross section for the profile line R-8 to R-16 is shown in Figure 31. A complete set of cross sections is included in Appendix E.

These correlations are based on: (1) relative and systematic changes between alternate or sequential high and/or low resistivity values; (2) similar thicknesses and depths of layers with comparable resistivity values; and (3) order of magnitude changes of resistivity values. Three distinct subsurface formations are suggested by these correlations, namely, four layers of sediments, one volcanic sequence, and two divisions of Paleozoic strata. The sedimentary layers are interpreted to be, in order of increasing depth: (1) late-Quaternary sands and gravels; (2) the Upper Santa Fe group of early-Quaternary age; (3) an upper division of the Lower Santa Fe group of late-Tertiary age; and (4) a lower division of the same group. The volcanic sequence could be the Orejon Andesite of late-Eocene or early-Oligocene (middle-Tertiary) age. A major increase in resistivity values defines the two divisions of Paleozoic strata, which are interpreted to be increasingly deep and dense layers of the Permo-Penn, or possibly Mississippian or Devonian, age.

Figure 32 is a subsurface fault map produced, in part, from the lithologic cross sections included in Appendix E. Included in Figure 32 are estimated depths to bedrock, which is interpreted as the Paleozoic strata. Some of the subsurface faults are inferred from offsets in the correlated resistivity layers. Additional data used to infer the distribution and orientation of subsurface faults include: surface faults and geology by

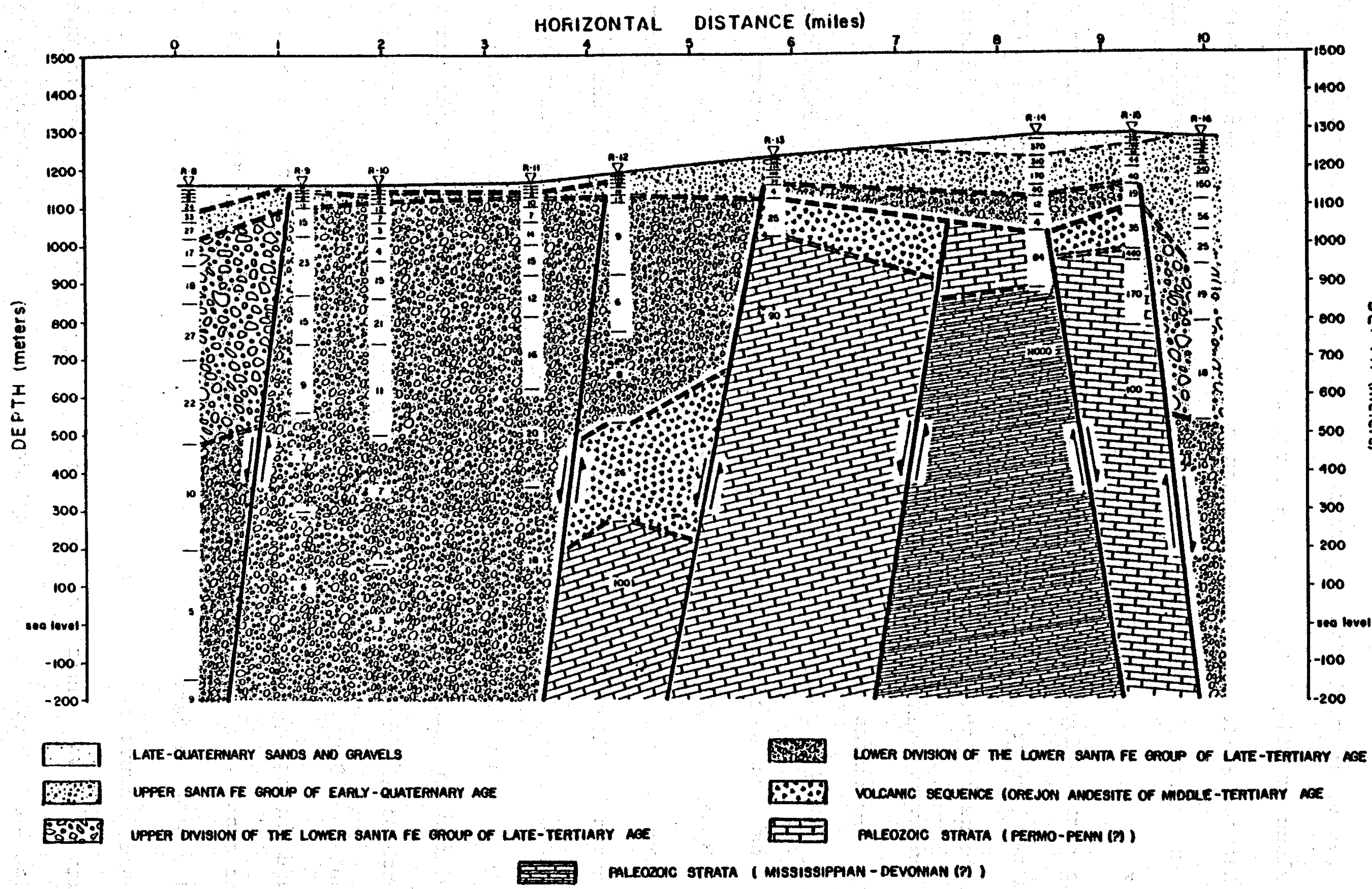


Figure 31. Lithologic cross section for profile line R-8 to R-16. The resistivity data are given in units of ohm-meters.

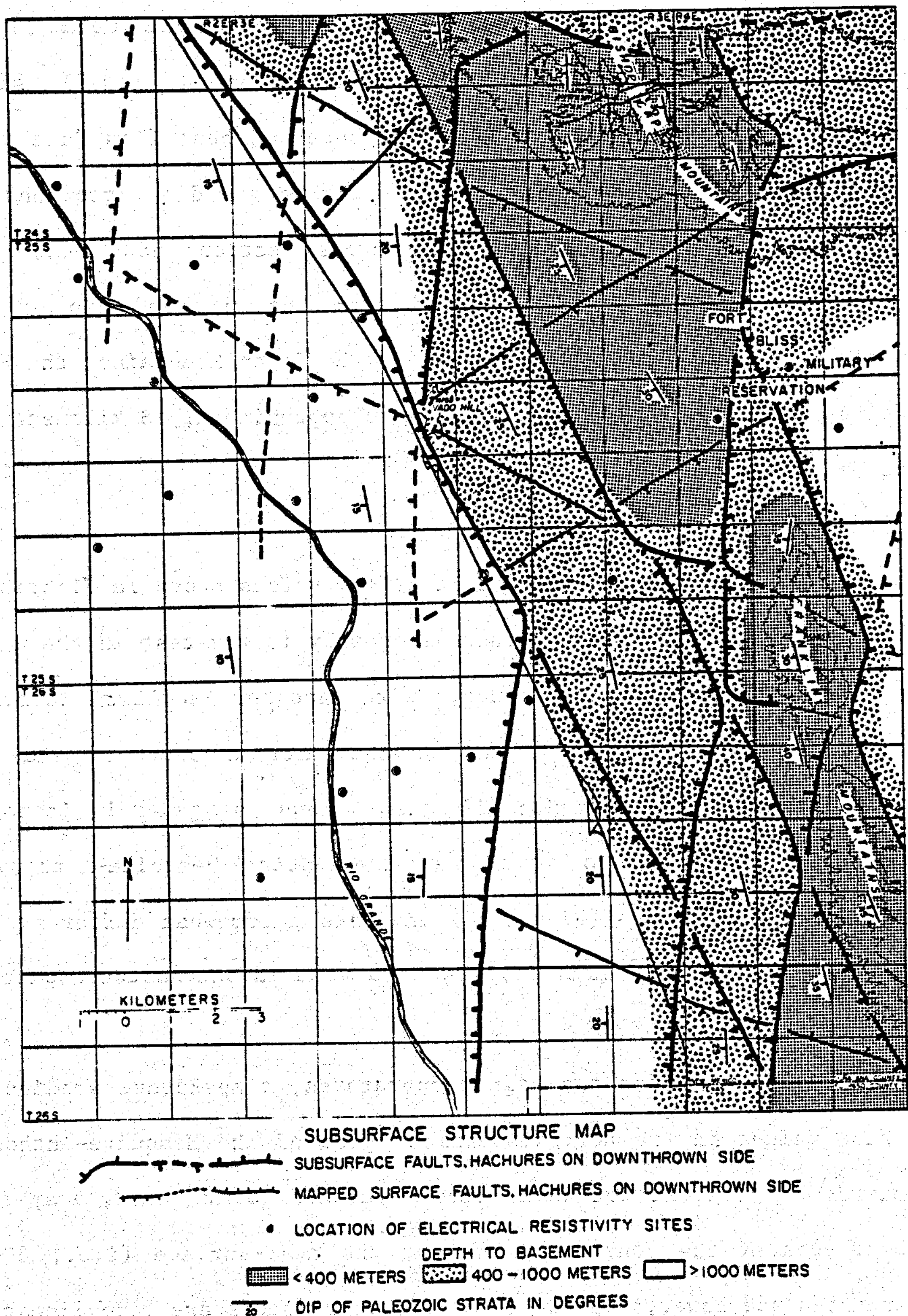


Figure 32. Subsurface structure of the Mesquite-Anthony area.

Kottlowski (1960), King and Kelley (1980), Seager (1981), and Seager et al. (1981); lineament data from Lepley (1982); aeromagnetic data by Keller (1979); residual Bouguer gravity data of Aiken et al. (1978); satellite imagery and aerial photography; and temperature and heat flow data from the temperature gradient holes. Estimated depths to and dip directions of the bedrock are derived from the lithologic cross sections and local geology. The magnitude of the dip is inferred from the observed dip of exposed Paleozoic strata in the Bishop Cap area of the Organ Mountains, the Franklin Mountains, and at Tortugas Mountain located approximately 8 kilometers north of the Mesquite-Anthony area.

4.5 Discussion

Examination of temperature and heat flow values shown in Figures 27 and 28, respectively, show that the thermal anomaly is greatest in the north and generally decreases to the south, with another smaller increase in temperature and heat flow values at the extreme southern end of the Mesquite-Anthony area. Figure 27 also shows a general increase of temperatures from east to west over the entire Mesquite-Anthony area; however, heat flow values (Figure 28) indicate a somewhat different pattern of high to low to high again from east to west in the northern part of the area.

One explanation for the high temperatures, temperature gradients, and heat flow values in the northwesternmost part of the Mesquite-Anthony area is lateral or vertical hot water flow. Further to the east, away from the local effects of the convective system, the near-surface (i.e., 30-meter) temperatures are lower, but the temperature gradients are more linear, which would be expected if this area were returning to a more conductive mode of heat transfer. In this respect, the heat flow values from this area would be more representative of the background heat flow for the northern part of the Mesquite-Anthony area. In general, the thermal anomaly may be characterized as having a gradual increase of background or regional heat flow from south to north, with a superimposed strong local convective system in the northwestern part of the Mesquite-Anthony area.

Additional information about the hydrothermal system may be gained by examining the residual gravity and subsurface structure maps (see Figures 29 and 32, respectivly). The residual gravity data show an increase in gravity toward the northeast. Part of this increase is due to the uplifted Paleozoic strata which is dipping steeply to the WSW. Removing the effects of this rotated Paleozoic block would leave a residual gravity anomaly which still increases toward the north but is centrally shifted to the west. This residual gravity anomaly may be related to the observed increase in the regional (background) heat flow from south to north. The subsurface structure (see Figure 32) suggests that the strong convective system in the northwest part of the Mesquite-Anthony area is fault controlled. Whether the geothermal fluids are flowing vertically up the faults, or laterally in a southerly direction within a small graben created by the faults, is uncertain. Probably, especially in light of the dip of the bedrock, both conditions are occurring, that is, the hot water ascends the faults and then flows laterally over the top of the bedrock through the overlying sediments and channeled by the structural graben.

5.0 Concluding Remarks

During the summers of 1981 and 1982, 64 shallow temperature gradient holes were drilled on the Mesilla Valley East Mesa (east of Interstate Highways 10 and 25), stretching from U.S. Highway 70 north of Las Cruces to N.M. Highway 404 adjacent to Anthony, New Mexico. The holes were drilled to delineate the magnitude and extent of geothermal resources in this area. The program was highly successful in that exploration activities resulted in the discovery and confirmation of a major low-temperature geothermal field just a few miles to the east of Las Cruces that has been newly named as the Las Cruces East Mesa Geothermal Field. Evidence collected as part of this exploration program suggests that the hydrothermal system may be ultimately hotter at depth and to the southeast, where an intermediate temperature (i.e., 100 to 150°C) system may be present.

Elevated temperature and heat flow data suggest that the thermal anomaly is approximately 45 kilometers long, with a width ranging from 4 to 8 kilometers. The highest temperature and heat flow values, 54°C and 19 HFU, respectively, are in the northern part of the anomaly in an area surrounding Tortugas Mountain, which is characterized by a strongly convective mode of heat transfer. With the exception of some localized perturbations, the thermal anomaly appears to decrease from the north to the south.

Sharp contrasts in temperature and heat flow values over relatively short distances of approximately 1 kilometer, plus a spatial relationship between suspected subsurface faults and the thermal anomaly, indicate the existence of a near-surface, fault-controlled hydrothermal system. Because the sharpest contrast occurs where the electrical basement (Paleozoic strata) is well exposed at Tortugas Mountain, the basement fault structure is suspected to control the hydrothermal system.

Subsurface structure maps constructed with the aid of available geological and geophysical data suggest that the geothermal fluids are ascending the basement faults and then flowing laterally to the west down over the top of the southwest dipping bedrock, through the overlying sediments, and gradually mixing with the cooler and cleaner southerly flowing groundwater of the Mesilla Basin.

The increased knowledge and understanding of the hydrothermal system results in an increased resolution of the regional heat flow since the areas where the regional heat flow has been enhanced due to strong convection may now be accounted for more accurately. These areas of strong convection are viewed as the near-surface manifestations of the hydrothermal system and are not believed to contain the highest temperatures of the hydrothermal system, partly because groundwater mixing is very probably occurring and also because the suspected center of the regional heat flow maximum, defined by subtracting the convective contributions to the total heat flow, is laterally offset to the southeast by some 12 kilometers.

The approximate center of the regional heat flow maximum is believed to be located just to the west of the Bishop Cap area, which is also characterized by regional gravity and magnetic maxima. This spatial relationship between regional heat flow and gravity and magnetic maxima persists throughout the East Mesa area, with the exception that the gravity and magnetic anomalies deviate slightly to the east of the heat flow anomaly in the strongly-convective area surrounding Tortugas Mountain. Although hydrothermal systems are often associated with gravity and magnetic minima, there may be a direct relationship between the three anomalies by being derived from the same source.

Immediately to the north of the Bishop Cap area and to the east of Tortugas Mountain is the very southernmost part of the Jornada Basin. The dip of the bedrock in this area is believed to be to the northwest and to be overlain with a very impermeable volcanic layer known as the Orejon Andesite. This volcanic layer apparently acts as a cap rock and creates a confined aquifer in which recharge occurs in the southern part of the Organ Mountains. The recharge appears to be constrained to flow towards the northwest over the thermal anomaly where it emerges as hot water in the area surrounding Tortugas Mountain. This volcanic layer also separates the cool near-surface groundwater flow in the basin from the thermal fluids and is probably a major cause for the lack of a shallow thermal anomaly within the basin. Thermal mixing almost certainly occurs as both thermal and nonthermal fluids migrate up the same westernmost boundary faults of the southern Jornada Basin in the vicinity of Tortugas Mountain.

At the present time, very few wells have been drilled deeper than 100 meters on the East Mesa and all of these are located in the area surrounding Tortugas Mountain. A few kilometers west of Tortugas Mountain, New Mexico State University has drilled two low-temperature geothermal production wells which together yield approximately 600 gallons per minute of 62°C (144°F) water and are producing from approximately 240 meters. During 1980, the City of Las Cruces drilled two wells in search for potable water within 7 kilometers to the north of Tortugas Mountain, but abandoned the wells when hot water was encountered. The wells were converted to temperature observation holes, labeled LC-1 and LC-2, with recorded temperatures of 56°C at 240 meters and 68°C at 265 meters, respectively. A large fracture zone, or fault, was encountered at the bottom of LC-1, which contained large quantities of hot water estimated to be producible at a rate of at least

1,000 gallons per minute. As part of this project, Chaffee Geothermal, Ltd. drilled two low-temperature geothermal production wells to the immediate north and south of Tortugas Mountain and encountered approximately 1,500 gallons per minute of 65°C (149°F) water produced from 270 to 380 meters in the northern well. An estimated flow of 750 gallons per minute of 68°C (154°F) water produced from 200 to 270 meters was encountered in the southern well. Deeper drilling into the now-known, low-temperature hydrothermal system is required to determine whether or not an intermediate temperature hydrothermal system exists.

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Appendix A

Temperature Data for the Area Surrounding Tortugas Mountain

Note: The data are for temperature gradient holes TG-25 through TG-67 (see Figure 12 for locations). Holes TG-35, TG-37, TG-39, TG-48, TG-49, and TG-56 were sited but not drilled. Holes TG-59 through TG-61 were drilled in the Deming-Faywood area as part of another drilling program. The reported temperature gradient data are least-squares fits to the empirical data, with the standard error of the estimate given. Bottom-hole temperature gradients were computed for a 20°C surface temperature.

Well Name: TG-25

Location: latitude, 32° 15.12', longitude, 106° 40.98', township & range, T24S.R2E.1.242; elevation, 1,289 meters; spudded, 9-16-81; temperature logged, 10-27-81; total depth, 91 meters; depth of 1½ inch PVC casing, 91 meters; bottom-hole temperature, 41.7°C; bottom-hole depth, 90 meters; bottom-hole temperature gradient, 241°C/km; best estimate heat flow value, 326 mW/m^2 (7.8 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mw/m^2)	(HFU)	Remarks
5	24.05						
10	23.84						Drilling rate was moderate. Formations are semi-consolidated.
15	25.37		gravel and sand		392	9.4	
20	26.78	280.2 ± 8.5					
25	28.04						
30	29.18						Formations have a gradual decrease of grain size with depth.
35	30.28				309	7.4	
40	31.36	220.7 ± 1.4	coarse sand				
45	32.54						
50	33.54			1.4			
55	34.68						
60	35.75						
65	36.79						
70	37.85				277	6.6	
75	38.81	198.1 ± 2.1	medium sand				
80	39.76						
85	40.75						
90	41.71						
91	41.79						

* Estimated thermal conductivity values.

Well Name: TG-26

Location: latitude, 32° 15.42', longitude, 106° 40.06', township & range, T23S.R3E.31.444; elevation, 1,311 meters; spudded, 9-14-81; temperature logged, 10-27-81; total depth, 68 meters; depth of 1½ inch PVC casing, 68 meters; bottom-hole temperature, 26.4°C; bottom-hole depth, 68 meters; bottom-hole temperature gradient, 94°C/km; best estimate heat flow value, 134 mW/m^2 (3.2 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mw/m^2)	(HFU)	Remarks
5	22.75		gravel and coarse sand	1.4			Drilling rate from 60 meters to T.D. was very slow (~3ft/hr). Formation is well cemented and very hard. Contains minor bits of rhyolite.
10	21.31	103.2 ± 7.5			145	3.5	
15	21.67						
20	22.27						
25	22.83						
30	23.25	90.0 ± 1.9	sand and gravel	1.6	144	3.4	
35	23.70						
40	24.18						
45	24.72	106.6 ± 0.3	coarse sand	1.4	149	3.6	Formations have a gradual decrease of grain size with depth.
50	25.25						
55	25.78						
60	26.14	46.8 ± 7.7	medium to very fine sand, well cemented, hard	1.9	89	2.1	
65	26.33						
68	26.39						

* Estimated thermal conductivity values

Well Name: TG-27

Location: latitude, 32° 16.21', longitude, 106° 40.00', township & range, T23S.R3E.31.222; elevation, 1,323 meters; spudded, 9-11-81; temperature logged, 10-27-81; total depth, 91 meters; depth of 1½ inch PVC casing, 83 meters; bottom-hole temperature, 25.7°C; bottom-hole depth, 83 meters; bottom-hole temperature gradient, 69°C/km; best estimate heat flow value, 109 mW/m^2 (2.6 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mw/m^2)	Estimated Heat Flow (HFU)	Remarks
5	23.40						Drilling rate was slow from 55 meters to T.D. Formation is consolidated and hard.
10	21.49		gravel, minor sand				
15	21.72						
20	22.03		gravel and sand				
25	22.35						
30	22.64	62.1 ± 1.2	gravel, minor sand & clay	1.6	99	2.4	
35	22.92		gravel, minor sand				
40	23.30						
45	23.51	42	clay and sand		59	1.4	
50	23.82		sand, minor gravel and clay	1.4	82	2.0	
55	24.09						
60	24.39						
65	24.73	58.3 ± 1.3					
70	25.01		gravel and sand, hard	1.9	111	2.7	
75	25.35						
80	25.58						
83	25.65						

* Estimated thermal conductivity values.

Well Name: TG-28

Location: latitude, 32° 16.30', longitude, 106° 41.93', township & range, T.23S.R2E.25.333; elevation, 1,295 meters; spudded, 9-4-81; temperature logged, 10-27-81; total depth, 91 meters; depth of 1½ inch PVC casing, 91 meters; bottom-hole temperature, 48.4°C; bottom-hole depth, 90 meters; bottom-hole temperature gradient, 316°C/km; best estimate heat flow value, 410 mW/m^2 (9.8 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mw/m^2)	Estimated Heat Flow (HFU)	Remarks
5	24.33						
10	24.52		sand and gravel				Drilling rate was moderate. Formations are simi-consolidated.
15	26.47	418.9 ± 16.7			587	14	
20	28.71						
25	30.30		sand, minor gravel				
30	31.91						Formations have a gradual decrease in grain size with depth from 0 to 85 meters.
35	33.50	320.6 ± 2.3			449	10.7	
40	34.98						
45	36.73		coarse sand	1.4			
50	38.36						
55	39.76						
60	41.16	273.2 ± 2.2			383	9.2	
65	42.50						
70	43.82						
75	45.00		medium sand				
80	46.21	240.2 ± 1.0			336	8.0	
85	47.42						
90	48.35	189.8 ± 4.7	gravel and sand, minor clay	1.6	303	7.2	
91	48.57						

* Estimated thermal conductivity values.

Well Name: TG-29

Location: latitude, 32° 16.93', longitude, 106° 41.20', township & range, T23S.R2E.25.241; elevation, 1,317 meters; spudded, 9-7-81; temperature logged, 10-27-81; total depth, 67 meters; depth of 1½ inch PVC casing, 67 meters; bottom-hole temperature, 25.5°C; bottom-hole depth, 65 meters; bottom-hole temperature gradient, 85°C/km; best estimate heat flow value, 88 mW/m^2 (2.1 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mw/m^2)	Estimated Heat Flow (HFU)	Remarks
5	23.81						Drilling rate was moderate. Formations are semi-consolidated.
10	21.99		gravel and sand				
15	22.35						
20	22.83	82.2 ± 3.3		1.4	115	2.8	
25	23.20		sand and clay				Loss of drilling fluids from 60 to 70 meters.
30	23.51				84	2.0	
35	23.82	60.2 ± 0.6					
40	24.10		gravel and clay	1.5	90	2.2	Drilling discontinued at 70 meters. Formation is fractured rock and large gravel.
45	24.41						
50	24.67		clay and gravel	1.4	73	1.7	
55	24.91	52.4 ± 0.9					
60	25.22						
65	25.46		large gravel, minor sand, fractured	1.6	84	2.0	
67	25.55						

* Estimated thermal conductivity values.

Well Name: TG-30

Location: latitude, 32° 17.55', longitude, 106° 40.43', township & range, T23S.R3E.19.411; elevation, 1,341 meters; spudded, 9-9-81; temperature logged, 10-27-81; total depth, 55 meters; depth of 1½ inch PVC casing, 34 meters; bottom-hole temperature, 22.4°C; bottom-hole depth, 34 meters; bottom-hole temperature gradient, 71°C/km; best estimate heat flow value, 70 mW/m^2 (1.7 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mw/m^2)	Estimated Heat Flow (HFU)	Remarks
5	23.00		gravel	1.4			Drilling rate was moderate. Formations are semi-consolidated.
10	21.34						
15	21.50	48.0 ± 9.2			67	1.6	
20	21.82		gravel and sand				
25	22.03	44.7 ± 0.8	gravel & clay, minor sand	1.6	72	1.7	Drill stem was lost in hole. Hole blocked at 34 meters.
30	22.27						
34	22.44		gravel & clay, minor sand				
40			gravel				
45							
50							
55							

* Estimated thermal conductivity values.

Well Name: TG-31

Location: latitude, 32° 17.54', longitude, 106° 41.38', township & range, T23S.R2E.24.411; elevation, 1,320 meters; spudded, 10-14-81; temperature logged, 11-24-81; total depth, 58 meters; depth of 1½ inch PVC casing, 57 meters; bottom-hole temperature, 47.7°C; bottom-hole depth, 55 meters; bottom-hole temperature gradient, 504°C/km; best estimate heat flow value, 811 mW/m^2 (19.4 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mw/m^2)	(HFU)	Remarks
5	24.95		sand and clay	1.4			Drilling was done with down-hole hammer and air.
10	27.17						
15	31.33	685.0 ± 84.9			959	22.9	
20	34.02						
25	36.05	371.4 ± 8.4	limestone, hard	2.1	780	18.7	Encountered a 3 inch fracture at 58 meters, lost circulation, and discontinued drilling.
30	37.76						
35	39.64						
40	41.86	447.0 ± 1.7	limestone and calcite, fractured	1.7	760	18.2	
45	44.11						
50	46.12						
55	47.72	334.9 ± 25.0	limestone, very hard	2.2	737	17.6	Formations are fractured and hard.
57	48.08						

* Estimated thermal conductivity values.

Well Name: TG-32

Location: latitude, 32° 17.93', longitude, 106° 42.02', township & range, T23S.R2E.23.222; elevation, 1,298 meters; spudded, 9-30-81; temperature logged, 11-12-81; total depth, 52 meters; depth of 1½ inch PVC casing, 50 meters; bottom-hole temperature, 42.6°C; bottom-hole depth, 50 meters; bottom-hole temperature gradient, 452°C/km; best estimate heat flow value, 619 mW/m^2 (14.8 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mw/m^2)	Estimated Heat Flow (HFU)	Remarks
5	24.05		gravel and sand				Drilling was done with a down-hole hammer and air.
10	25.24						
15	27.78						
20	30.81	534.4 ± 9.9	clay and sand	1.4	748	17.9	
25	33.26						
30	35.86						Formation from 30 to 40 meters contained quartz (?) crystals and limonite indicating probable fracture zone.
35	38.03	398.0 ± 20.8	clay and calcite	1.3	517	12.4	
40	39.84						
45	41.41						
50	42.62	278.0 ± 20.8	limestone, minor clay, hard	2.1	584	14.0	Encountered large fracture at 47 meters, drilled with no return to 49 meters, encountered 5 foot fracture and discontinued drilling.

* Estimated thermal conductivity values.

Well Name: TG-33

Location: latitude, 32° 18.45', longitude, 106° 41.55', township & range, T23S.R2E.13.322; elevation, 1,317 meters; spudded, 9-24-81; temperature logged, 11-12-81; total depth, 91 meters; depth of 1½ inch PVC casing, 91 meters; bottom-hole temperature, 25.7°C; bottom-hole depth, 90 meters; bottom-hole temperature gradient, 63°C/km; best estimate heat flow value, 88 mW/m^2 (2.1 HFU).

<table>
<tr><th rowspan="2">Depth (m)</th><th rowspan="2">Temperature (°C)</th><th rowspan="2">Temperature Gradient (°C)</th><th rowspan="2">Lithology</th><th rowspan="2">K* (W/m-°K)</th><th colspan="2">Estimated Heat Flow</th><th rowspan="2">Remarks</th></tr>
<tr><th>(mw/m^2)</th><th>(HFU)</th></tr>
<tr><td>5</td><td>22.56</td><td rowspan="2"></td><td rowspan="7">gravel</td><td rowspan="7">1.4</td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="19">Drilling rate was slow from 50 meters to T.D. Formation, is consolidated and hard.</td></tr>
<tr><td>10</td><td>21.53</td></tr>
<tr><td>15</td><td>21.71</td><td rowspan="5">62.0 ± 0.8</td><td rowspan="5">87</td><td rowspan="5">2.1</td></tr>
<tr><td>20</td><td>22.04</td></tr>
<tr><td>25</td><td>22.33</td></tr>
<tr><td>30</td><td>22.66</td></tr>
<tr><td>35</td><td>22.95</td></tr>
<tr><td>40</td><td>23.23</td><td rowspan="3">53.4 ± 1.0</td><td rowspan="3">gravel and sand, minor clay</td><td rowspan="3">1.6</td><td rowspan="3">85</td><td rowspan="3">2.0</td></tr>
<tr><td>45</td><td>23.50</td></tr>
<tr><td>50</td><td>23.75</td></tr>
<tr><td>55</td><td>23.98</td><td rowspan="6">50.7 ± 0.8</td><td rowspan="6">gravel, minor sand, hard</td><td rowspan="9">1.9</td><td rowspan="6">96</td><td rowspan="6">2.3</td></tr>
<tr><td>60</td><td>24.22</td></tr>
<tr><td>65</td><td>24.48</td></tr>
<tr><td>70</td><td>24.76</td></tr>
<tr><td>75</td><td>25.00</td></tr>
<tr><td>80</td><td>25.25</td></tr>
<tr><td>85</td><td>25.46</td><td rowspan="3">41.9 ± 0.1</td><td rowspan="3">gravel and sand, hard</td><td rowspan="3">79</td><td rowspan="3">1.9</td></tr>
<tr><td>90</td><td>25.67</td></tr>
<tr><td>91</td><td>25.71</td></tr>
</table>

* Estimated thermal conductivity values.

Well Name: TG-34

Location: latitude, 32° 18.38', longitude, 106° 40.80', township & range, T23S.R3E.18.312; elevation, 1,347 meters; spudded, 10-26-81; temperature logged, 11-24-81; total depth, 47 meters; depth of 1½ inch PVC casing, 47 meters; bottom-hole temperature, 22.6°C; bottom-hole depth, 45 meters; bottom-hole temperature gradient, 58°C/km; best estimate heat flow value, 67 mW/m^2 (1.6 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mw/m^2)	Estimated Heat Flow (HFU)	Remarks
5	22.19						Drilling rate was slow from 40 meters to T.D. Formation is consolidated and hard.
10	21.04		gravel, minor clay, hard				
15	21.18						
20	21.43						
25	21.69						
30	21.91	48.6 ± 0.5	clay and gravel	1.4	68	1.6	
35	22.16						
40	22.40						
45	22.61						
47	22.67	39.2 ± 2.6	gravel, minor clay, hard	1.8	71	1.7	

* Estimated thermal conductivity values.

Well Name: TG-36

Location: latitude, 32° 19.39', longitude, 106° 41.09', township & range, T23S.R2E.12.243; elevation, 1,353 meters; spudded, 10-28-81; temperature logged, 12-1-81; total depth, 36 meters; depth of 1½ inch PVC casing, 35 meters; bottom-hole temperature, 21.7°C; bottom-hole depth, 35 meters; bottom-hole temperature gradient, 49°C/km; best estimate heat flow value, 63 mW/m^2 (1.5 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mw/m^2)	Estimated Heat Flow (HFU)	Remarks
5	21.57						
10	20.87		gravel, minor clay				Drilling rate was slow from 25 meters to T.D. Formation is consolidated and hard.
15	20.93						
20	21.19	48.0 ± 2.3	clay and gravel	1.4	67	1.6	
25	21.41						
30	21.58	33.0 ± 0.6	gravel and clay, hard	1.8	59	1.4	Lost cone on bit, ceased drilling.
35	21.74						

* Estimated thermal conductivity values.

Well Name: TG-38

Location: latitude, 32° 20.28', longitude, 106° 40.39', township & range, T23S.R3E.6.233; elevation, 1,387 meters; spudded, 10-9-81; temperature logged, 11-24-81; total depth, 91 meters; depth of 1½ inch PVC casing, 91 meters; bottom-hole temperature, 23.6°C; bottom-hole depth, 90 meters; bottom-hole temperature gradient, 40°C/km; best estimate heat flow value, 71 mW/m^2 (1.7 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mw/m^2)	(HFU)	Remarks
5	22.09		gravel				Drilling rate was slow. Formations are consolidated and hard. Drilling fluids were gradually being lost during drilling (possibly due to fractures).
10	20.72						
15	20.79	36.9 ± 0.2	gravel, minor clay, hard	1.8	66	1.6	
20	20.99						
25	21.13						
30	21.29						
35	21.51		gravel, minor sand, hard	1.9	70	1.7	
40	21.71						
45	21.91						
50	22.07						
55	22.29						
60	22.46						
65	22.61						
70	22.80						
75	22.98						
80	23.18						
85	23.37						
90	23.56						
91	23.57						

* Estimated thermal conductivity values.

Well Name: TG-40

Location: latitude, 32° 19.75', longitude, 106° 42.18', township & range, T23S.R2E.11.212; elevation, 1,329 meters; spudded, 10-6-81; temperature logged, 11-24-81; total depth, 68 meters; depth of 1½ inch PVC casing, 68 meters; bottom-hole temperature, 23.7°C; bottom-hole depth, 68 meters; bottom-hole temperature gradient, 54°C/km; best estimate heat flow value, 92 mW/m^2 (2.2 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mw/m^2)	Estimated Heat Flow (HFU)	Remarks
5	21.72						Drilling rate was slow from 35 meters to T.D. Formation is consolidated and hard.
10	20.62		gravel and clay				
15	20.79						
20	21.12						
25	21.46	68.4 ± 1.3	clay and gravel	1.4	96	2.3	
30	21.78						
35	22.17						
40	22.46						
45	22.72						
50	22.97						
55	23.21	48.8 ± 1.5	gravel, minor sand, hard	1.9	93	2.2	
60	23.49						
65	23.70						
68	23.74						

* Estimated thermal conductivity values.

Well Name: TG-41

Location: latitude, 32° 19.40', longitude, 106° 42.86', township & range, T23S.R2E.11.133; elevation, 1,311 meters; spudded, 10-2-81; temperature logged, 11-13-81; total depth, 80 meters; depth of 1½ inch PVC casing, 80 meters; bottom-hole temperature, 37.3°C; bottom-hole depth, 80 meters; bottom-hole temperature gradient, 216°C/km; best estimate heat flow value, 343 mW/m^2 (8.2 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mw/m^2)	Estimated Heat Flow (HFU)	Remarks
5	23.01		clay, minor gravel				Drilling rate was slow from 50 meters to T.D. Formation is consolidated and hard.
10	22.78	212.8 ± 0.7	gravel, minor clay and sand	1.4	298	7.1	
15	23.85						
20	24.94						
25	25.99						
30	27.03						
35	28.11						
40	29.73	316.6 ± 7.3	clay and gravel		443	10.6	
45	31.40						
50	32.83						
55	33.60	150.8 ± 3.5	gravel, minor sand, hard	1.9	287	6.9	
60	34.38						
65	35.20						
70	35.97						
75	36.73						
80	37.25						

* Estimated thermal conductivity values.

Well Name: TG-42

Location: latitude, 32° 18.76', longitude, 106° 42.42', township & range, T23S.R2E.14.213; elevation, 1,298 meters; spudded, 9-22-81; temperature logged, 11-12-81; total depth, 91 meters; depth of 1½ inch PVC casing, 91 meters; bottom-hole temperature, 37.6°C; bottom-hole depth, 90 meters; bottom-hole temperature gradient, 196°C/km; best estimate heat flow value, 297 mW/m^2 (7.1 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mw/m^2)	Estimated Heat Flow (HFU)	Remarks
5	23.13		gravel				Drilling rate was slow from 45 meters to T.D. Formations are consolidated and hard.
10	23.40						
15	24.97						
20	26.45	300.4 ± 2.1	gravel and sand, minor clay	1.4	421	10.1	
25	27.91						
30	29.44	212	gravel, sand, and clay	1.5	318	7.6	
35	30.50						
40	31.15		sand, minor gravel	1.6	206	4.9	
45	31.80						
50	32.40						
55	33.05		gravel, minor sand, hard				
60	33.69						
65	34.33	128.7 ± 0.5					
70	34.94		sand, minor gravel, hard	1.9	245	5.9	
75	35.58						
80	36.28						
85	36.93		gravel and sand, hard				
90	37.58						
91	37.74						

* Estimated thermal conductivity values.

Well Name: TG-43

Location: latitude, 32° 18.17', longitude, 106° 43.22', township & range, T23S.R2E.15.441; elevation, 1,283 meters; spudded, 9-21-81; temperature logged, 11-12-81; total depth, 91 meters; depth of 1½ inch PVC casing, 91 meters; bottom-hole temperature, 53.6°C; bottom-hole depth, 90 meters; bottom-hole temperature gradient, 373°C/km; best estimate heat flow value, 477 mW/m^2 (11.4 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mw/m^2)	Estimated Heat Flow (HFU)	Remarks
5	24.27		gravel and sand				Drilling rate was moderate. Formations are semi-consolidated.
10	24.88						
15	26.70	480.1 ± 13.3	sand	1.4	672	16.1	
20	29.50						
25	31.47						
30	33.67						
35	37.39						
40	39.47						
45	41.71						
50	43.59						
55	45.57						
60	47.35	322.9 ± 19.1	sand, minor clay		452	10.8	
65	48.80	191.2 ± 2.2	gravel and sand	1.6	306	7.3	
70	49.80						
75	50.68		gravel, minor sand				
80	51.66						
85	52.69						
90	53.64						
91	53.71						

* Estimated thermal conductivity values.

Well Name: TG-44

Location: latitude, 32° 19.36', longitude, 106° 43.44', township & range, T23S.R2E.10.233; elevation, 1,304 meters; spudded, 10-1-81; temperature logged, 11-13-81; total depth, 91 meters; depth of 1½ inch PVC casing, 89 meters; bottom-hole temperature, 38.7°C; bottom-hole depth, 85 meters; bottom-hole temperature gradient, 220°C/km; best estimate heat flow value, 259 mW/m^2 (6.2 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mw/m^2)	(HFU)	Remarks
5	24.76						
10	23.65		gravel				Drilling rate was slow from 75 meters to T.D. Formation is consolidated and hard.
15	24.37						
20	25.52						
25	26.46						
30	27.45						
35	28.52		sand, minor clay				
40	29.72						
45	30.79	223.3 ± 2.0		1.4	313	7.5	
50	32.12						
55	33.18						
60	34.30						
65	35.59		coarse sand				
70	36.62						
75	37.52						
80	38.11						
85	38.69	107.9 ± 5.8	gravel, minor sand, hard	1.9	205	4.9	
89	39.01						

* Estimated thermal conductivity values.

Well Name: TG-45

Location: latitude, 32° 19.76', longitude, 106° 43.95', township & range, T23S.R2E.10.111; elevation, 1,295 meters; spudded, 10-21-81; temperature logged, 11-24-81; total depth, 91 meters; depth of 1½ inch PVC casing, 90 meters; bottom-hole temperature, 24.0°C; bottom-hole depth, 90 meters; bottom-hole temperature gradient, 44°C/km; best estimate heat flow value, 50 mW/m^2 (1.2 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mw/m^2)	Estimated Heat Flow (HFU)	Remarks
5	22.15		coarse sand and gravel				Drilling rate was moderate. Formations are semi-consolidated.
10	21.13	40.0 ± 0.8	medium sand, minor gravel	1.5	60	1.4	
15	21.32						
20	21.56						
25	21.82						
30	22.04						
35	22.25		medium sand	1.4	56	1.3	
40	22.43						
45	22.58						
50	22.78						
55	22.97						
60	23.13						
65	23.35						
70	23.49	25.6 ± 0.3	gravel, fine sand, and clay	1.6	41	1.0	
75	23.61						
80	23.74						
85	23.86						
90	24.00						

* Estimated thermal conductivity values.

Well Name: TG-46

Location: latitude, 32° 20.19', longitude, 106° 43.35', township & range, T23S.R2E.3.412; elevation, 1,311 meters; spudded, 10-13-81; temperature logged, 11-24-81; total depth, 91 meters; depth of 1½ inch PVC casing, 90 meters; bottom-hole temperature, 39.6°C; bottom-hole depth, 90 meters; bottom-hole temperature gradient, 218°C/km; best estimate heat flow value, 276 mW/m^2 (6.6 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mw/m^2)	Estimated Heat Flow (HFU)	Remarks
5	22.91		gravel and coarse sand				
10	23.12						Drilling rate was moderate. Formations are semi-consolidated.
15	24.40						
20	25.88		coarse sand				
25	27.44						
30	28.80	290.1 ± 1.7		1.4			Drilling fluids were being lost during drilling.
35	30.23				406	9.7	
40	31.79		medium sand				
45	33.15						
50	34.66	166	fine sand and clay		232	5.6	
55	35.49						
60	36.13						
65	36.67						
70	37.25						
75	37.87	119.1 ± 2.0	large gravel, minor sand	1.6	191	4.6	
80	38.58						
85	39.14						
90	39.58						

* Estimated thermal conductivity values.

Well Name: TG-47

Location: latitude, 32° 20.68', longitude, 106° 42.40', township & range, T22S.R2E.35.433; elevation, 1,338 meters; spudded, 10-29-81; temperature logged, 11-25-81; total depth, 49 meters; depth of 1½ inch PVC casing, 49 meters; bottom-hole temperature, 23.5°C; bottom-hole depth, 49 meters; bottom-hole temperature gradient, 71°C/km; best estimate heat flow value, 109 mW/m^2 (2.6 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mw/m^2)	(HFU)	Remarks
5	21.33						Drilling rate was moderate. Formations are semi-consolidated.
10	20.59		gravel, minor sand & clay				
15	20.89						
20	21.37						
25	21.79	80.0 ± 2.5	clay, minor gravel	1.4	112	2.7	
30	22.20						
35	22.55						
40	22.90						
45	23.22	65.5 ± 1.0	gravel, minor sand & clay	1.6	105	2.5	
49	23.49						

* Estimated thermal conductivity values.

Well Name: TG-50

Location: latitude, 32° 21.44', longitude, 106° 42.33', township & range, T22S.R2E.35.211; elevation, 1,347 meters; spudded, 10-31-81; temperature logged, 11-25-81; total depth, 51 meters; depth of 1½ inch PVC casing, 51 meters; bottom-hole temperature, 25.1°C; bottom-hole depth, 50 meters; bottom-hole temperature gradient, 102°C/km; best estimate heat flow value, 150 mW/m^2 (3.6 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mw/m^2)	Estimated Heat Flow (HFU)	Remarks
5	22.07						Drilling rate was moderate. Formations are semi-consolidated.
10	21.17		gravel and clay				
15	21.51						
20	22.04						
25	22.57		clay and gravel	1.4	143	3.4	
30	23.07						
35	23.60	102.3 ± 0.6	gravel and clay	1.5	154	3.7	
40	24.10		clay and gravel	1.4	143	3.4	
45	24.62						
50	25.11		gravel, minor clay	1.5	154	3.7	
51	25.18						

* Estimated thermal conductivity values.

Well Name: TG-51

Location: latitude, 32° 20.96', longitude, 106° 43.80', township & range, T22S.R2E.34.314; elevation, 1,314 meters; spudded, 10-29-81; temperature logged, 11-25-81; total depth, 82 meters; depth of 1½ inch PVC casing, 81 meters; bottom-hole temperature, 33.5°C; bottom-hole depth, 80 meters; bottom-hole temperature gradient, 169°C/km; best estimate heat flow value, 205 mW/m^2 (4.9 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mw/m^2)	Estimated Heat Flow (HFU)	Remarks
5	22.28		gravel				
10	22.01						Drilling rate was moderate. Formations are semi-consolidated.
15	22.98						
20	24.06						
25	25.05				286	6.8	
30	26.11	204.5 ± 0.9	sand, minor clay	1.4			
35	27.07						
40	28.19						
45	29.12						
50	30.17						
55	30.75	120.0 ± 2.3	clay, minor sand		168	4.0	
60	31.37						
65	31.90						
70	32.44						
75	33.00	103.8 ± 2.4	gravel, minor clay	1.5	163	3.9	
80	33.48						
81	33.51						

* Estimated thermal conductivity values.

Well Name: TG-52

Location: latitude, 32° 20.85', longitude, 106° 44.51', township & range, T22S.R2E.33.342; elevation, 1,311 meters; spudded, 10-26-81; temperature logged, 11-25-81; total depth, 91 meters; depth of 1½ inch PVC casing, 91 meters; bottom-hole temperature, 27.4°C; bottom-hole depth, 90 meters; bottom-hole temperature gradient, 82°C/km; best estimate heat flow value, 96 mW/m^2 (2.3 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mw/m^2)	(HFU)	Remarks
5	22.70		gravel				
10	21.89						Drilling rate was moderate. Formations are semi-consolidated.
15	22.32						
20	22.81						
25	23.28	88.5 ± 1.9	coarse sand		124	3.0	
30	23.69						Formations have a gradual decrease in grain size with depth.
35	24.07						
40	24.38						
45	24.65						
50	24.97						
55	25.32						
60	25.64	65.6 ± 0.9	medium sand	1.4	92	2.2	
65	25.99						
70	26.37						
75	26.66						
80	26.90						
85	27.13	47.3 ± 0.2	fine sand, minor clay		66	1.6	
90	27.37						
91	27.42						

* Estimated thermal conductivity values.

Well Name: TG-53

Location: latitude, 32° 21.56', longitude, 106° 44.74', township & range, T22S.R2E.28.334; elevation, 1,295 meters; spudded, 10-28-81; temperature logged, 11-25-81; total depth, 91 meters; depth of 1½ inch PVC casing, 90 meters; bottom-hole temperature, 24.8°C; bottom-hole depth, 90 meters; bottom-hole temperature gradient, 53°C/km; best estimate heat flow value, 59 mW/m^2 (1.4 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mw/m^2)	(HFU)	Remarks
5	22.03		clay and fine sand				Drilling rate was moderate. Formations are semi-consolidated.
10	21.39		medium sand and clay				
15	21.77						
20	22.10	69.6 ± 1.5			97	2.3	
25	22.44		clay and fine sand				
30	22.71	52.0 ± 1.2			73	1.7	
35	22.96			1.4			
40	23.18	41.2 ± 0.7	medium sand and clay				
45	23.38		clay and fine sand, minor gravel		58	1.4	
50	23.58						
55	23.74		medium sand and clay		42	1.0	
60	23.88						
65	24.04		clay				
70	24.18			1.3	39	0.9	
75	24.35	29.8 ± 0.3					
80	24.48		clay and fine sand, minor gravel				
85	24.64			1.4	42	1.0	
90	24.76						

Well Name: TG-54

Location: latitude, 32° 21.56', longitude, 106° 43.82', township & range, T22S.R2E.27.334; elevation, 1,298 meters; spudded, 10-31-81; temperature logged, 11-25-81; total depth, 92 meters; depth of 1½ inch PVC casing, 92 meters; bottom-hole temperature, 51.2°C; bottom-hole depth, 90 meters; bottom-hole temperature gradient, 347°C/km; best estimate heat flow value, 435 mW/m^2 (10.4 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mw/m^2)	Estimated Heat Flow (HFU)	Remarks
5	19.59		gravel				Drilling rate was moderate. Formations are semi-consolidated.
10	23.82						
15	25.44						
20	27.14						
25	29.06	351.2 ± 3.8	gravel and sand		492	11.8	
30	30.77						
35	32.53						
40	34.53						
45	36.47			1.4			
50	38.40						
55	40.27	379.8 ± 4.0	sand		532	12.7	
60	42.00						
65	43.80						
70	46.06						
75	47.57						
80	48.92	278.4 ± 6.0	sand and gravel		445	10.6	
85	50.25			1.6			
90	51.21	167.1 ± 23.8	gravel, minor sand		267	6.4	
92	51.38						

* Estimated thermal conductivity values.

Well Name: TG-55

Location: latitude, 32° 22.24', longitude, 106° 42.18', township & range, T22S.R2E.26.214; elevation, 1,347 meters; spudded, 11-1-81; temperature logged, 11-30-81; total depth, 52 meters; depth of 1½ inch PVC casing, 51 meters; bottom-hole temperature, 23.2°C; bottom-hole depth, 50 meters; bottom-hole temperature gradient, 64°C/km; best estimate heat flow value, 100 mW/m^2 (2.4 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mw/m^2)	(HFU)	Remarks
5	20.79		gravel and clay				Drilling rate was moderate. Formations are semi-consolidated.
10	20.50						
15	20.73						
20	21.18	83.0 ± 4.0	clay and gravel	1.4	116	2.8	
25	21.56						
30	21.91	69.0 ± 0.6	gravel and clay	1.5	104	2.5	
35	22.25						
40	22.55		clay	1.3	82	2.0	
45	22.87	62.8 ± 0.5					
50	23.19						
51	23.25		coarse sand and clay	1.4	88	2.1	

* Estimated thermal conductivity values.

Well Name: TG-57

Location: latitude, 32° 22.88', longitude, 106° 43.13', township & range, T22S.R2E.22.244; elevation, 1,336 meters; spudded, 11-2-81; temperature logged, 11-30-81; total depth, 91 meters; depth of 1½ inch PVC casing, 88 meters; bottom-hole temperature, 36.5°C; bottom-hole depth, 88 meters; bottom-hole temperature gradient, 188°C/km; best estimate heat flow value, 268 mW/m^2 (6.4 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mw/m^2)	Estimated Heat Flow (HFU)	Remarks
5	21.50		clay and gravel	1.4			Drilling rate was slow 70 meters to T.D. Formations are hard and fractured. Lost circulation at 37 meters. Drilled from 37 meters to T.D. with air.
10	21.84						
15	22.85						
20	24.03	271.8 ± 16.2			381	9.1	
25	25.29						
30	26.96						
35	28.04	210.2 ± 2.4	clay	1.3	273	6.5	
40	29.04						
45	30.13	178.0 ± 4.6	clay and gravel, hard	1.5	267	6.4	
50	31.06						
55	31.91	151.8 ± 1.2			228	5.5	
60	32.72						
65	33.48						
70	34.24						
75	34.97						
80	35.72						
85	36.32	100.8 ± 15.0	gravel and clay, hard and fractured	1.8	181	4.3	
88	36.51						

* Estimated thermal conductivity values.

Well Name: TG-58

Location: latitude, 32° 22.93', longitude, 106° 44.45', township & range, T22S.R2E.21.231; elevation, 1,315 meters; spudded, 10-23-81; temperature logged, 12-1-81; total depth, 91 meters; depth of 1½ inch PVC casing, 65 meters; bottom-hole temperature, 23.7°C; bottom-hole depth, 65 meters; bottom-hole temperature gradient, 57°C/km; best estimate heat flow value, 105 mW/m^2 (2.5 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mw/m^2)	Estimated Heat Flow (HFU)	Remarks
5	20.19						Drilling rate was moderate. Formations are semi-consolidated.
10	19.62		gravel and clay				
15	20.02						
20	20.51						
25	21.05	99.4 ± 1.4	clay and gravel	1.4	139	3.3	Obstruction or cave-in at 65 meters.
30	21.50						
35	22.01						
40	22.36	70.0	gravel and clay	1.5	105	2.5	
45	22.71						
50	22.97						
55	23.20	49.8 ± 0.9	clay and sand, minor gravel	1.4	70	1.7	
60	23.48						
65	23.70						
70							
75							
80			clay and fine sand, minor gravel				
85							
90							

* Estimated thermal conductivity values.

Well Name: TG-62

Location: latitude, 23° 13.59', longitude, 106° 40.85', township & range, T24S.R3E.18.112; elevation, 1,280 meters; spudded, 10-9-81; temperature logged, 11-13-81; total depth, 91 meters; depth of 1½ inch PVC casing, 91 meters; bottom-hole temperature, 35.1°C; bottom-hole depth, 90 meters; bottom-hole temperature gradient, 168°C/km; best estimate heat flow value, 217 mW/m^2 (5.2 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mw/m^2)	(HFU)	Remarks
5	24.10						
10	23.34						Drilling rate was fast. Formations are unconsolidated.
15	24.41	194.0 ± 11.5	gravel	1.4	272	6.5	
20	25.28						
25	26.04						Formations have a gradual decrease in grain size with depth.
30	26.79	149.4 ± 0.5			209	5.0	
35	27.53						
40	28.27	140	sand and gravel	1.5	210	5.0	
45	28.97						
50	29.62	130.4 ± 0.8	coarse sand		183	4.4	
55	30.26						
60	30.93						
65	31.67						
70	32.36			1.4	195	4.7	
75	33.06	139.5 ± 0.8					
80	33.79		medium sand				
85	34.45						
90	35.14						
91	35.26						

* Estimated thermal conductivity values.

Well Name: TG-63

Location: latitude, 32° 14.15', longitude, 106° 39.68', township & range, T24S.R3E.8.134; elevation, 1,295 meters; spudded, 10-12-81; temperature logged, 11-13-81; total depth, 91 meters; depth of 1½ inch PVC casing, 91 meters; bottom-hole temperature, 40.8°C; bottom-hole depth, 90 meters; bottom-hole temperature gradient, 231°C/km; best estimate heat flow value, 339 mW/m^2 (8.1 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mw/m^2)	Estimated Heat Flow (HFU)	Remarks
5	22.69						Drilling rate was fast. Formations are unconsolidated.
10	22.08						
15	23.39		gravel	1.4			
20	25.13	298.4 ± 8.0			418	10.0	
25	26.61						
30	27.93						Formations have a gradual decrease in grain size with depth.
35	28.98	213.0 ± 0.8	gravel and sand		320	7.7	
40	30.06						
45	31.12			1.5			
50	32.11						
55	33.01	195.6 ± 2.9	coarse sand and gravel		293	7.0	
60	34.01						
65	35.06						
70	36.23						
75	37.35						
80	38.41	228.8 ± 2.3	coarse sand	1.4	320	7.7	
85	39.68						
90	40.84						
91	40.96						

* Estimated thermal conductivity values.

Well Name: TG-64

Location: latitude, 32° 14.84', longitude, 106° 40.44', township & range, T24S.R3E.6.413; elevation, 1,289 meters; spudded, 10-5-81; temperature logged, 11-13-81; total depth, 92 meters; depth of 1½ inch PVC casing, 92 meters; bottom-hole temperature, 39.7°C; bottom-hole depth, 90 meters; bottom-hole temperature gradient, 219°C/km; best estimate heat flow value, 280 mW/m^2 (6.7 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mw/m^2)	(HFU)	Remarks
5	23.65						
10	23.32						Drilling rate was fast. Formations are consolidated.
15	24.65		gravel	1.4			
20	25.83						
25	27.08	244.2 ± 3.7			342	8.2	
30	28.21						Formations have a gradual decrease in grain size with depth.
35	29.18						
40	30.19	200.8 ± 1.9	sand and gravel	1.5	301	7.2	
45	31.22						
50	32.11	179.0 ± 0.6	coarse sand		251	6.0	
55	33.01						
60	34.03						
65	35.09		medium sand		276	6.6	
70	36.05	197.1 ± 2.3					
75	36.96			1.4			
80	37.96						
85	38.85						
90	39.71	170.4 ± 3.9	fine sand		239	5.7	
92	39.99						

* Estimated thermal conductivity values.

Well Name: TG-65

Location: latitude, 32° 14.38', longitude, 106° 41.20', township & range, T24S.R2E.12.223; elevation, 1,280 meters; spudded, 10-7-81; temperature logged, 11-13-81; total depth, 91 meters; depth of 1½ inch PVC casing, 91 meters; bottom-hole temperature, 37.1°C; bottom-hole depth, 90 meters; bottom-hole temperature gradient, 190°C/km; best estimate heat flow value, 251 mW/m^2 (6.0 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mw/m^2)	Estimated Heat Flow (HFU)	Remarks
5	24.11		gravel and sand				
10	23.56						Drilling rate was fast. Formations are unconsolidated.
15	24.75	236.0 ± 1.2	sand and gravel	1.4	330	7.9	
20	25.92						
25	26.88						
30	27.69	174.2 ± 2.4	gravel and sand	1.5	261	6.2	Formations have a gradual decrease in grain size with depth.
35	28.57						
40	29.43						
45	30.15						
50	30.95						
55	31.77						
60	32.56	158.4 ± 0.7	medium sand		222	5.3	
65	33.31						
70	34.14			1.4			
75	34.92						
80	35.75						
85	36.44						
90	37.10	134.4 ± 1.1	fine sand		188	4.5	
91	37.23						

* Estimated thermal conductivity values.

Well Name: TG-66

Location: latitude, 32° 13.29', longitude, 106° 41.84', township & range, T24S.R2E.13.134; elevation, 1,225 meters; spudded, 10-20-81; temperature logged, 11-17-81; total depth, 91 meters; depth of 1½ inch PVC casing, 91 meters; bottom-hole temperature, 27.9°C; bottom-hole depth, 90 meters; bottom-hole temperature gradient, 88°C/km; best estimate heat flow value, 113 mW/m^2 (2.7 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mw/m^2)	Estimated Heat Flow (HFU)	Remarks
5	23.07						
10	22.02						Drilling rate was fast. Formations are unconsolidated. Formations have a gradual decrease in grain size with depth.
15	22.60		gravel	1.4			
20	23.39	136.0 ± 4.3			190	4.5	
25	24.10						
30	24.67						
35	25.12						
40	25.53	82.0 ± 2.5	gravel and sand		123	2.9	
45	25.90			1.5			
50	26.24	64.0 ± 2.3	sand and gravel		96	2.3	
55	26.54						
60	26.76						
65	26.95						
70	27.14						
75	27.30	37.1 ± 0.4					
80	27.49		medium sand	1.4	52	1.2	
85	27.67						
90	27.85						
91	27.91						

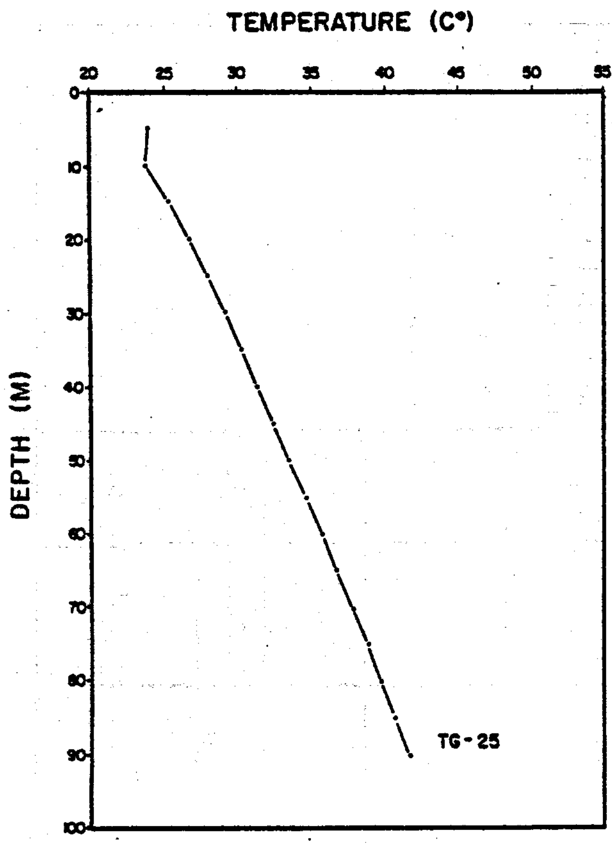
* Estimated thermal conductivity values.

Well Name: TG-67

Location: latitude, 32° 15.29', longitude, 106° 41.73', township & range, T24S.R2E.1.114; elevation, 1,274 meters; spudded, 10-6-81; temperature logged, 11-13-81; total depth, 92 meters; depth of 1½ inch PVC casing, 92 meters; bottom-hole temperature, 46.1°C; bottom-hole depth, 90 meters; bottom-hole temperature gradient, 290°C/km; best estimate heat flow value, 368 mW/m^2 (8.8 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mw/m^2)	Estimated Heat Flow (HFU)	Remarks
5	24.50						
10	24.92						Drilling rate was fast. Formations are unconsolidated to semi-consolidated.
15	26.67		sand and gravel	1.4			
20	28.45	322.4 ± 10.1			451	10.8	
25	29.95						
30	31.34						
35	32.59						Formations have a gradual decrease in grain size with depth.
40	33.84	251.4 ± 0.6	coarse sand, minor gravel	1.5	377	9.0	
45	35.12						
50	36.36						
55	37.70		medium sand		392	9.4	
60	39.12	279.8 ± 3.0					
65	40.55						
70	41.71		fine sand		340	8.1	
75	42.98	242.9 ± 6.4		1.4			
80	44.07						
85	45.06	203.3 ± 4.5					
90	46.13		very fine sand		285	6.8	
92	46.40						

* Estimated thermal conductivity values.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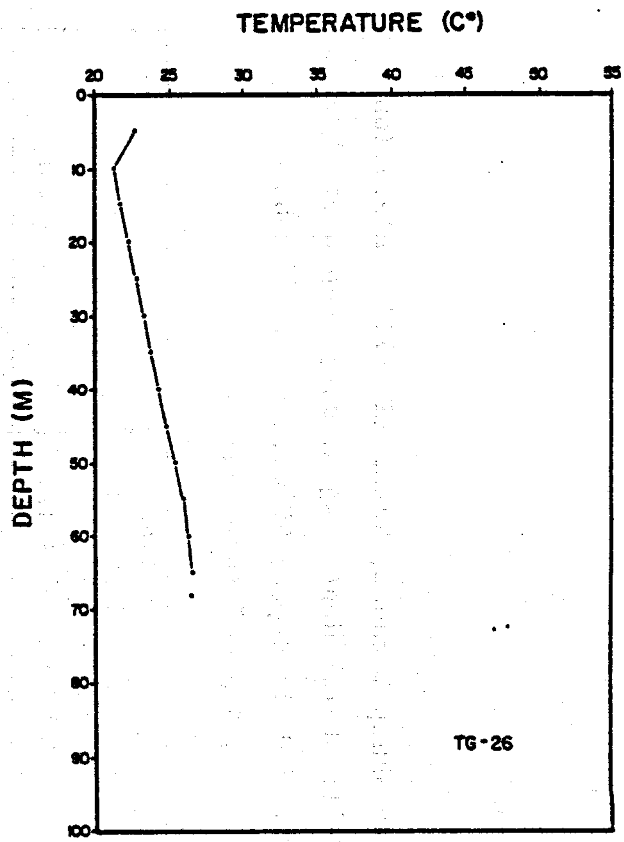
TG-25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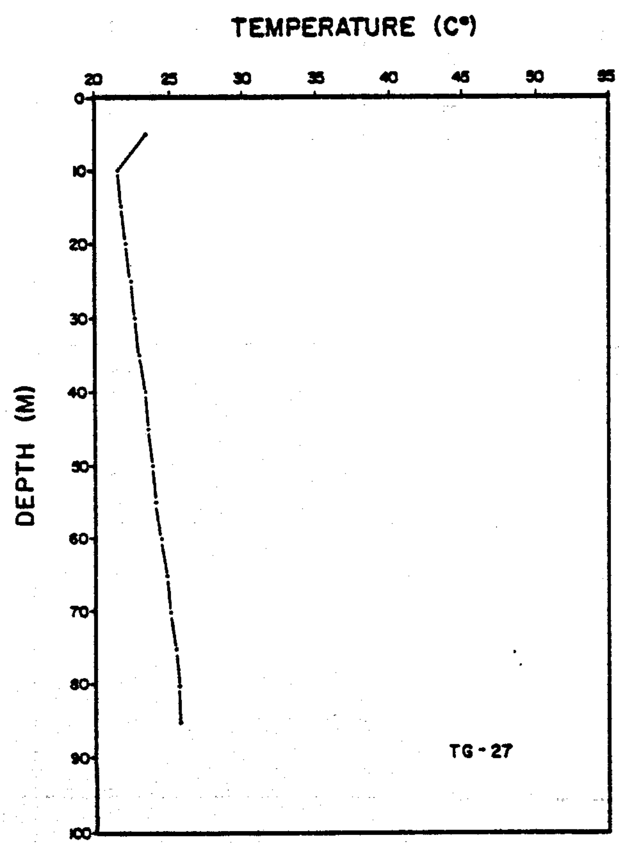
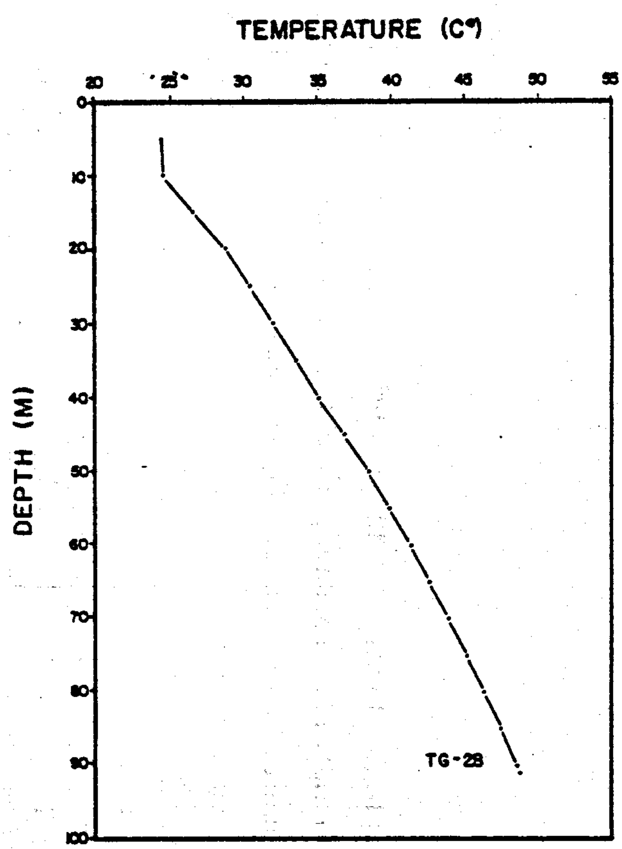
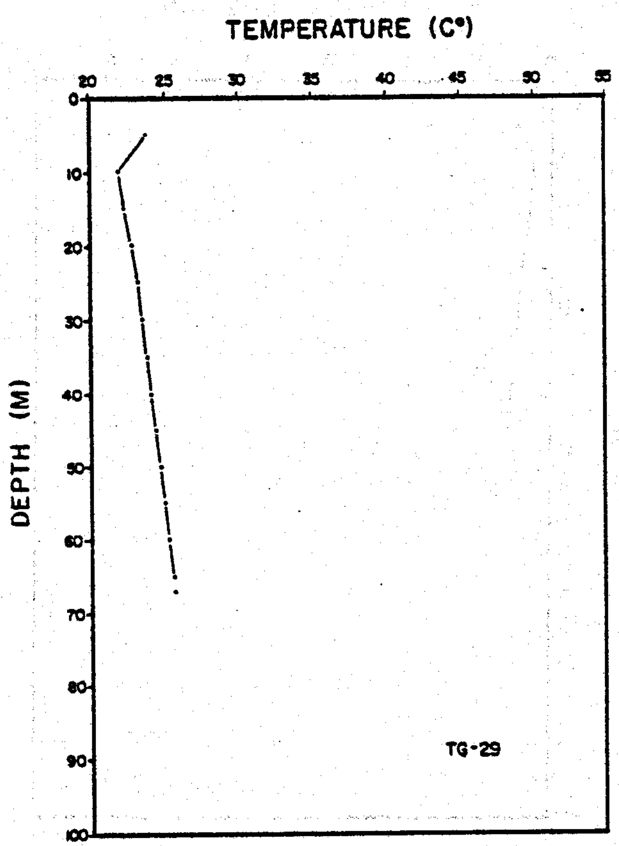
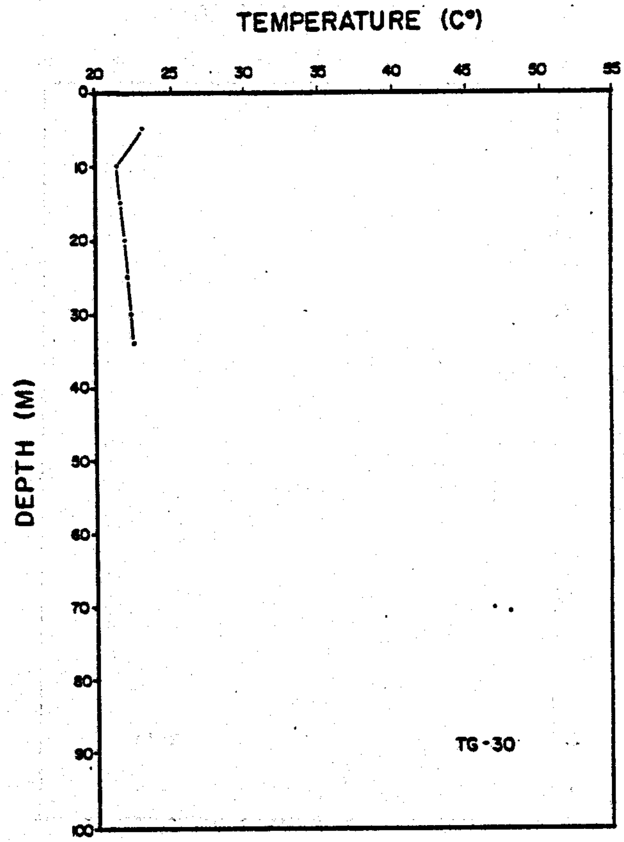
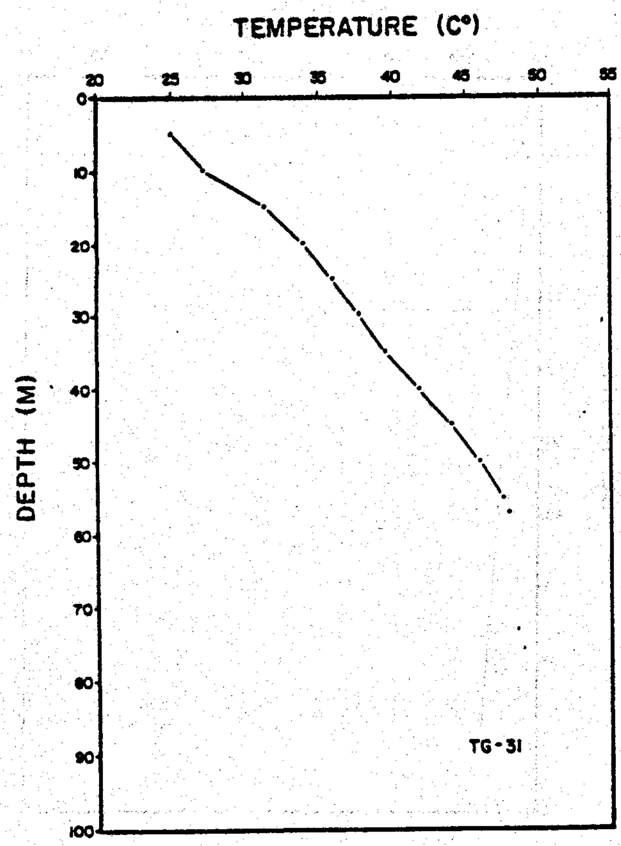
DEPTH (M)
TG-26

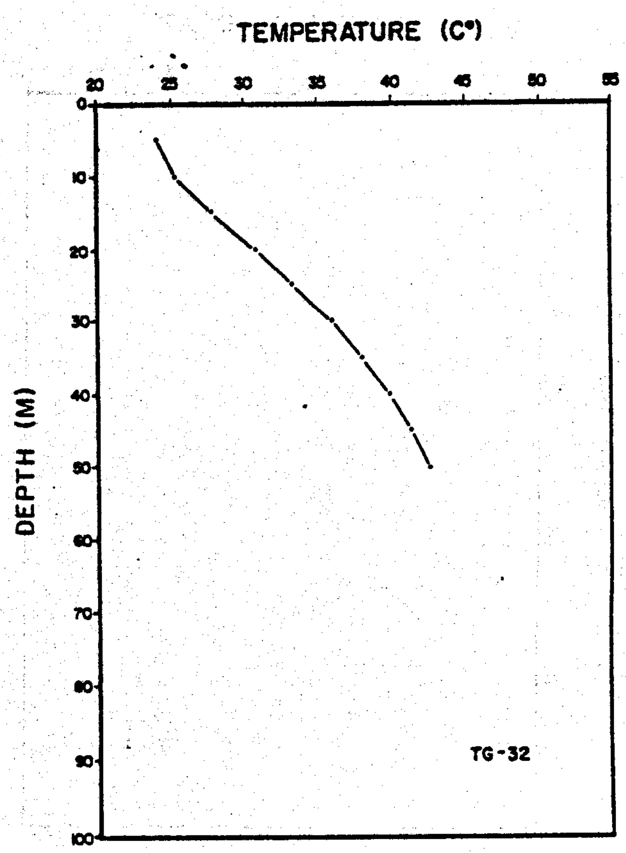

TEMPERATURE (C°)
DEPTH (M)
TG-27

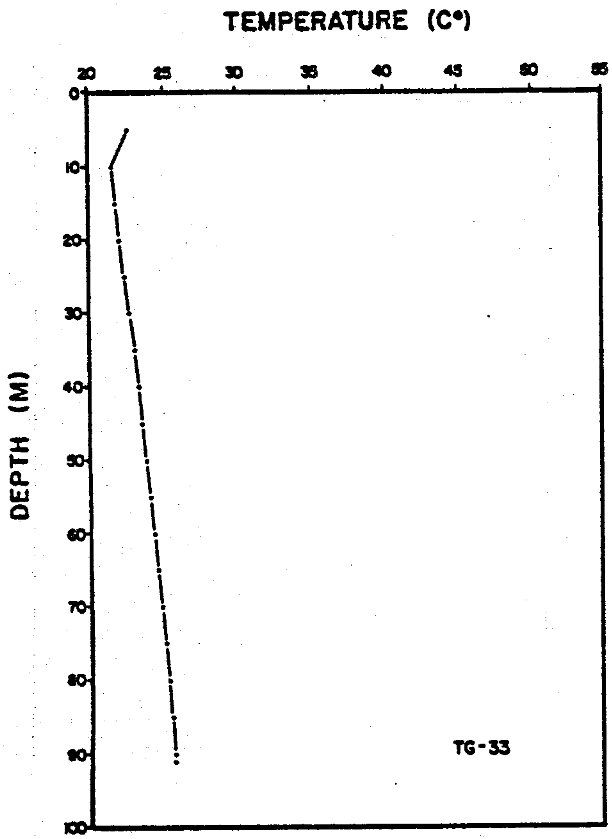

TEMPERATURE (C°)
DEPTH (M)
TG-28

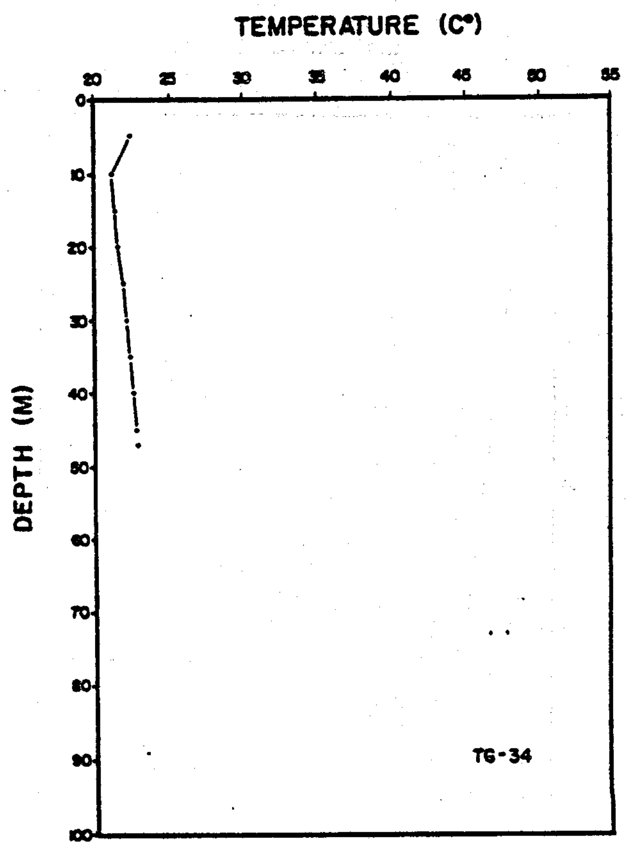

TEMPERATURE (C°)
20 25 30 35 40 45 50 55
DEPTH (M)
0 10 20 30 40 50 60 70 80 90 100
TG-29

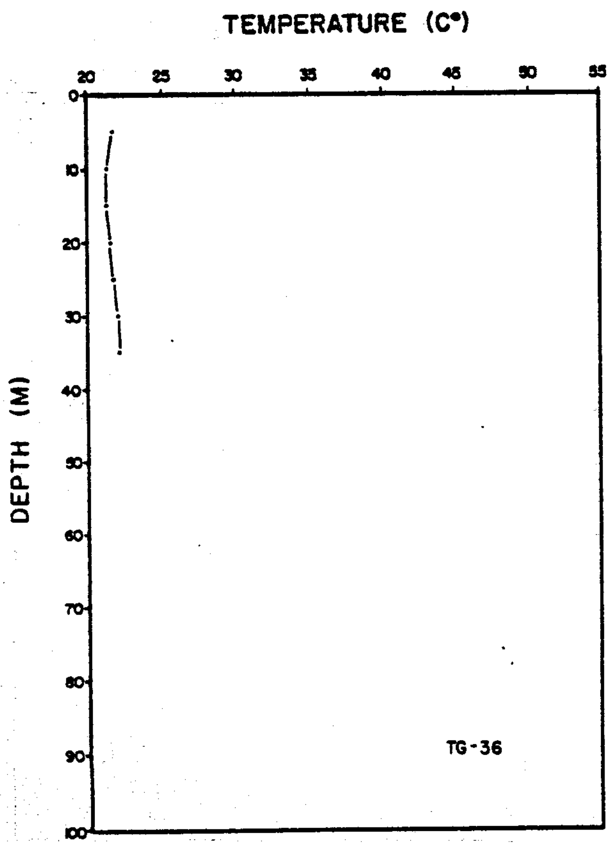

TEMPERATURE (C°)
20 25 30 35 40 45 50 55
DEPTH (M)
0 10 20 30 40 50 60 70 80 90 100
TG-30

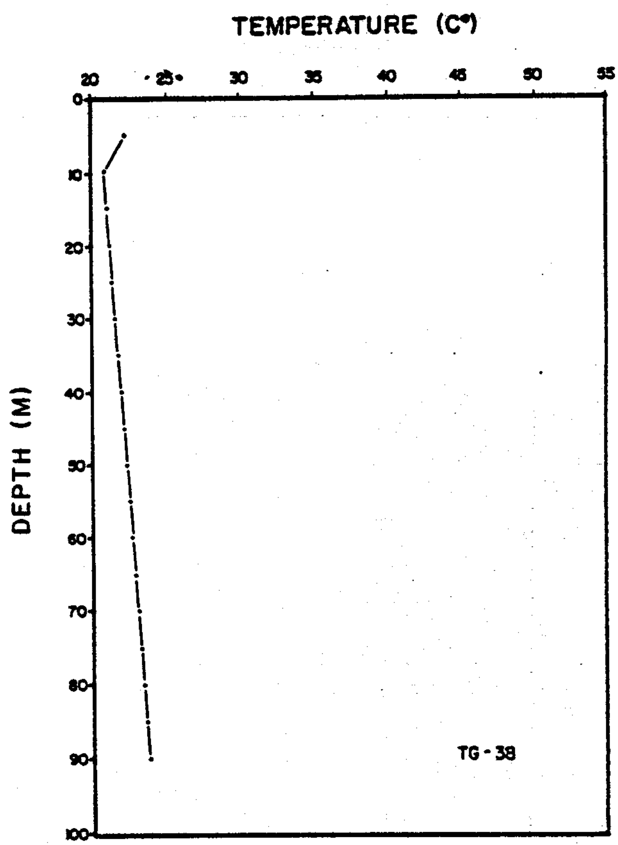

TEMPERATURE (C°)
20 25 30 35 40 45 50 55
DEPTH (M)
0 10 20 30 40 50 60 70 80 90 100
TG-31

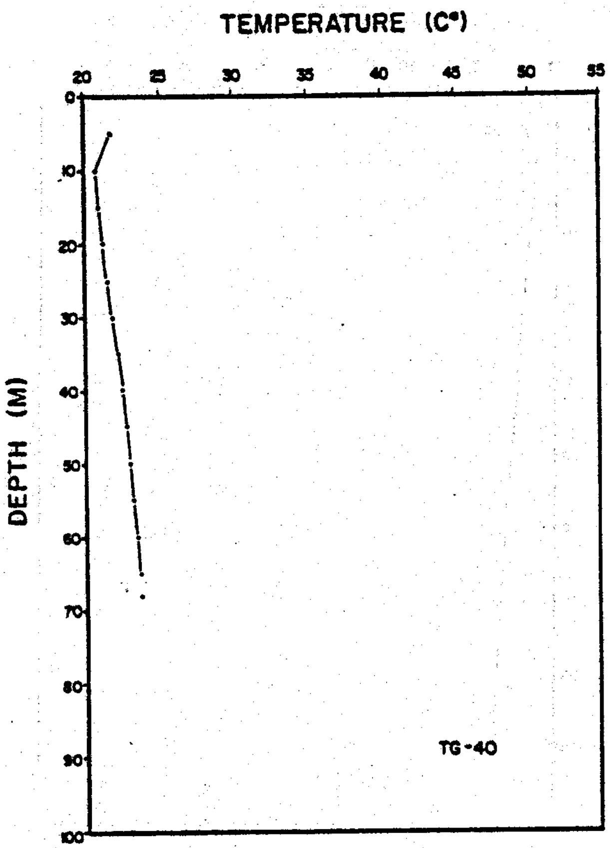

TEMPERATURE (C°)
20 25 30 35 40 45 50 55
DEPTH (M)
0 10 20 30 40 50 60 70 80 90 100
TG-32

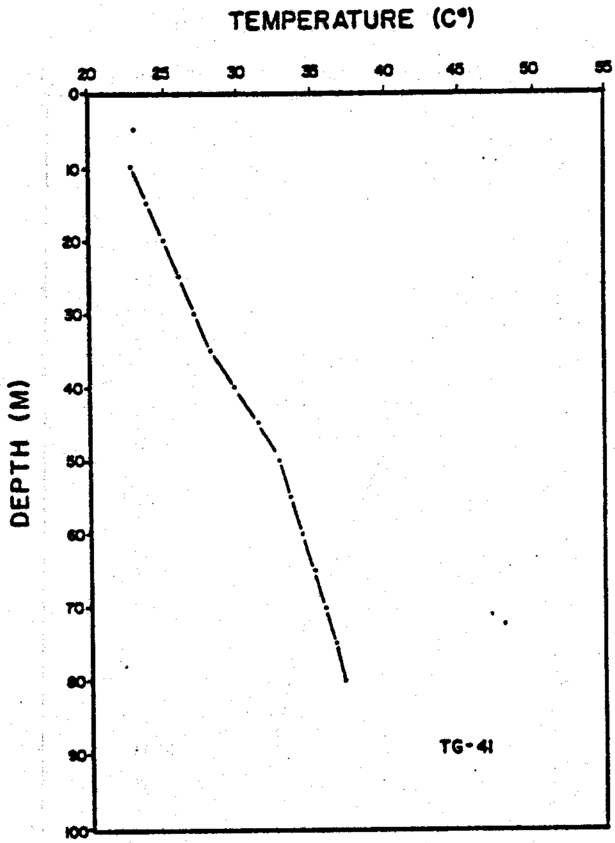

TEMPERATURE (C°)
20 25 30 35 40 45 50 55
DEPTH (M)
0 10 20 30 40 50 60 70 80 90 100
TG-33

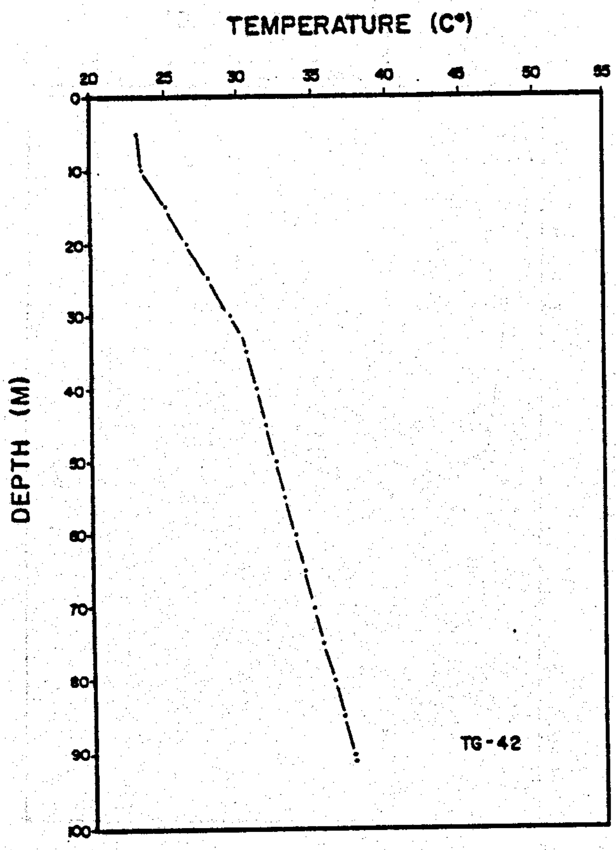

TEMPERATURE (C°)
20 25 30 35 40 45 50 55
DEPTH (M)
0 10 20 30 40 50 60 70 80 90 100
TG-34

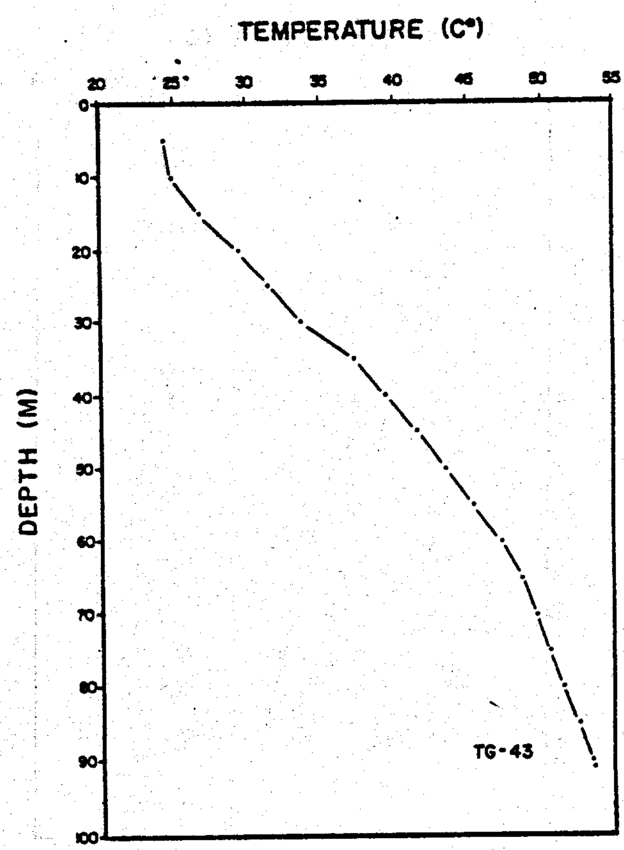

TEMPERATURE (C°)
20 25 30 35 40 45 50 55
DEPTH (M)
0 10 20 30 40 50 60 70 80 90 100
TG-36

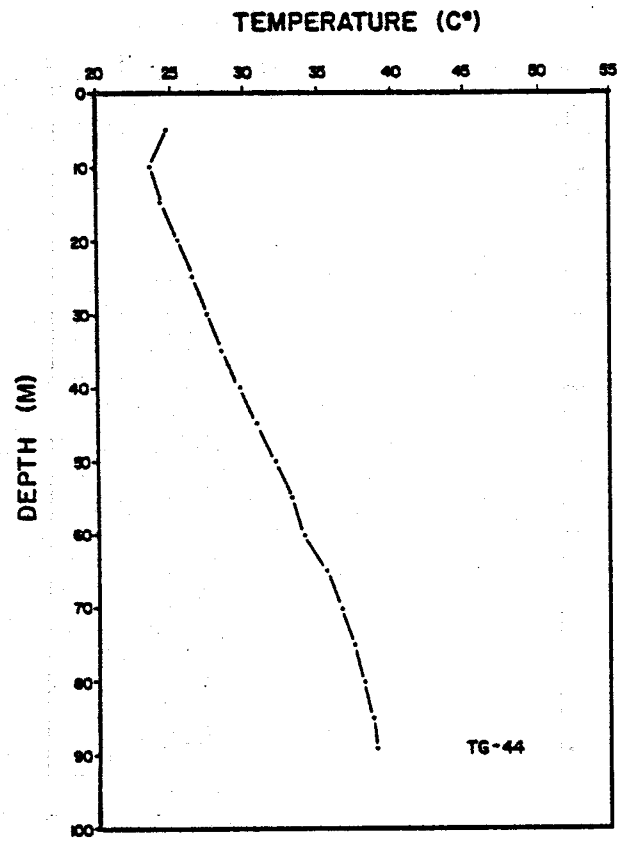

TEMPERATURE (C°)
20 25 30 35 40 45 50 55
DEPTH (M)
0 10 20 30 40 50 60 70 80 90 100
TG-38

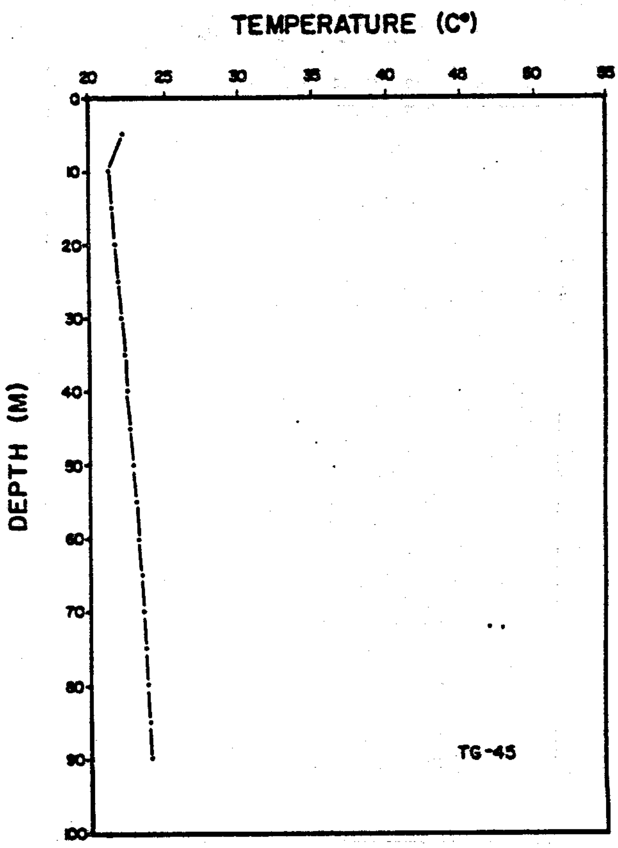

TEMPERATURE (C°)
DEPTH (M)
TG-40

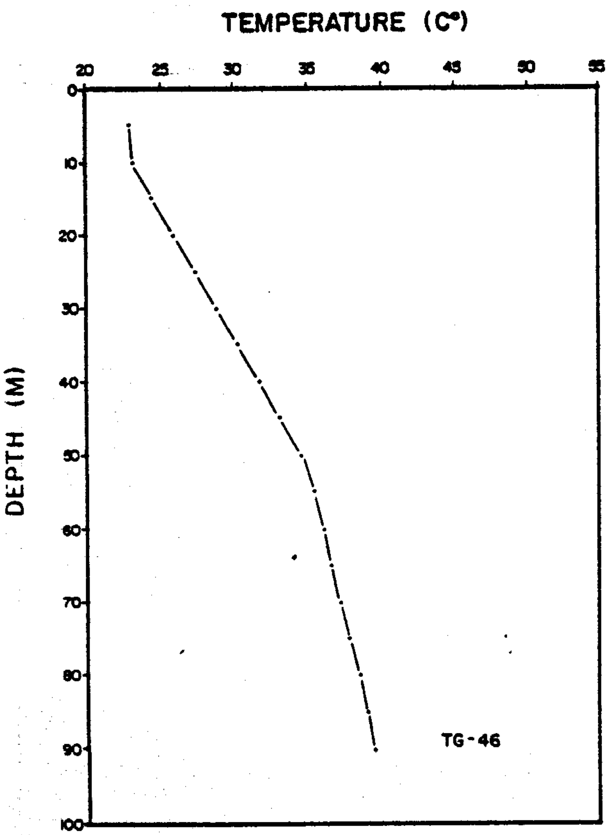

TEMPERATURE (C°)
DEPTH (M)
TG-41

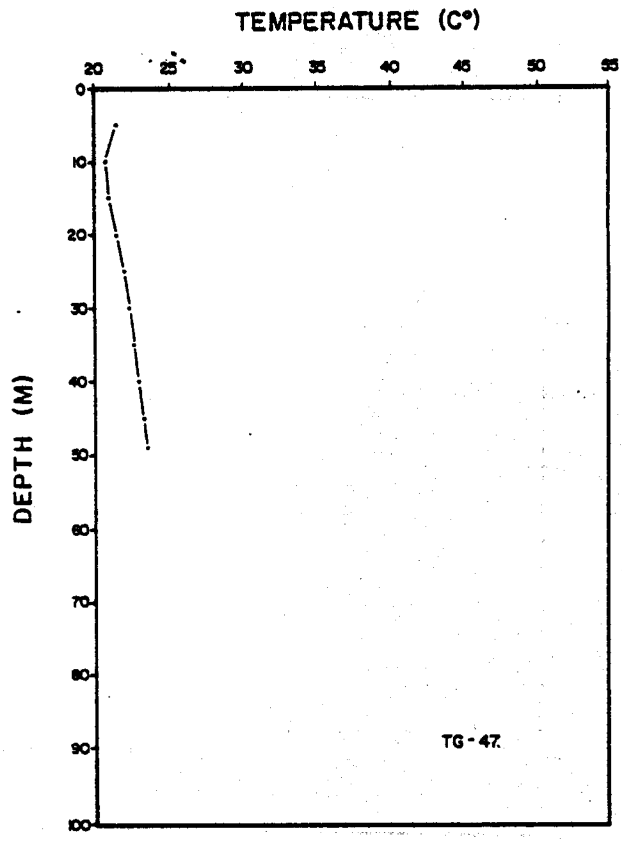

TEMPERATURE (C°)
DEPTH (M)
TG-42

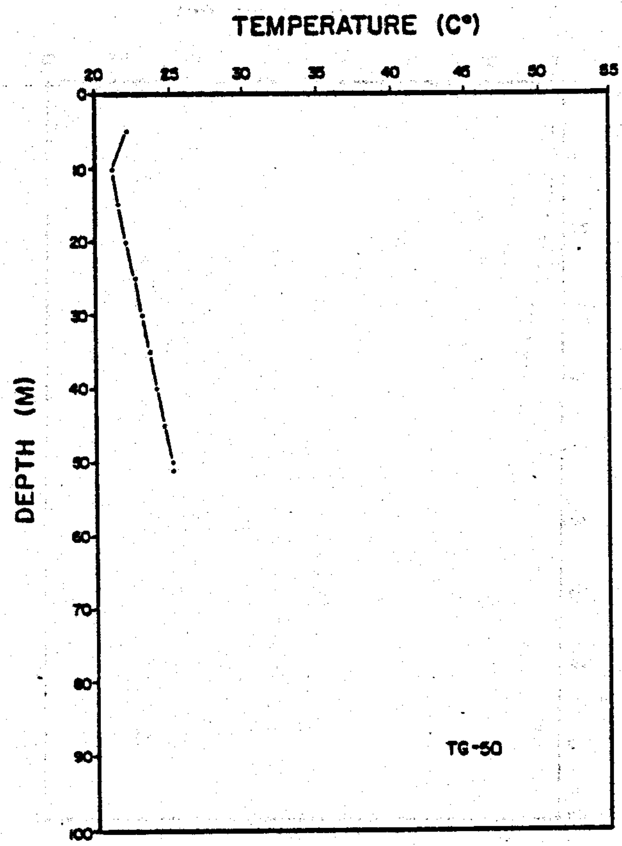

TEMPERATURE (C°)
DEPTH (M)
TG-43

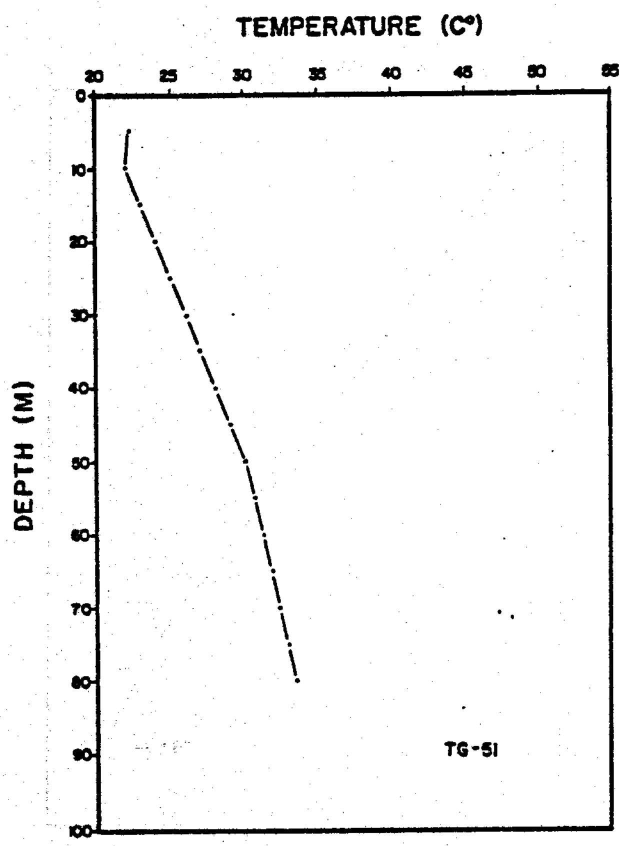

TEMPERATURE (C°)
20 25 30 35 40 45 50 55
DEPTH (M)
0 10 20 30 40 50 60 70 80 90 100
TG-44

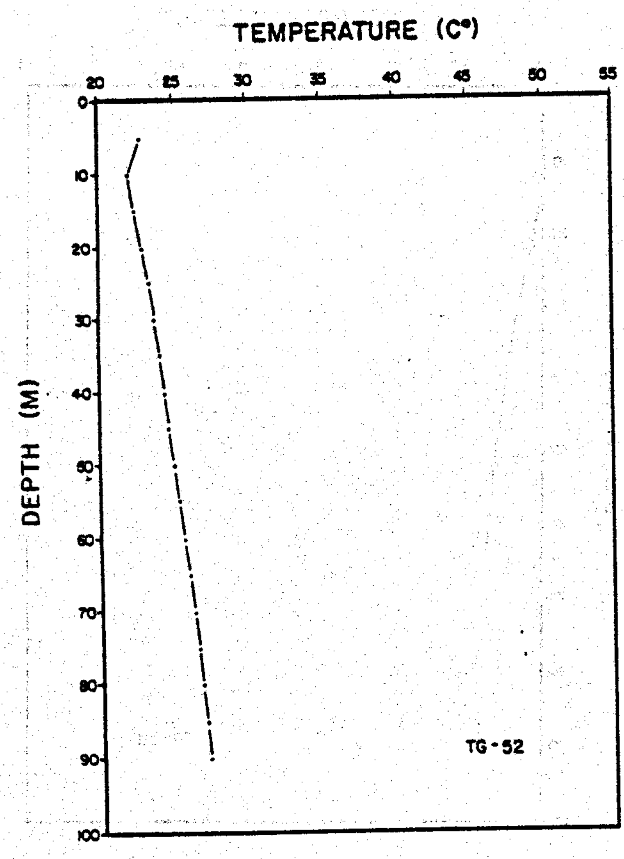

TEMPERATURE (C°)
20 25 30 35 40 45 50 55
DEPTH (M)
0 10 20 30 40 50 60 70 80 90 100
TG-45

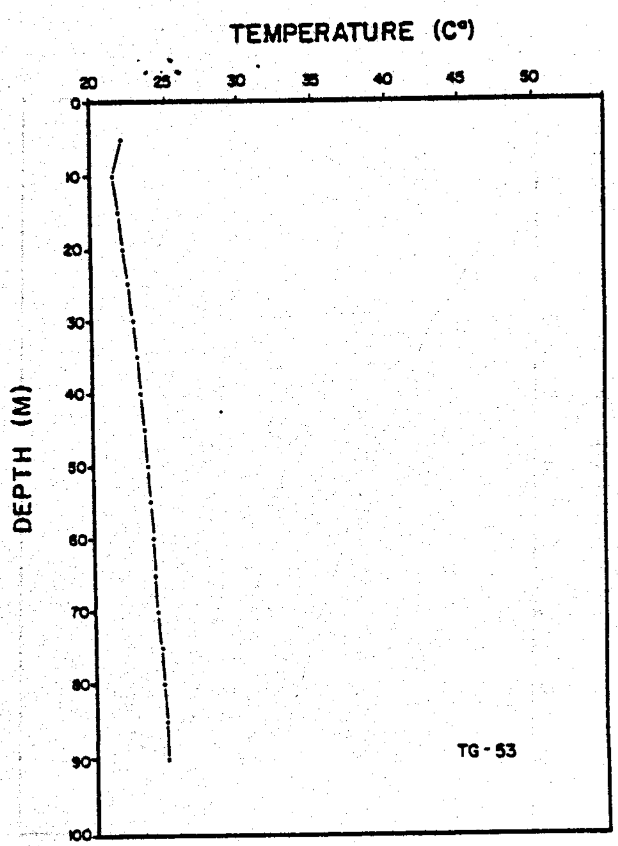

TEMPERATURE (C°)
20 25 30 35 40 45 50 55
DEPTH (M)
0 10 20 30 40 50 60 70 80 90 100
TG-46

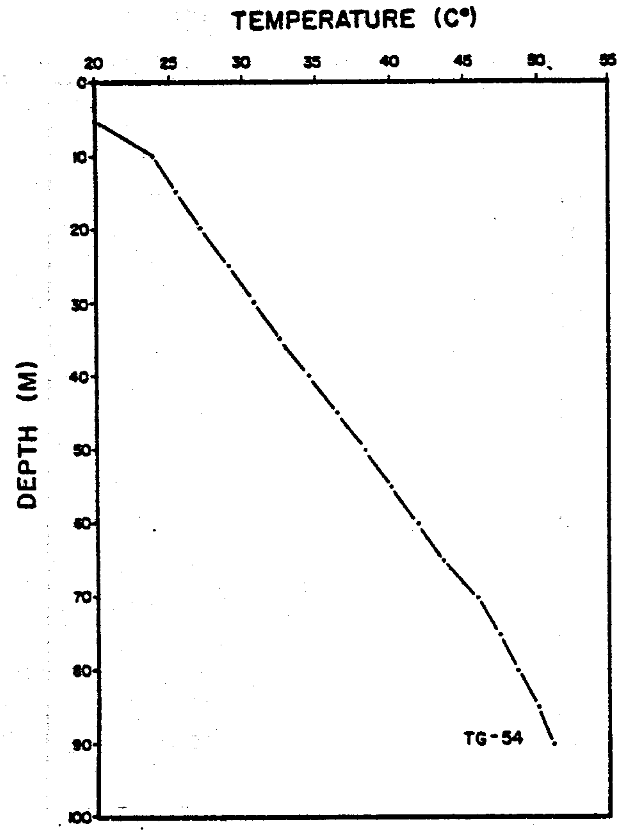

TEMPERATURE (C°)
20 25 30 35 40 45 50 55
DEPTH (M)
0 10 20 30 40 50 60 70 80 90 100
TG-47

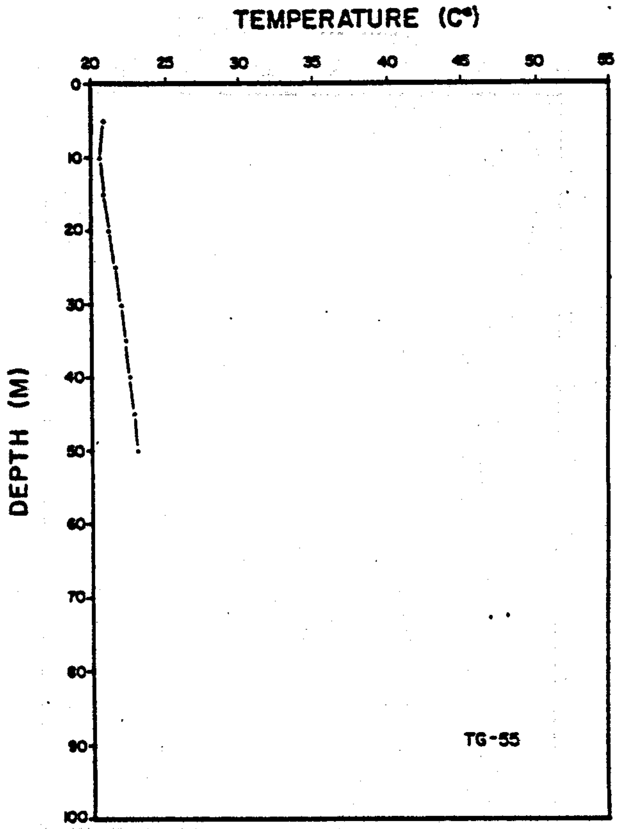

TEMPERATURE (C°)
20 25 30 35 40 45 50 55
DEPTH (M)
0 10 20 30 40 50 60 70 80 90 100
TG-50

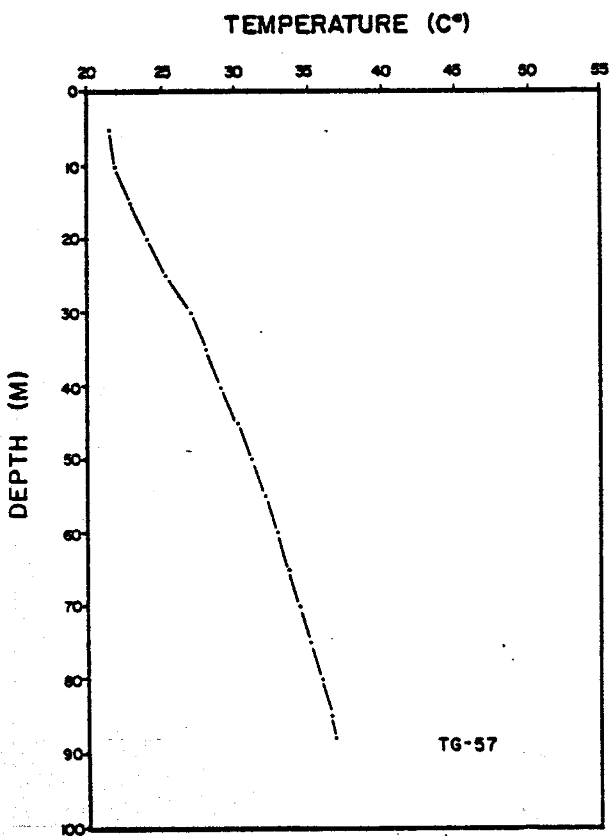

TEMPERATURE (C°)
20 25 30 35 40 45 50 55
DEPTH (M)
0 10 20 30 40 50 60 70 80 90 100
TG-51

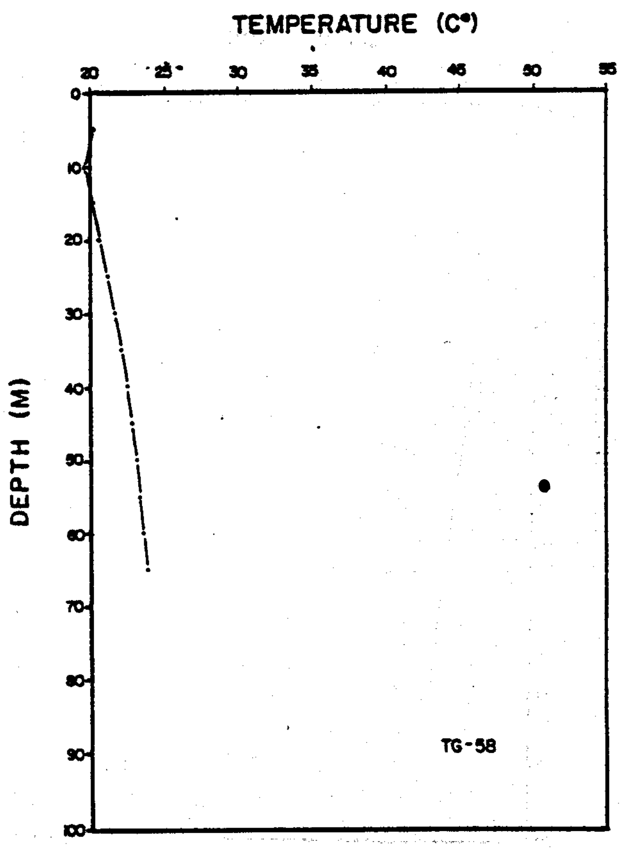

TEMPERATURE (C°)
20 25 30 35 40 45 50 55
DEPTH (M)
0 10 20 30 40 50 60 70 80 90 100
TG-52

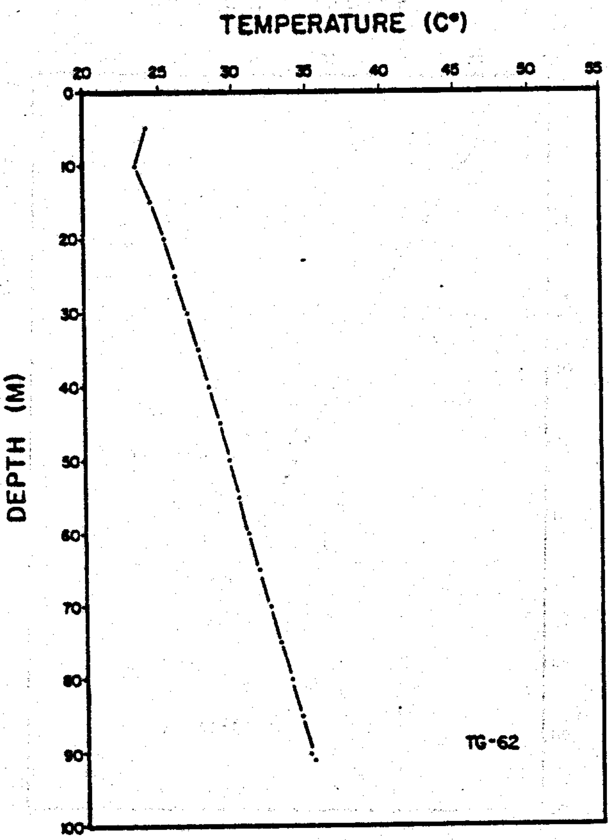

TEMPERATURE (C°)
20 25 30 35 40 45 50
DEPTH (M)
0 10 20 30 40 50 60 70 80 90 100
TG-53

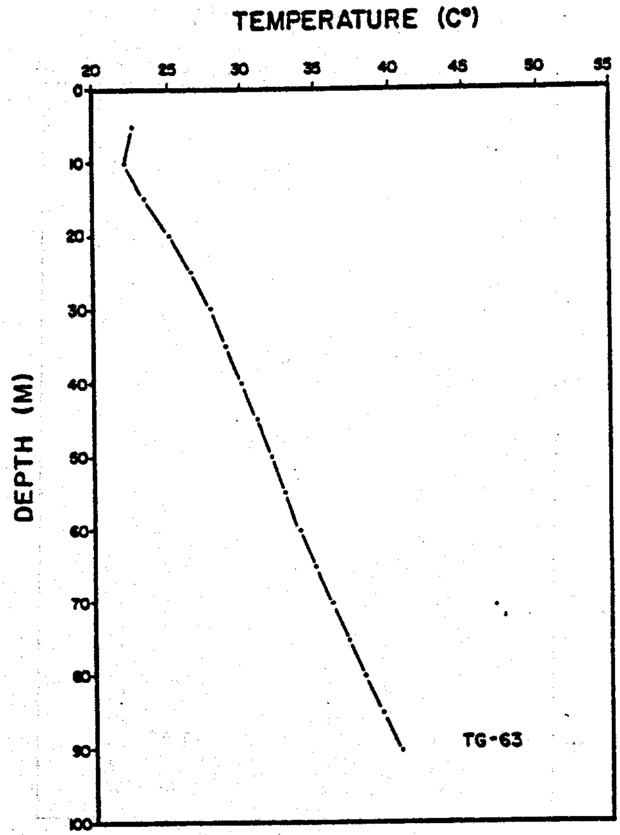

TEMPERATURE (C°)
20 25 30 35 40 45 50 55
DEPTH (M)
0 10 20 30 40 50 60 70 80 90 100
TG-54

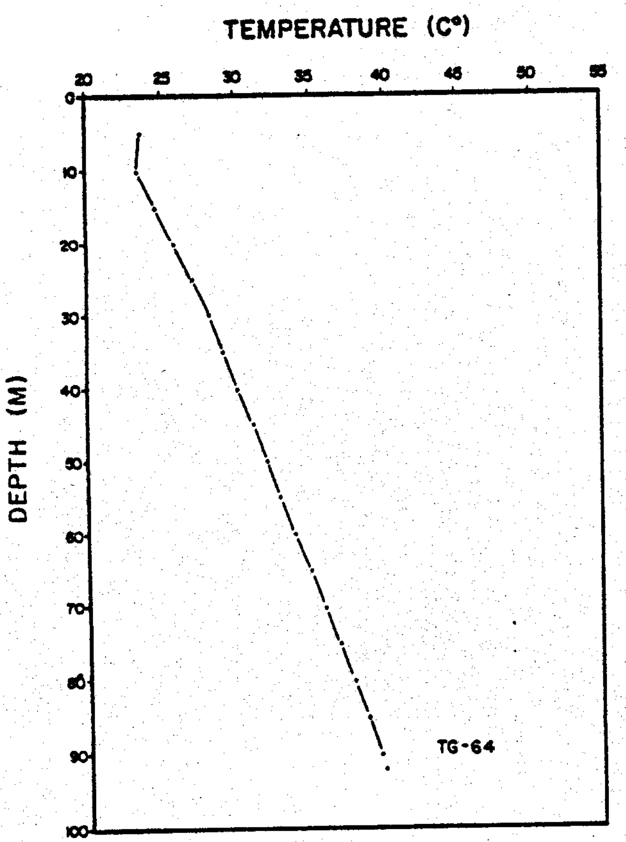

TEMPERATURE (C°)
20 25 30 35 40 45 50 55
DEPTH (M)
0 10 20 30 40 50 60 70 80 90 100
TG-55

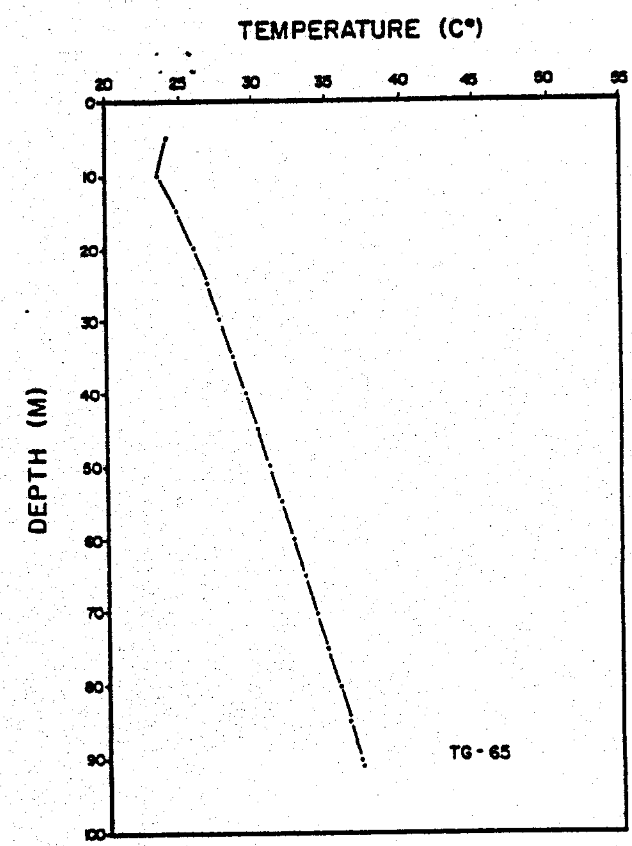

TEMPERATURE (C°)
20 25 30 35 40 45 50 55
DEPTH (M)
0 10 20 30 40 50 60 70 80 90 100
TG-57

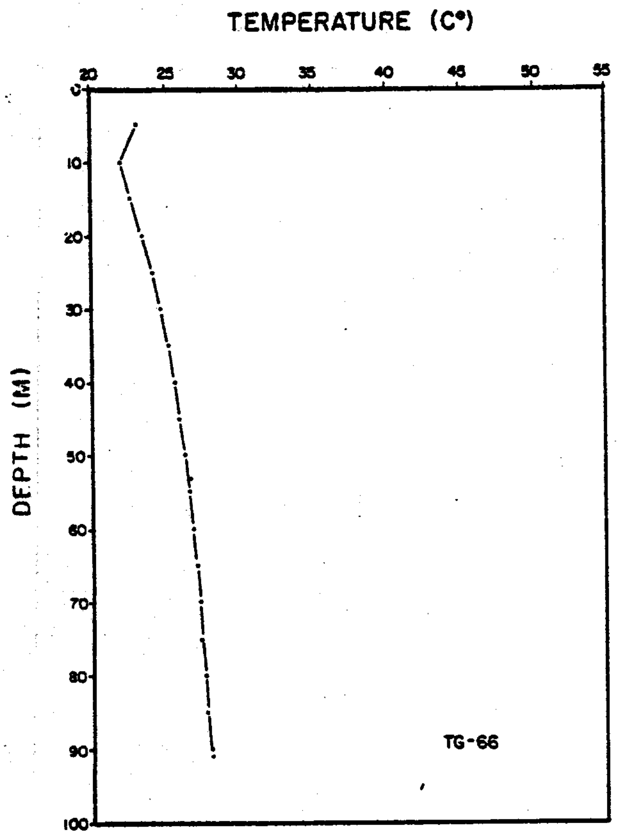

TEMPERATURE (C°)
20 25 30 35 40 45 50 55
DEPTH (M)
0 10 20 30 40 50 60 70 80 90 100
TG-58

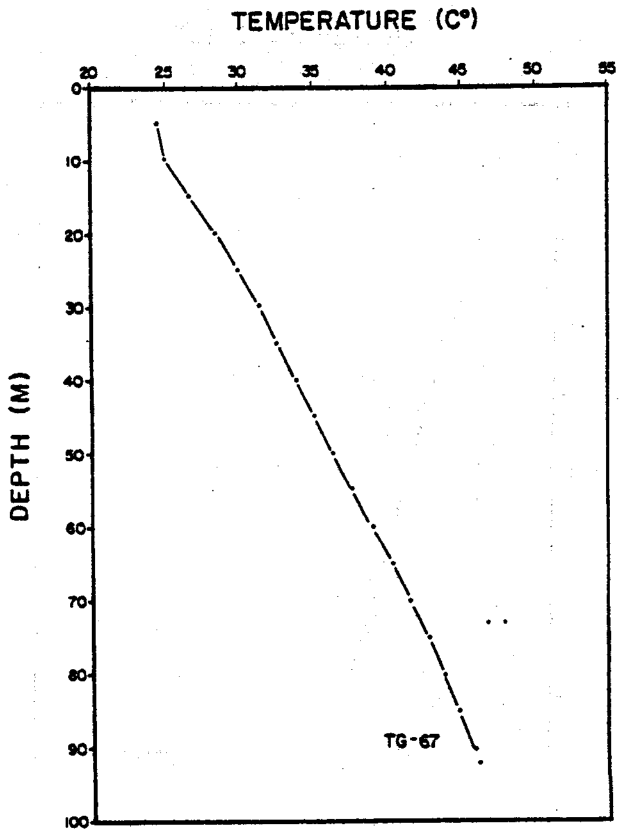

TEMPERATURE (C°)
20 25 30 35 40 45 50 55
DEPTH (M)
0 10 20 30 40 50 60 70 80 90 100
TG-62


TEMPERATURE (C°)
20 25 30 35 40 45 50 55
DEPTH (M)
0 10 20 30 40 50 60 70 80 90 100
TG-63


TEMPERATURE (C°)
20 25 30 35 40 45 50 55
DEPTH (M)
0 10 20 30 40 50 60 70 80 90 100
TG-64


TEMPERATURE (C°)
20 25 30 35 40 45 50 55
DEPTH (M)
0 10 20 30 40 50 60 70 80 90 100
TG-65


TEMPERATURE (C°)
20
25
30
35
40
45
50
55
DEPTH (M)
0
10
20
30
40
50
60
70
80
90
100
TG-66


TEMPERATURE (C°)
20
25
30
35
40
45
50
55
DEPTH (M)
0
10
20
30
40
50
60
70
80
90
100
TG-67

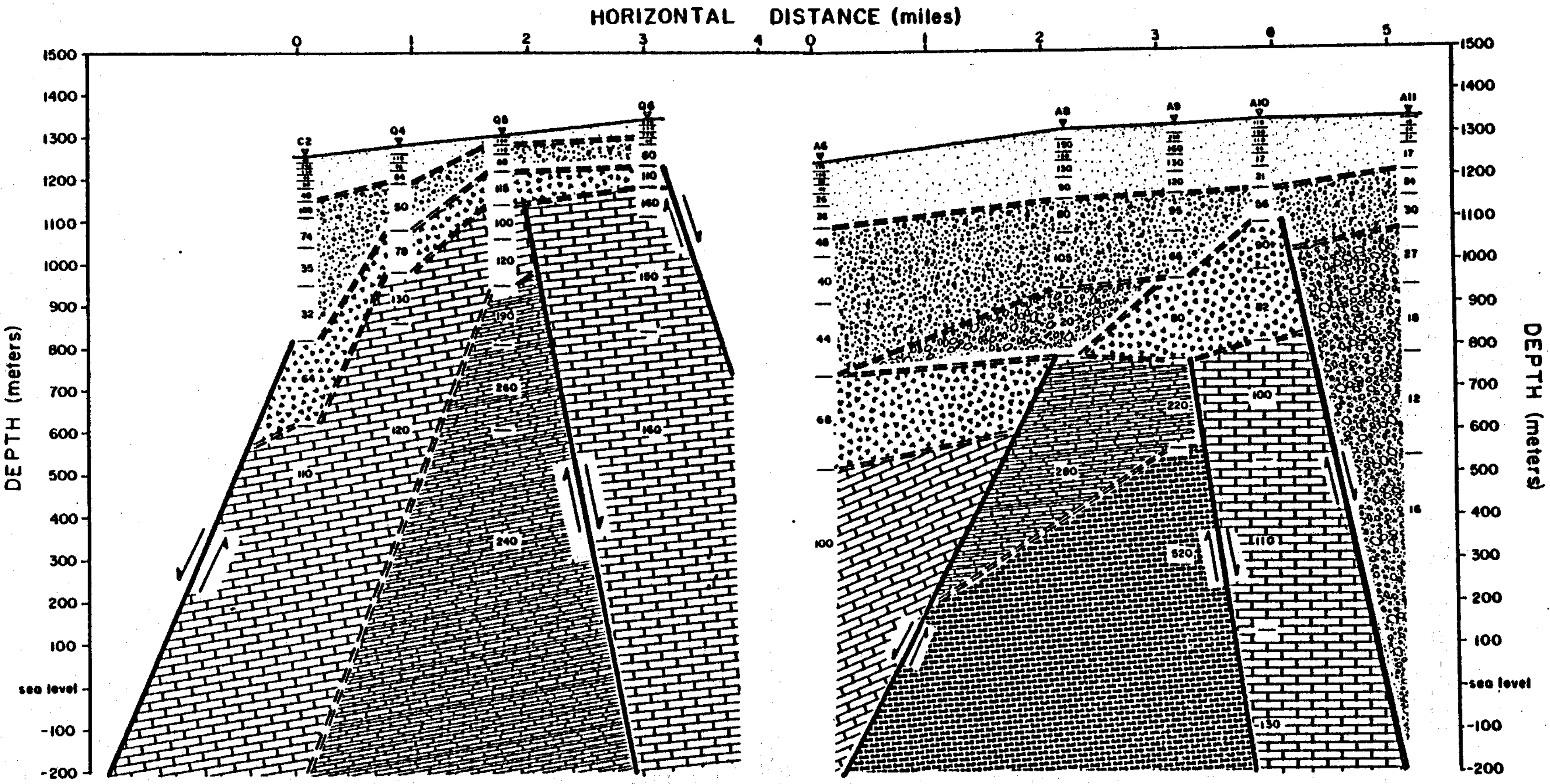
Appendix B

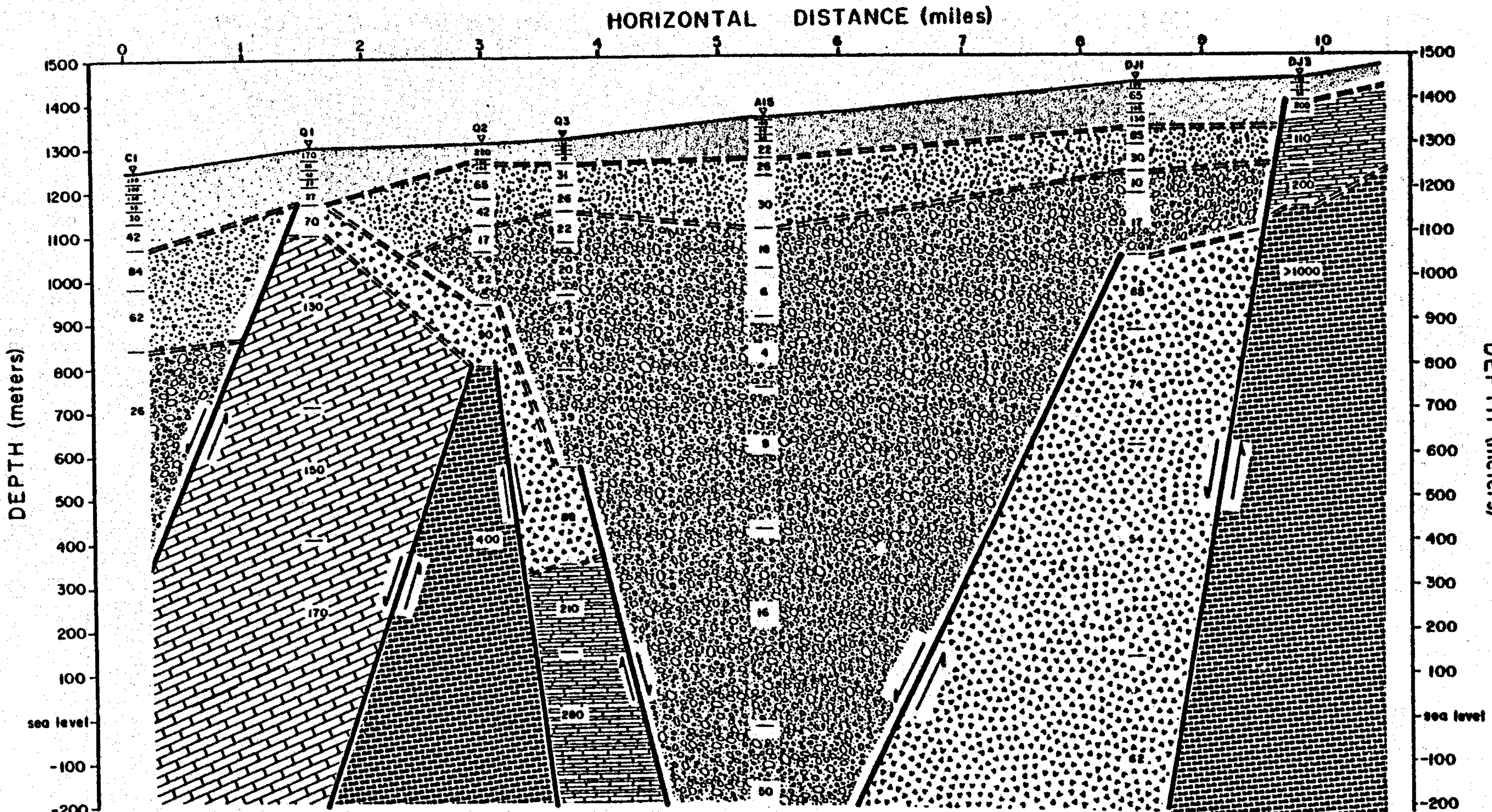
Lithologic Cross Sections for the Area Surrounding Tortugas mountain

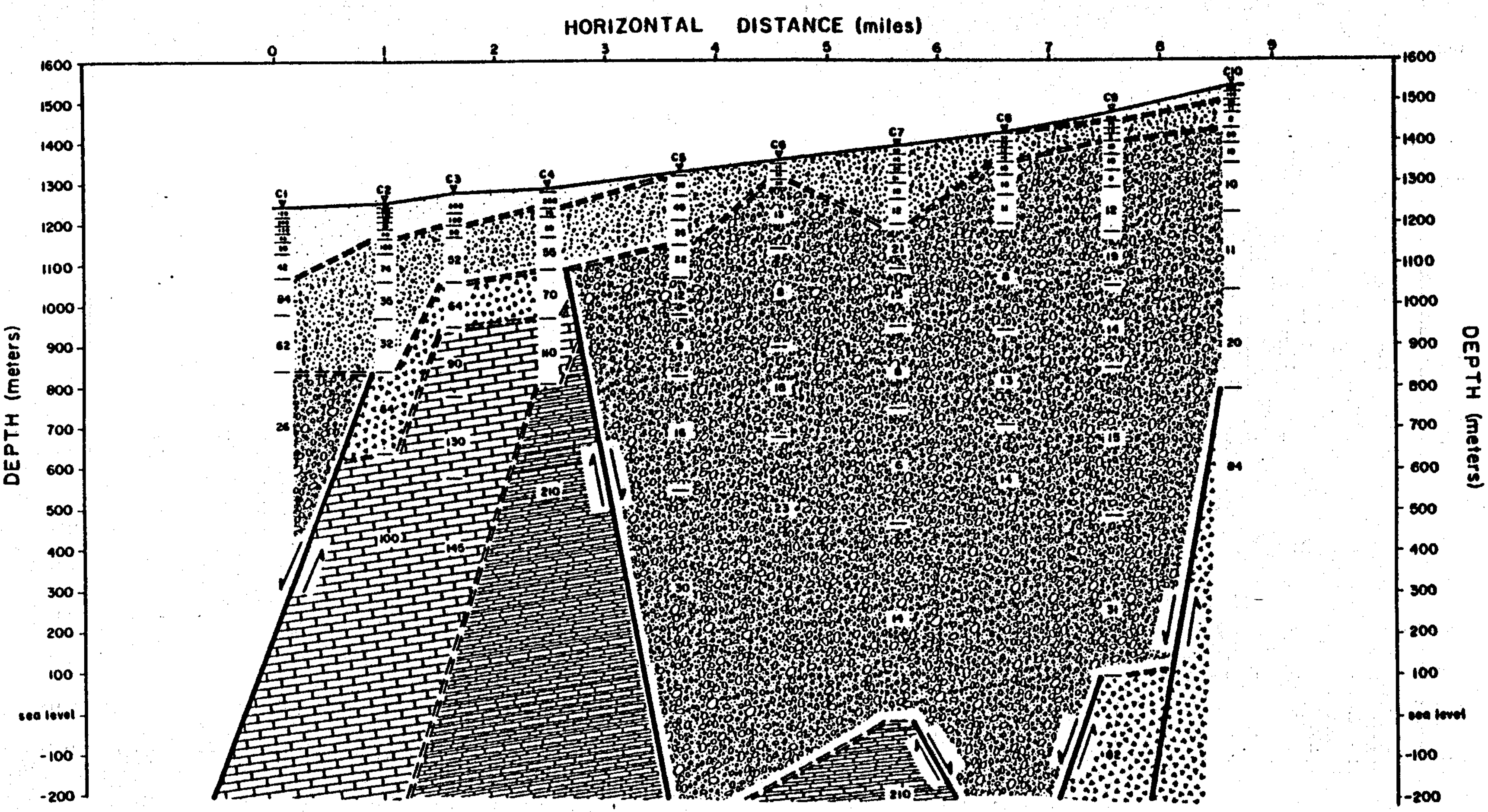
Note: Locations of the profile lines are given in Figure 19. The resistivity data are given in units of ohm-meters.

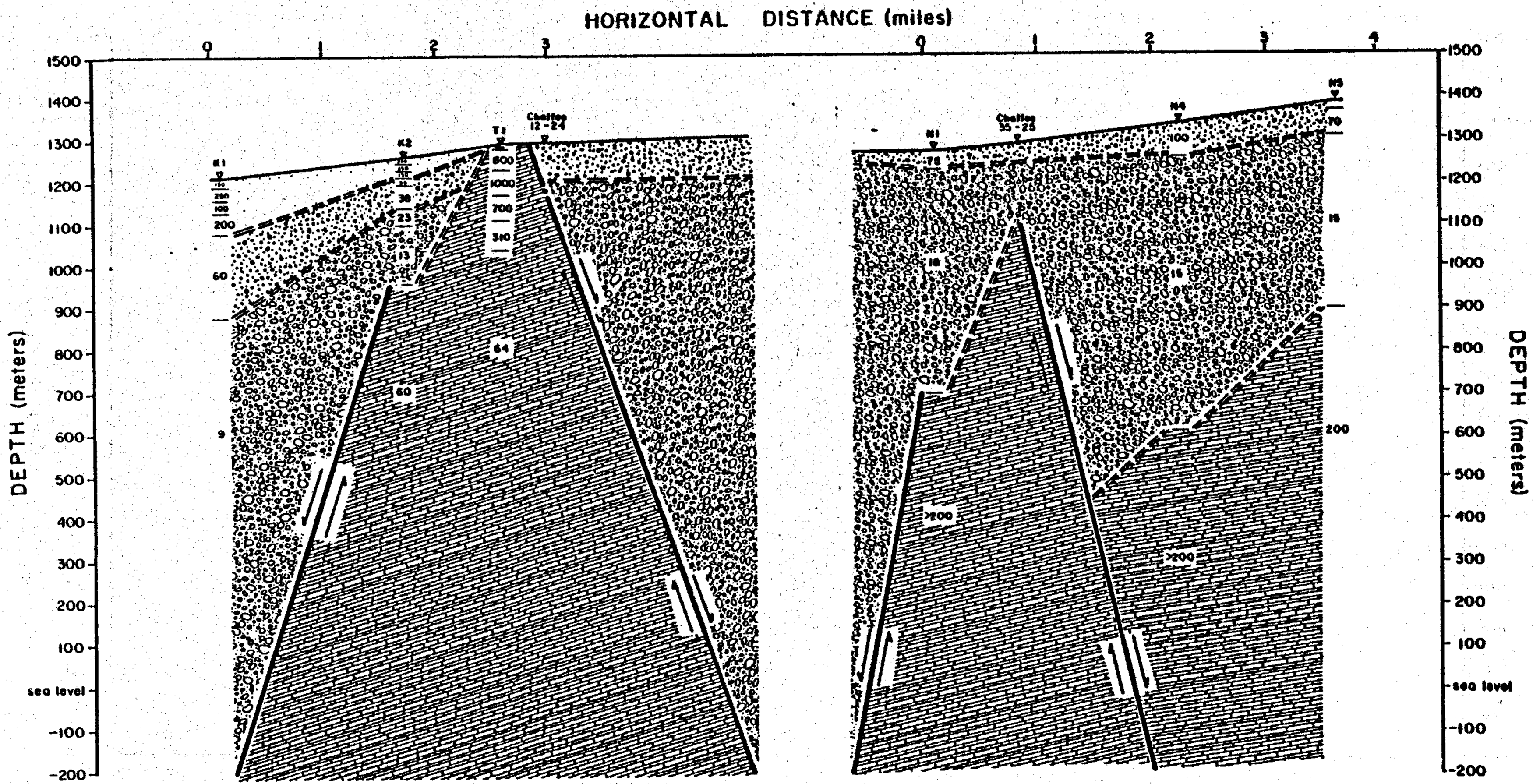
Legend:

- Late-Quaternary sands and gravels
- Upper Santa Fe group of early-Quaternary age
- Lower Santa Fe group of late-Tertiary age
- Volcanic sequence [Orejon Andesite of middle-Tertiary age (?)]
- Paleozoic strata [Permian (?)]
- Paleozoic strata [Pennsylvanian (?)]
- Paleozoic strata [Mississippian-Devonian (?)]

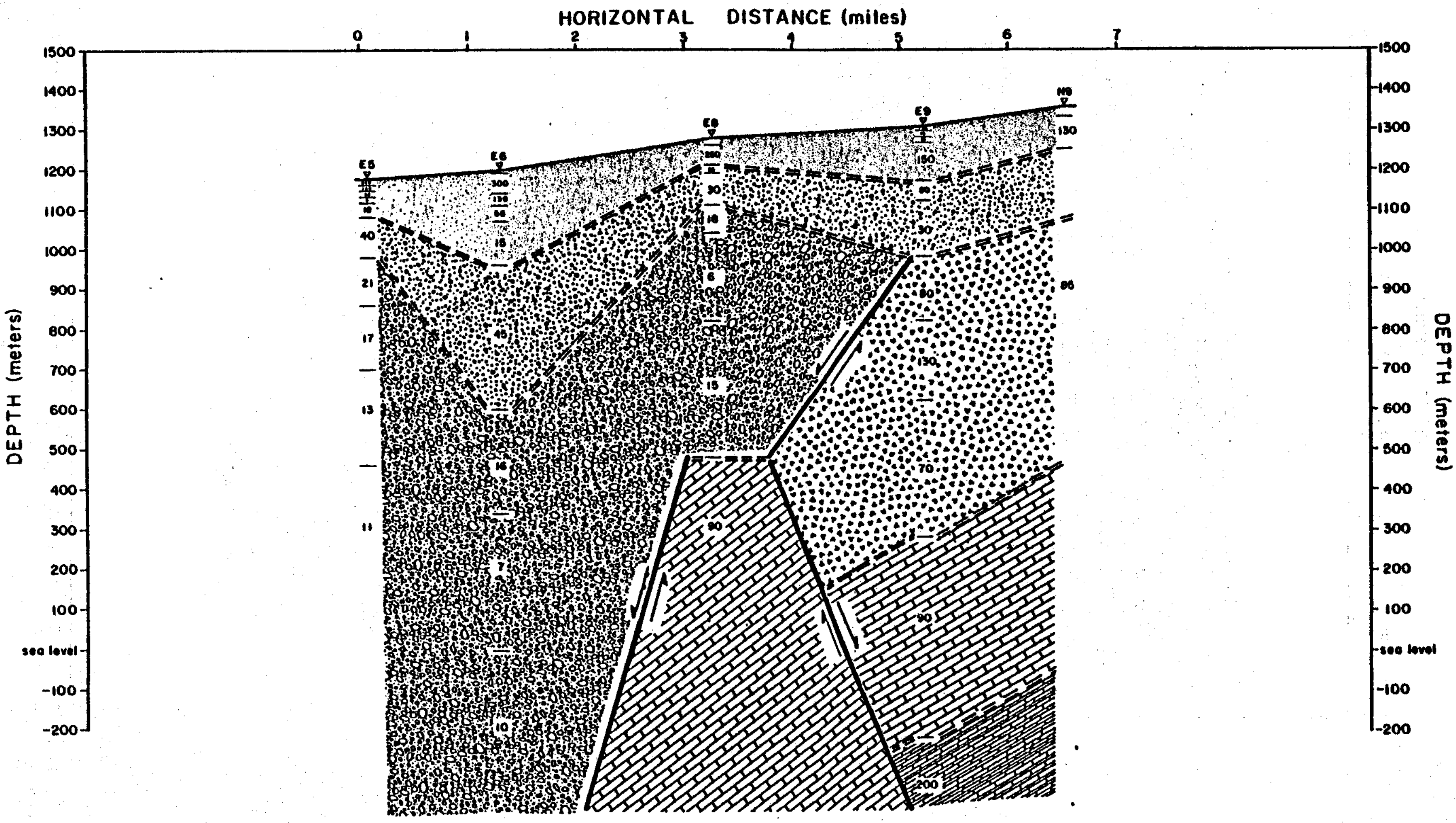

HORIZONTAL DISTANCE (miles)
DEPTH (meters)
DEPTH (meters)
sea level
sea level
C2
Q4
Q5
Q6
A6
A8
A9
A10
A11

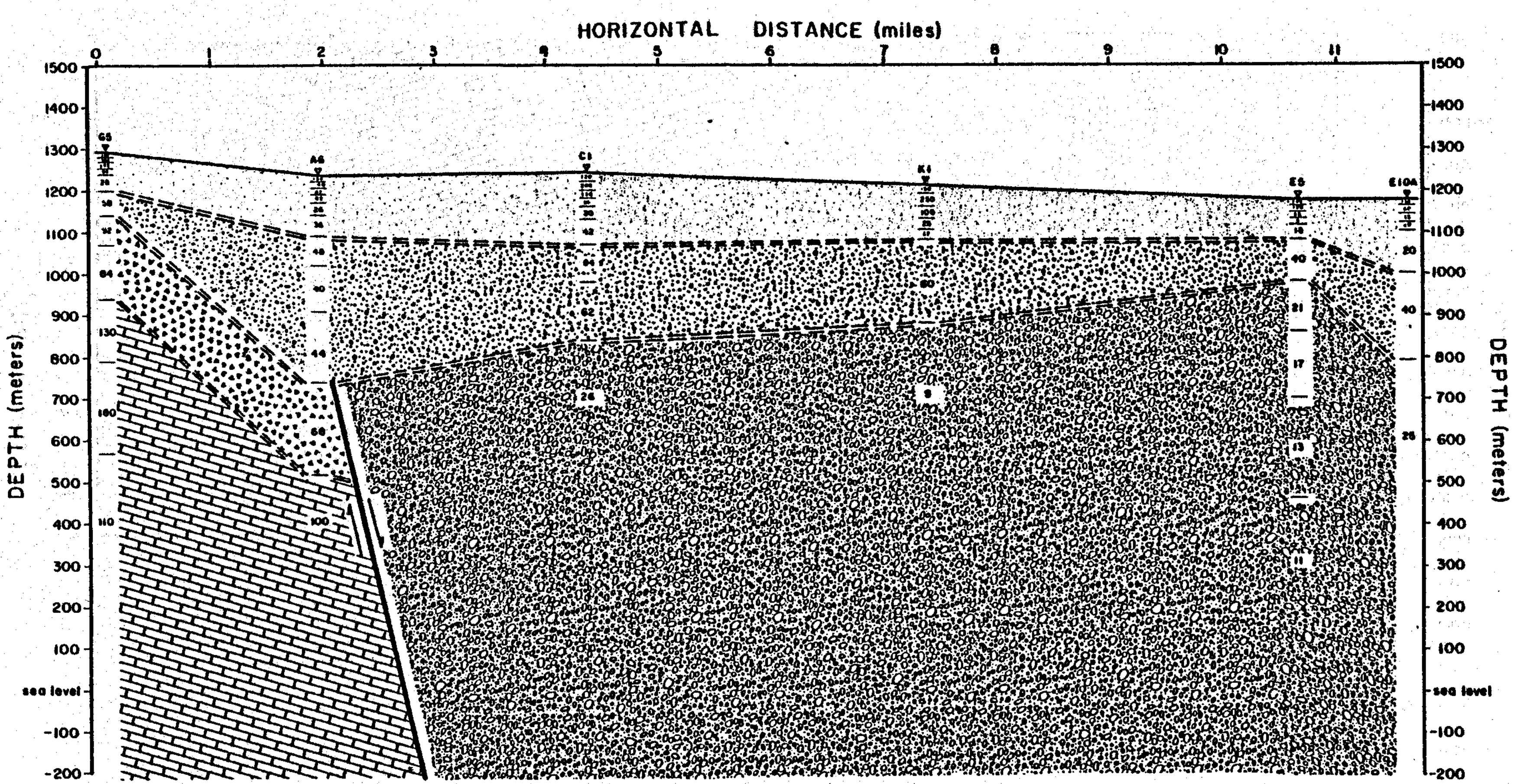

HORIZONTAL DISTANCE (miles)
0 1 2 3 4 5 6 7 8 9 10
DEPTH (meters)
1500 1400 1300 1200 1100 1000 900 800 700 600 500 400 300 200 100 sea level -100 -200
C1
Q1
Q2
Q3
A15
DJ1
DJ3
>1000
400
210
280
130
150
170

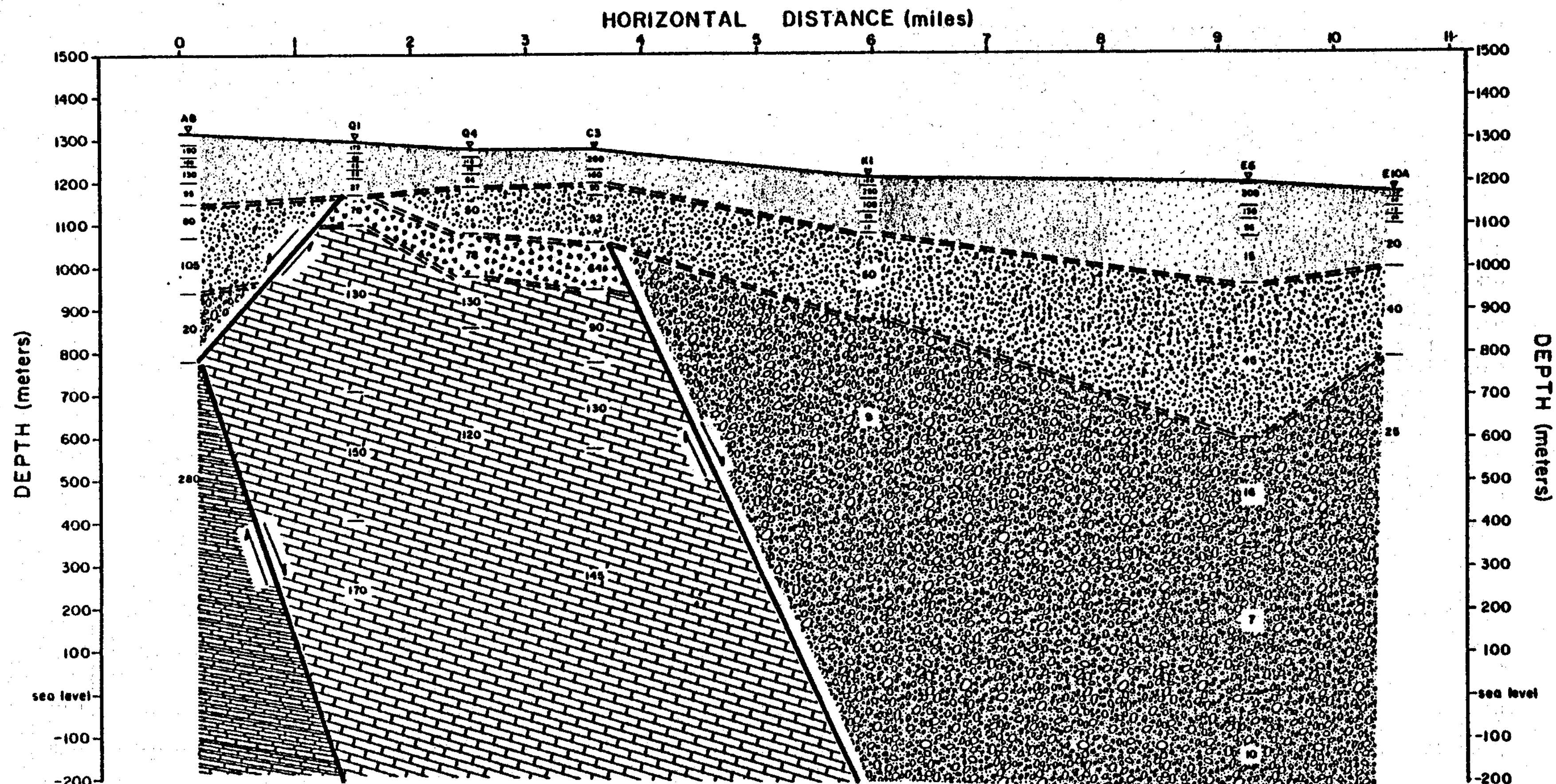

HORIZONTAL DISTANCE (miles)
0
1
2
3
4
5
6
7
8
9
DEPTH (meters)
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
sea level
-100
-200
C1
C2
C3
C4
C5
C6
C7
C8
C9
C10

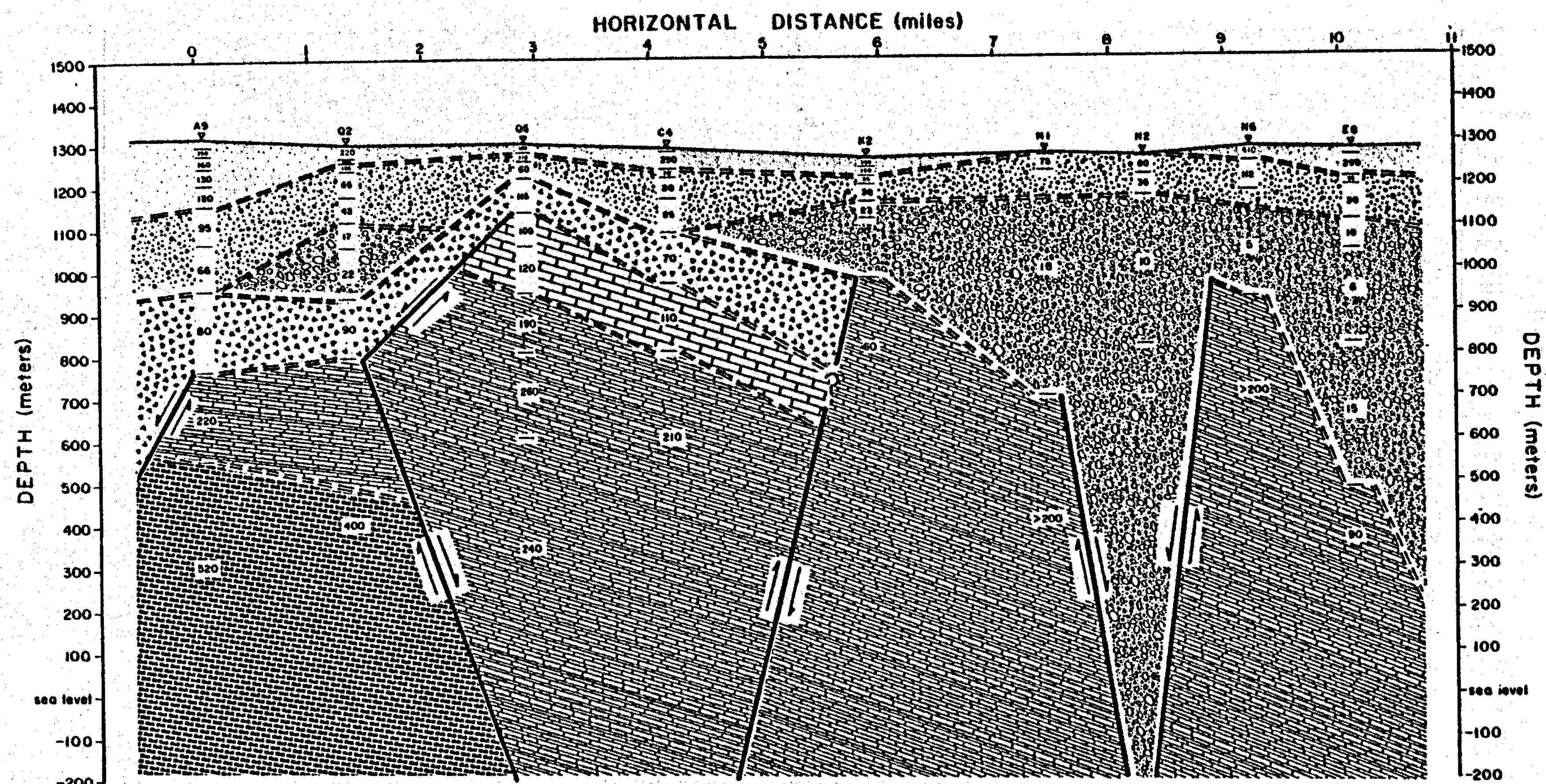


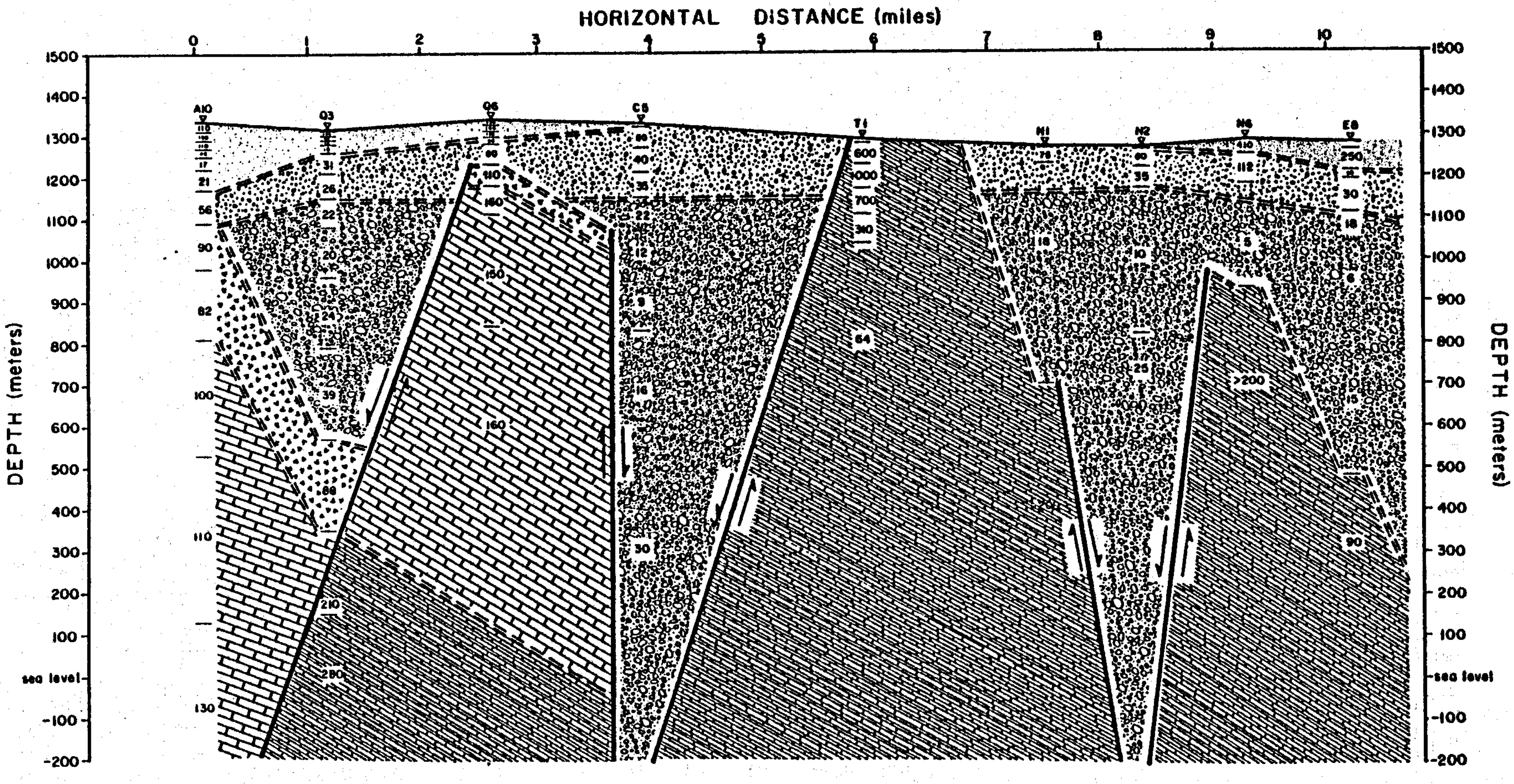
HORIZONTAL DISTANCE (miles)
DEPTH (meters)
DEPTH (meters)
sea level
sea level
Chaffee 12-24
Chaffee 35-25
K1
K2
T1
N1
N4
N5

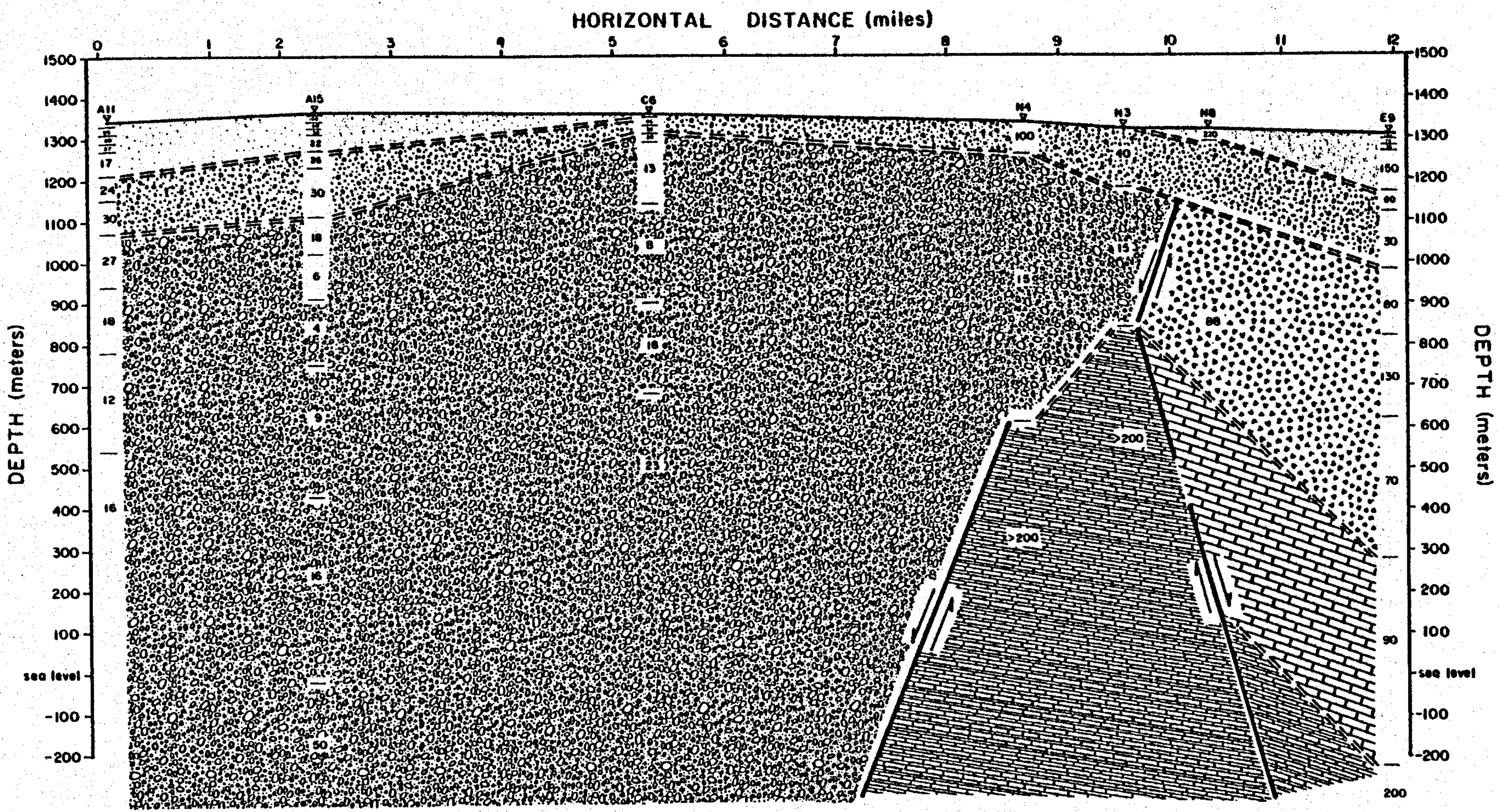

HORIZONTAL DISTANCE (miles)
0
1
2
3
4
5
6
7
DEPTH (meters)
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
sea level
-100
-200
DEPTH (meters)
E5
E6
E8
E9
N9
90
90
70
130
200


HORIZONTAL DISTANCE (miles)
0
1
2
3
4
5
6
7
8
9
10
11
DEPTH (meters)
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
sea level
-100
-200
G5
A6
C1
K1
E5
E10A


HORIZONTAL DISTANCE (miles)
0 1 2 3 4 5 6 7 8 9 10 11
DEPTH (meters)
1500 1400 1300 1200 1100 1000 900 800 700 600 500 400 300 200 100 sea level -100 -200
A8
Q1
Q4
C3
K1
E6
E10A


HORIZONTAL DISTANCE (miles)
0
1
2
3
4
5
6
7
8
9
10
11
DEPTH (meters)
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
sea level
-100
-200
DEPTH (meters)


HORIZONTAL DISTANCE (miles)
0 1 2 3 4 5 6 7 8 9 10
DEPTH (meters)
1500 1400 1300 1200 1100 1000 900 800 700 600 500 400 300 200 100 sea level -100 -200
A10
Q3
Q6
C5
T1
M1
M2
N6
E8


HORIZONTAL DISTANCE (miles)
DEPTH (meters)
DEPTH (meters)
sea level
sea level
A11
A15
C6
N4
N3
N8
E9
>200
>200
88
100

Appendix C

Lithologic Logs, Temperature-Depth Curves, and Water Analyses for Chaffee Geothermal Wells 35-25 and 12-24

Cross Section through the Las Cruces East Mesa Geothermal Field

Table C-1. Lithologic log for Well 35-25.

Elevation: 4,277 feet Date drilled: 11/13/81 - 12/3/81
Location: T23S R2E 25 NW¼ NE¼ SW¼ Method: air/foam
Geologists: Dorcas Kircher and Jim Gross

Depth (ft)	Description
<u>0 to 560</u>	alluvium
0 to 15	missing
15 to 125	sub-angular to sub-rounded volcanic rock fragments and associated fines granular to pebbles conglomerate rock fragments brown with varying color of rock fragments
125 to 245	sub-angular to sub-rounded granular to pebbles various color volcanic rock fragments conglomerate rock fragments
245 to 290	granular to pebbles; 260 to 275 ft, large pebbles sub-rounded to rounded volcanic rock fragments carbonate coating brownish-gray
290 to 365	sub-angular volcanic rock fragments granular to pebbles brownish-gray
365 to 560	sub-angular to sub-rounded volcanic rock fragments granular to pebbles brownish-gray
<u>560 to 755</u>	dolomite - bedrock
560 to 575	transition to bedrock sub-angular to sub-rounded volcanic and dolomite rock fragments
575 to 590	sub-angular to sub-rounded gray dolomite granular, few pebbles

Table C-1. (continued).

Depth (ft)	Description
590 to 620	sub-angular brownish-gray dolomite and associated fines granular, few pebbles
620 to 635	medium gray dolomite granular, few pebbles sub-angular
635 to 740	missing, lost circulation drilling
740 to 755	light gray dolomite sub-angular granular, few pebbles
755 to 950	missing, lost circulation drilling

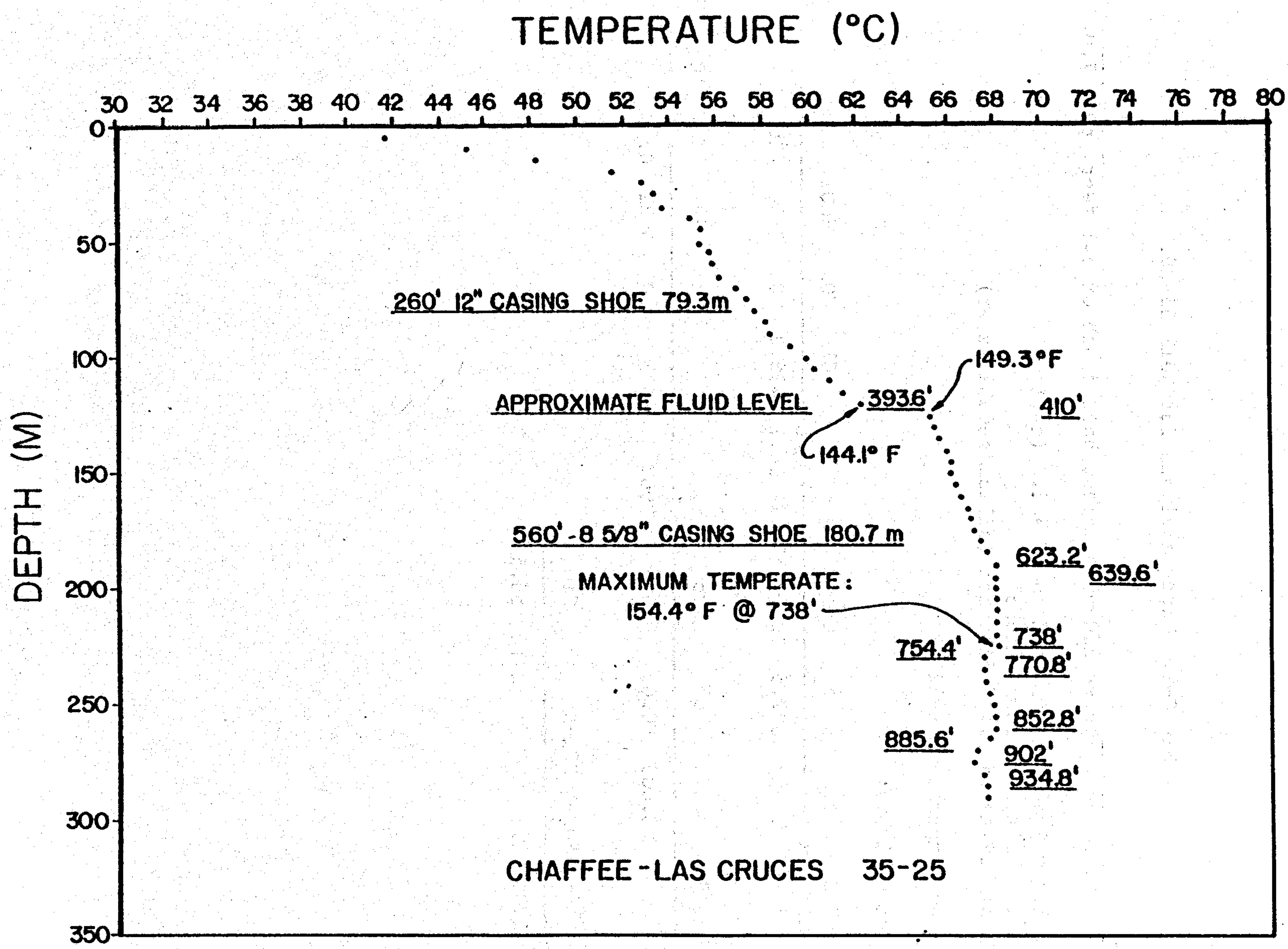


Figure C-1. Temperature-depth curve for Well 35-25. The data were collected on November 21, 1981, two hours after circulation had been stopped.

Table C-2. Water analysis for Well 35-25.

Sampling technique: Three 250-ml samples, hole depth of 645 feet, pH 7.0

Sample 1: filtered, acidified to pH = 2.0 (cations)
Sample 2: filtered, raw (anions)
Sample 3: filtered, 1:10 dilution (silica geothermeter)

Silica geotemperature = 225°F

Chemical analysis:

pH	E.C. mhos/cm	TDS	Na	Ca	Mg	K	Cl	CO_3	HCO_3	SO_4
		mg/L								
8.05	2,580	1,626	397.5	129.2	31.2	54.7	496.3	0	394.2	300.0

As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Fe	Mn	Cu
mg/L										
0.014	0.4	0.005	0.05	0.005	0.0002	0.002	0.05	0.22	0.10	0.10

B	NH_4-N	NO_3-N	NO_2-N	F	SiO_2
mg/L					
0.36	1.00	1.89	±0.01	2.16	56.5

Table C-3. Lithologic log for Well 12-24.

Elevation: 4,290 feet
Location: T23S R2E 24 SW¼ NW¼ NW¼
Geologists: Dorcas Kircher and Jim Gross

Date drilled: 12/3/81 - 1/27/82
Method: air/foam

Depth (ft)	Description
<u>0 to 425</u>	alluvium
0 to 15	sub-rounded volcanic rock fragments granular to pebbles
15 to 110	sub-angular granular to pebbles mostly brown, volcanic rock fragments and associated fines
110 to 155	sub-angular to sub-rounded granular to pebbles various color volcanic rock fragments
155 to 215	sub-angular; pebbles decreasing fragment size with depth thin carbonate coating brownish-gray volcanic rock fragments
215 to 275	brown and reddish-brown volcanic rock fragments and associated fines sub-angular to sub-rounded granular to pebbles
275 to 350	grayish-brown rock fragments and associated fines sub-rounded; carbonate coating granular to pebbles large fragments between 305 to 320 ft
350 to 425	brown to reddish-brown volcanic rock fragments increasing fragment size with depth granular to pebbles angular
<u>425 to 485</u>	missing - lost circulation drilling

Table C-3. (continued).

Depth (ft)	Description
485 to 575	limestone - bedrock granular with a few platy pebbles light gray; 530 to 545 ft, evidence of pyrite top 15 ft with volcanic rock fragments sub-angular to sub-rounded
575 to 770	shale
575 to 595	missing, lost circulation drilling
595 to 665	granular to pebbles, platy gray shale fragments sub-rounded
665 to 770	granular to pebbles, platy blackish-gray shale fragments sub-angular to sub-rounded very soft 695 to 740 ft, evidence of pyrite
700 to 1,245	dolomite
770 to 785	missing, lost circulation drilling
785 to 830	granular to pebbles sub-angular fine-grained brownish-gray to gray dolomite
830 to 890	granular to pebbles sub-angular gray fine-grained dolomite evidence of pyrite
890 to 905	granular to pebbles gray and reddish-brown volcanic and fine-grained dolomite rock fragments angular
905 to 980	missing, lost circulation drilling
980 to 995	pebbles light gray crystalline dolomite sub-angular to angular
995 to 1,010	missing, lost circulation drilling

Table C-3. (continued).

Depth (ft)	Description
1,010 to 1,055	granular to pebbles, platy light gray crystalline dolomite sub-angular
1,055 to 1,070	granular, few platy pebbles gray crystalline dolomite sub-angular
1,070 to 1,100	missing, lost circulation drilling
1,100 to 1,115	pebbles light gray to dark gray crystalline dolomite angular to sub-angular
1,115 to 1,180	missing, lost circulation drilling
1,180 to 1,195	whitish-gray to gray crystalline dolomite granular to pebbles, platy angular
1,195 to 1,245	whitish-gray to light gray crystalline dolomite granular, few pebbles angular to sub-angular
1,245 to 1,255	missing, lost circulation drilling
1,255 to 1,315	limestone gray pebbles, platy angular

Table C-4. Water analysis for Well 12-24.

Sampling technique: Three 250-ml samples, hole depth of 1,315 feet

Sample 1: filtered, acidified to pH = 2.0 (cations)
Sample 2: filtered, raw (anions)
Sample 3: filtered, 1:4 dilution (silica geothermeter)

Silica geotemperature = 217°F

Chemical analysis:

pH	E.C. mhos/cm	TDS (mg/L)	Na (mg/L)	Ca (mg/L)	Mg (mg/L)	K (mg/L)	Cl (mg/L)	CO_3 (mg/L)	HCO_3 (mg/L)	SO_4 (mg/L)
7.57	3,000	1,968	392.4	107.4	28.0	58.3	499.2	0	448.7	220.8

As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Fe	Mn
mg/L									
0.003	0.4	0.005	0.05	0.005	0.0002	0.002	0.05	0.13	0.12

Cu	B	NH_4-N	NO_3-N	NO_2-N	F	SiO_2	Hardness (as $CaCO_3$)	Alkalinity (as $CaCO_3$)
mg/L								
0.10	0.18	0.30	0.07	0.01	2.20	50.9	383	356

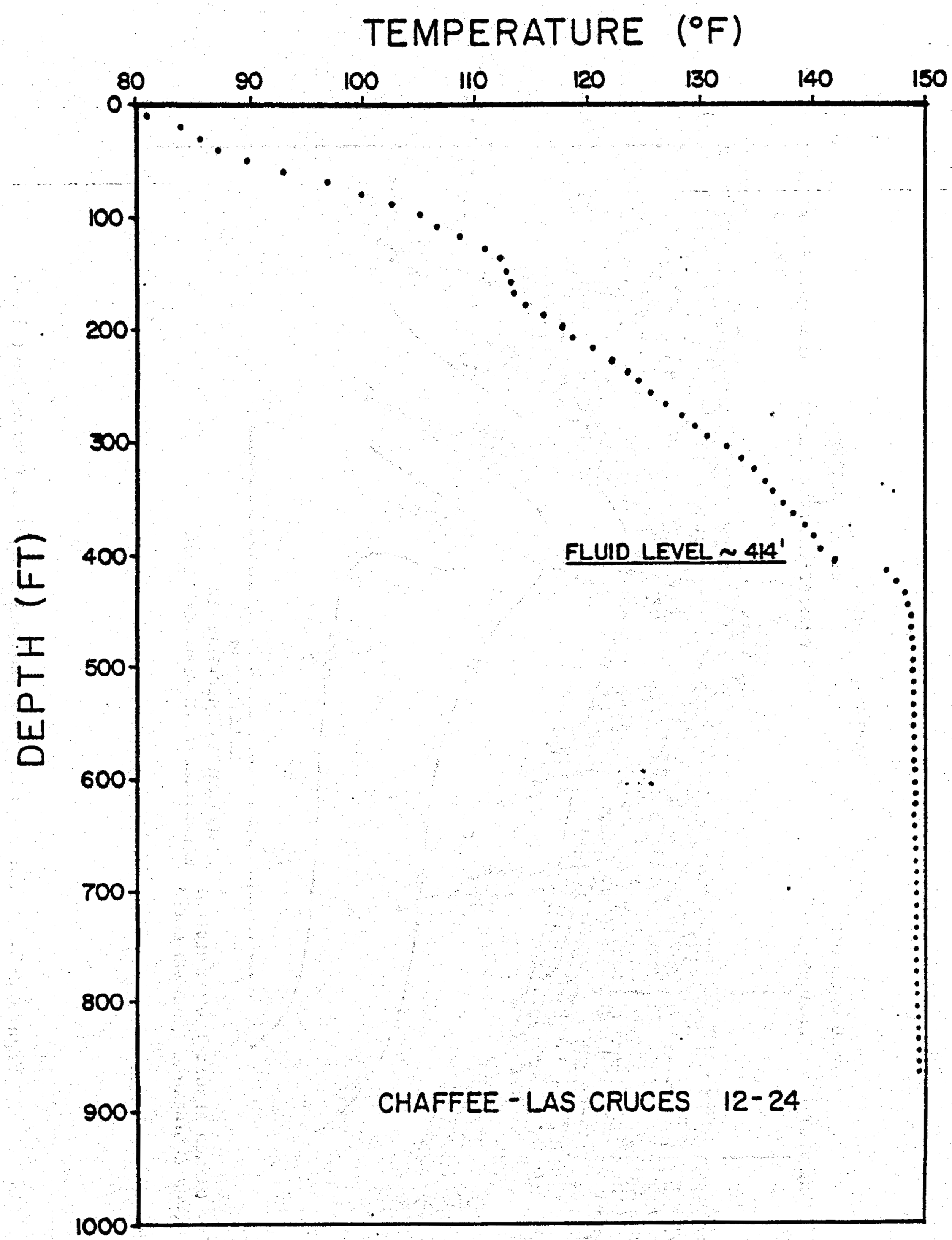


Figure C-2. Temperature-depth curve for Well 12-24. The data were collected on February 1, 1982, five days after terminating air lifting. The total depth of the well is 1,315 feet.

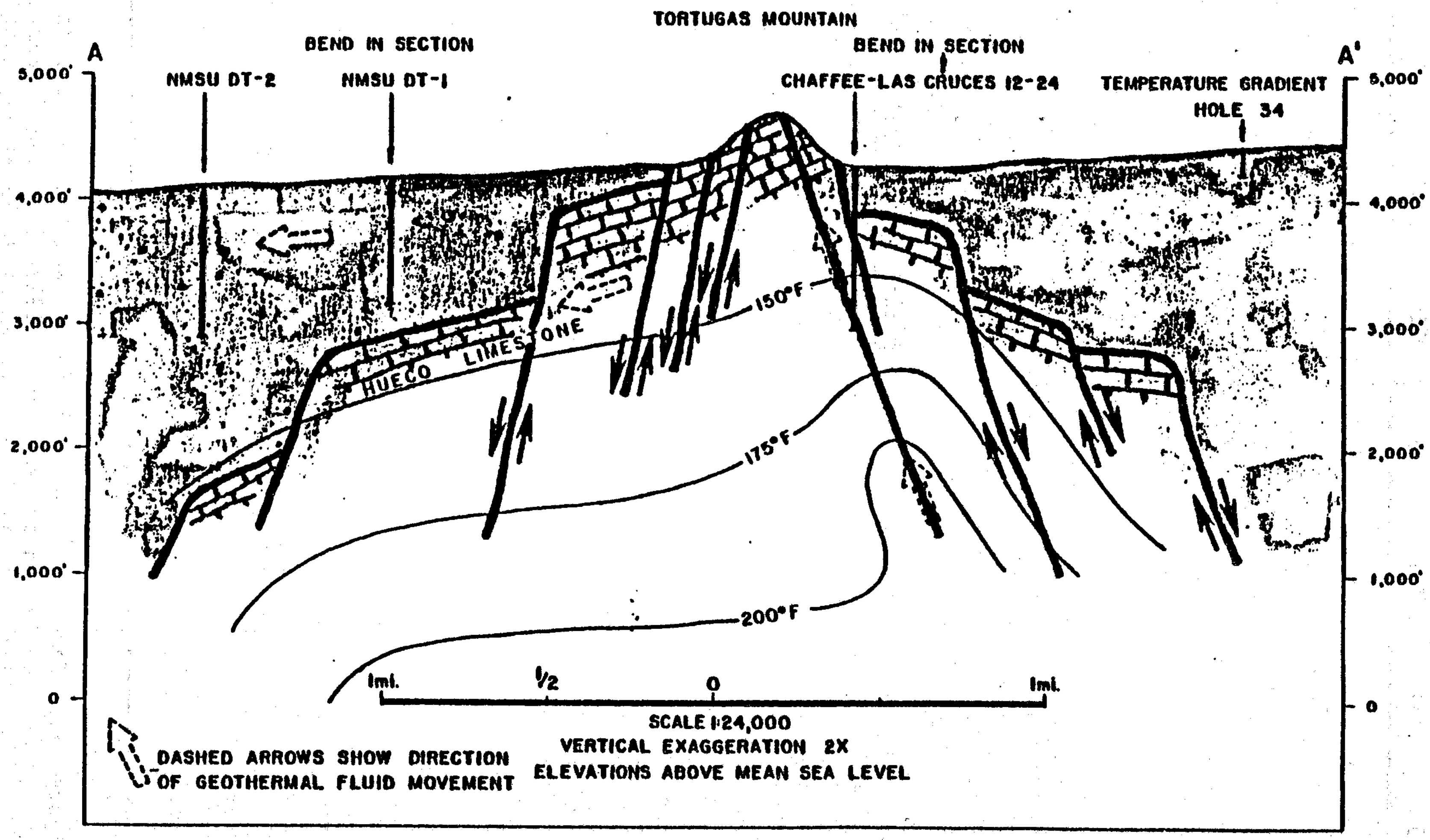


Figure C-3. Cross section A-A' through the Las Cruces East Mesa Geothermal Field. The location of profile line A-A' is shown on Figure 19.

Appendix D

Temperature Data for the Mesquite-Anthony Area

Note: The data are for temperature holes TG-68 through TG-97 (see Figure 25 for locations). The reported temperature gradient data are least-squares fits to the empirical data, with the standard error of the estimate given. Bottom-hole temperature gradients were computed for a 20°C surface temperature.

Well Name: TG-68

Location: latitude, 32° 10.86', longitude, 106° 38.88', township & range, T24S.R3E.33.113; elevation, 1,274 meters; spudded, 7-23-82; temperature logged, 11-1-82 (10:30 am); total depth, 95 meters; depth of 1½ inch PVC casing, 95 meters; bottom-hole temperature, 34.1°C; bottom-hole depth, 95 meters; bottom-hole temperature gradient, 149°C/km; best estimate heat flow value, 184 mW/m^2 (4.4 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mW/m^2)	Estimated Heat Flow (HFU)	Remarks
1	22.06						
2	23.55						
3	24.28						
4	24.36						
5	23.72		gravel and sand	1.4			
6	23.24						
7	23.05						
8	23.11						
9	23.18						
10	23.36						
15	24.22						
20	24.92						
25	25.63						
30	26.28	144.8 ± 5.2	sand, gravel, and clay	1.5	217	5.20	
35	27.19						
40	27.76				173	4.13	
45	28.49	115.2 ± 0.8					
50	29.01		sand and clay	1.4	161	3.86	

* Estimated thermal conductivity values.

TG-68 (Con't.)

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mW/m^2)	(HFU)	Remarks
55	29.58						
60	30.19						
65	30.74						
70	31.31						
75	31.93	115.2 ± 0.8	sand and clay	1.4	161	3.86	
80	32.49						
85	33.08						
90	33.59						
95	34.12						

*Estimated thermal conductivity values.

Well Name: TG-69

Location: latitude, 32° 10.87', longitude, 106° 37.62', township & range, T24S.R3E.34.123; elevation, 1,282 meters; spudded, 7-28-82; temperature logged, 10-5-82 (1:10 pm); total depth, 95 meters; depth of 1½ inch PVC casing, 95 meters; bottom-hole temperature, 27.9°C; bottom-hole depth, 95 meters; bottom-hole temperature gradient, 83°C/km; best estimate heat flow value, 124 mW/m^2 (3.0 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mW/m^2)	Estimated Heat Flow (HFU)	Remarks
1	23.15						Clay and caliche encountered from 0 to 3 meters.
2	23.43						
3	23.00						
4	22.00						
5	21.04						
6	20.55		gravel and sand	1.4			
7	20.39						
8	20.40						
9	20.49						
10	20.63						
15	21.22						
20	21.73						
25	22.15		sand, gravel, and clay	1.5	134	3.19	
30	22.63	89.0 ± 2.5					
35	23.00				125	2.98	
40	23.53						
45	23.93	80.9 ± 0.5	sand and clay	1.4	113	2.71	
50	24.32						

*Estimated thermal conductivity values.

TG-69 (Con't.)

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mW/m^2)	Estimated Heat Flow (HFU)	Remarks
55	24.76						
60	25.14						
65	25.57						
70	26.02						
75	26.39	80.9 ± 0.5	sand and clay	1.4	113	2.71	
80	26.76						
85	27.18						
90	27.61						
95	27.93						

* Estimated thermal conductivity values.

Well Name: TG-70

Location: latitude, 32° 10.25', longitude, 106° 38.45', township & range, T24S.R3E.33.344; elevation, 1,268 meters; spudded, 7-26-82; temperature logged, 10-25-82 (1:00 pm); total depth, 43.8 meters; depth of 1½ inch PVC casing, 43.8 meters; bottom-hole temperature, 26.9°C; bottom-hole depth, 43.8 meters; bottom-hole temperature gradient, 158°C/km; best estimate heat flow value, 172 mW/m^2 (4.1 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mW/m^2)	(HFU)	Remarks
1	23.62						
2	24.26						
3	24.60						
4	24.34		gravel and sand	1.4			
5	23.36						
6	22.82						
7	22.64						
8	22.71						
9	22.80						
10	22.89						
15	23.45						
20	24.09		sand, gravel, and clay	1.5	178	4.26	
25	24.77						
30	25.52						
35	26.08	118.6 ± 5.8	sand and clay	1.4	166	3.97	
40	26.56						
43.8	26.90						

* Estimated thermal conductivity values.

Well Name: TG-71

Location: latitude, 32° 10.09', longitude, 106° 37.30', township & range, T25S.R3E.3.211; elevation, 1,282 meters; spudded, 7-27-82; temperature logged, 10-5-82 (12:30 pm); total depth, 45 meters; depth of 1½ inch PVC casing, 45 meters; bottom-hole temperature, 23.0°C; bottom-hole depth, 45 meters; bottom-hole temperature gradient, 67°C/km; best estimate heat flow value, 135 mW/m^2 (3.2 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mW/m^2)	Estimated Heat Flow (HFU)	Remarks
1	23.38						Clay with gravel encountered from 0 to 3 meters.
2	23.61						
3	22.03						
4	20.88						
5	20.01		gravel and sand	1.4			
6	19.44						
7	19.25						
8	19.28						
9	19.36						
10	19.51						
15	20.13						
20	20.72		sand, gravel, and clay	1.5			
25	21.25				139	3.32	
30	21.71						
35	22.12	92.5 ± 2.1					
40	22.66		sand and clay	1.4	130	3.10	
45	23.03						

* Estimated thermal conductivity values.

Well Name: TG-72

Location: latitude, 32° 09.42', longitude, 106° 38.80', township & range, T25S.R3E.4.333; elevation, 1,225 meters; spudded, 7-26-82; temperature logged, 10-5-82 (11:45 am); total depth, 40 meters; depth of 1½ inch PVC casing, 40 meters; bottom-hole temperature, 27.1°C; bottom-hole depth, 40 meters; bottom-hole temperature gradient, 177°C/km; best estimate heat flow value, 223 mW/m^2 (5.3 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mW/m^2)	Estimated Heat Flow (HFU)	Remarks
1	25.23						Clay with sand encountered from 3 to 6 meters.
2	25.82						
3	25.90						
4	24.77						
5	23.64						
6	23.01		gravel and sand	1.4			
7	22.61						
8	22.58						
9	22.61						
10	22.69						
15	23.42						
20	24.03						
25	24.72		sand and gravel	1.5	231	5.52	
30	25.55	153.8 ± 2.2					
35	26.31		sand and clay	1.4	215	5.15	
40	27.08						

* Estimated thermal conductivity values.

Well Name: TG-73

Location: latitude, 32° 09.33', longitude, 106° 37.82', township & range, T25S.R3E.3.333; elevation, 1,269 meters; spudded, 7-26-82; temperature logged, 10-4-82 (4:00 pm); total depth, 45 meters; depth of 1½ inch PVC casing, 45 meters; bottom-hole temperature, 25.4°C; bottom-hole depth, 45 meters; bottom-hole temperature gradient, 119°C/km; best estimate heat flow value, 116 mW/m^2 (2.8 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mW/m^2)	Estimated Heat Flow (HFU)	Remarks
1	25.52						
2	25.99						
3	25.35						
4	23.47						
5	22.64		gravel, sand, and clay	1.5			
6	22.15						
7	22.06						
8	22.10						
9	22.20						
10	22.28						
15	22.74						
20	23.37						
25	23.86		sand, clay, and gravel	1.5	120	2.86	
30	24.26						
35	24.69	79.8 ± 2.7					
40	25.04		clay and sand	1.4	112	2.67	
45	25.37						

* Estimated thermal conductivity values.

Well Name: TG-74

Location: latitude, 32° 09.41', longitude, 106° 37.02', township & range T25S.R3E.3.444; elevation, 1,279 meters; spudded, 7-27-82; temperature logged, 10-4-82 (4:30 pm); total depth, 45 meters; depth of 1½ inch PVC casing, 45 meters; bottom-hole temperature, 23.4°C; bottom-hole depth, 45 meters; bottom-hole temperature gradient, 76°C/km; best estimate heat flow value, 120 mW/m^2 (2.9 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mW/m^2)	Estimated Heat Flow (HFU)	Remarks
1	24.33						Clay encountered from 0 to 3 meters.
2	24.64						
3	23.67						
4	22.01						Very hard strata penetrated from 9 to 12 meters.
5	21.03						
6	20.49		gravel, sand, and clay	1.5			
7	20.34						
8	20.35						Quantity of gravel decreased with depth.
9	20.44						
10	20.54						
15	21.02						
20	21.43						
25	21.85						
30	22.23		sand, clay, and gravel	1.5			
35	22.64	79.7 ± 0.4			120	2.86	
40	23.03						
45	23.43						

* Estimated thermal conductivity values.

Well Name: TG-75

Location: latitude, 32° 08.47', longitude, 106° 37.83', township & range, T25S.R3E.10.333; elevation, 1,250 meters; spudded, 7-29-82; temperature logged, 10-5-82 (2:40 pm); total depth, 45 meters; depth of 1½ inch PVC casing, 45 meters; bottom-hole temperature, 26.1°C; bottom-hole depth, 45 meters; bottom-hole temperature gradient, 135°C/km; best estimate heat flow value, 137 mW/m^2 (3.3 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mW/m^2)	Estimated Heat Flow (HFU)	Remarks
1	24.72		sand and clay, alternating layers	1.4			
2	24.99						
3	24.22						
4	23.02						
5	22.11						
6	21.87						
7	21.90						
8	22.02						
9	22.16						
10	22.31						
15	23.03		sand and clay	1.4			
20	23.61	98.0 ± 1.2			137	3.28	
25	24.16						
30	24.62						
35	25.13						
40	25.61						
45	26.07						

* Estimated thermal conductivity values.

Well Name: TG-76

Location: latitude, 32° 08.76', longitude, 106° 37.45', township & range, T25S.R3E.10.324; elevation, 1,276 meters; spudded, 7-29-82; temperature logged, 10-5-82 (2:05 pm); total depth, 45 meters; depth of 1½ inch PVC casing, 45 meters; bottom-hole temperature, 24.9°C; bottom-hole depth, 45 meters; bottom-hole temperature gradient, 108°C/km; best estimate heat flow value, 117 mW/m^2 (2.8 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mW/m^2)	Estimated Heat Flow (HFU)	Remarks
1	25.37						
2	25.60						
3	24.60						
4	23.24						
5	22.22						
6	21.72		sand and gravel	1.5			
7	21.55						
8	21.58						
9	21.67						
10	21.81						
15	22.30						
20	22.81						
25	23.33						
30	23.71						
35	24.19	83.3 ± 3.2	sand and clay	1.4	117	2.79	
40	24.58						
45	24.88						

* Estimated thermal conductivity values.

Well Name: TG-77

Location: latitude, 32° 07.62', longitude, 106° 37.79', township & range, T25S.R3E.15.333; elevation, 1,210 meters; spudded, 7-30-82; temperature logged, 10-5-82 (4:20 pm); total depth, 45 meters; depth of 1½ inch PVC casing, 45 meters; bottom-hole temperature, 26.2°C; bottom-hole depth, 45 meters; bottom-hole temperature gradient, 137°C/km; best estimate heat flow value, 114 mW/m^2 (2.7 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mW/m^2)	Estimated Heat Flow (HFU)	Remarks
1	25.24		sand, clay, and gravel	1.5			
2	25.47						
3	24.59						
4	23.01						
5	22.35						
6	22.21						
7	22.24						
8	22.31						
9	22.45						
10	22.55						
15	23.28		clay and sand	1.4			
20	24.13	81.1 ± 2.6			114	2.72	
25	24.61						
30	25.07						
35	25.45						
40	25.80						
45	26.18						

* Estimated thermal conductivity values.

Well Name: TG-78

Location: latitude, 32° 08.08', longitude, 106° 37.16', township & range, T25S.R3E.15.243; elevation, 1,257 meters; spudded, 7-30-82; temperature logged, 10-5-82 (3:10 pm); total depth, 45 meters; depth of 1½ inch PVC casing, 45 meters; bottom-hole temperature, 25.0°C; bottom-hole depth, 45 meters; bottom-hole temperature gradient, 110°C/km; best estimate heat flow value, 116 mW/m^2 (2.8 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mW/m^2)	Estimated Heat Flow (HFU)	Remarks
1	25.54						
2	25.77						
3	25.01						
4	23.52						
5	22.41		sand, clay, and gravel	1.5			
6	21.82						
7	21.64						
8	21.65						
9	21.74						
10	21.79						
15	22.34						
20	22.86						
25	23.39						
30	23.85		clay and sand	1.4			
35	24.24	83.0 ± 3.4			116	2.78	
40	24.60						
45	24.96						

* Estimated thermal conductivity values.

Well Name: TG-79

Location: latitude, 32° 08.46', longitude, 106° 36.13', township & range, T25S.R3E.11.443; elevation, 1,277 meters; spudded, 8-19-82; temperature logged, 10-5-82 (3:45 pm); total depth, 45 meters; depth of 1½ inch PVC casing, 45 meters; bottom-hole temperature, 23.3°C; bottom-hole depth, 45 meters; bottom-hole temperature gradient, 74°C/km; best estimate heat flow value, 143 mW/m^2 (3.4 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow		Remarks
					(mW/m^2)	(HFU)	
1	22.36						
2	22.68						
3	22.20						
4	20.96						
5	19.99						
6	19.55		gravel and sand	1.4			
7	19.54						
8	19.53						
9	19.63						
10	19.76						
15	20.37						
20	20.92						
25	21.40		sand, gravel, and clay	1.5	148	3.54	
30	21.94						
35	22.44	98.6 ± 2.1					
40	22.95		sand and clay	1.4	138	3.30	
45	23.34						

* Estimated thermal conductivity values.

Well Name: TG-80

Location: latitude, 32° 07.35', longitude, 106° 36.75', township & range, T25S.R3E.23.132; elevation, 1,247 meters; spudded, 8-2-82; temperature logged, 10-6-82 (10:45 am); total depth, 45 meters; depth of 1½ inch PVC casing, 45 meters; bottom-hole temperature, 25.4°C; bottom-hole depth, 45 meters; bottom-hole temperature gradient, 119°C/km; best estimate heat flow value, 122 mW/m^2 (2.9 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow		Remarks
					(mW/m^2)	(HFU)	
1	24.37						
2	24.98						
3	24.55						
4	23.36						
5	22.28						
6	21.78						
7	21.66						
8	21.67		sand and clay	1.4			
9	21.75						
10	21.90						
15	22.54						
20	23.20						
25	23.67						
30	24.16						
35	24.56	87.4 ± 2.1			122	2.93	
40	25.02		clay and sand	1.4			
45	25.37						

* Estimated thermal conductivity values.

Well Name: TG-81

Location: latitude, 32° 07.27', longitude, 106° 36.00', township & range, T25S.R3E.23.242; elevation, 1,265 meters; spudded, 8-17-82; temperature logged, 10-6-82 (12:30 pm); total depth, 45 meters; depth of 1½ inch PVC casing, 45 meters; bottom-hole temperature, 24.9°C; bottom-hole depth, 45 meters; bottom-hole temperature gradient, 109°C/km; best estimate heat flow value, 104 mW/m^2 (2.5 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mW/m^2)	(HFU)	Remarks
1	24.48						
2	24.97						
3	24.48						
4	23.13						
5	22.13						
6	21.58		sand, gravel, and clay	1.5			
7	21.47						
8	21.52						
9	21.64						
10	21.88						
15	22.49						
20	23.04						
25	23.44						
30	23.81						
35	24.19	74.0 ± 0.9	sand and clay	1.4	104	2.48	
40	24.55						
45	24.89						

* Estimated thermal conductivity values.

Well Name: TG-82

Location: latitude, 32° 06.38', longitude, 106° 36.95', township & range, T25S.R3E.27.244; elevation, 1,222 meters; spudded, 8-2-82; temperature logged, 10-6-82 (12:00 noon); total depth, 45 meters; depth of 1½ inch PVC casing, 45 meters; bottom-hole temperature, 25.3°C; bottom-hole depth, 45 meters; bottom-hole temperature gradient, 117°C/km; best estimate heat flow value, 134 mW/m^2 (3.2 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mW/m^2)	Estimated Heat Flow (HFU)	Remarks
1	23.65						
2	24.15						
3	23.79						
4	22.45						
5	21.78						
6	21.32						
7	21.18						
8	21.22		sand and clay, alternating layers				
9	21.30			1.4			
10	21.48						
15	22.13						
20	22.91						
25	23.42						
30	24.04						
35	24.55	95.9 ± 5.3			134	3.21	
40	24.93						
45	25.26						

* Estimated thermal conductivity values.

Well Name: TG-83

Location: latitude, 32° 06.57', longitude, 106° 36.20', township & range, T25S.R3E.26.214; elevation, 1,242 meters; spudded, 8-17-82; temperature logged, 10-6-82 (11:30 am); total depth, 45 meters; depth of 1½ inch PVC casing, 45 meters; bottom-hole temperature, 24.4°C; bottom-hole depth, 45 meters; bottom-hole temperature gradient, 98°C/km; best estimate heat flow value, 107 mW/m^2 (2.6 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mW/m^2)	Estimated Heat Flow (HFU)	Remarks
1	23.54						
2	23.97						
3	24.23						
4	23.05						
5	21.87		sand, gravel, and clay	1.5			
6	21.13						
7	21.04						
8	21.05						
9	21.14						
10	21.24						
15	21.90						
20	22.41		sand and clay	1.4			
25	22.88				111	2.66	
30	23.18						
35	23.61	79.5 ± 1.8	clay	1.3	103	2.47	
40	24.01						
45	24.43						

* Estimated thermal conductivity values.

Well Name: TG-84

Location: latitude, 32° 06.85', longitude, 106° 35.08', township & range, T25S.R3E.24.432; elevation, 1,271 meters; spudded, 8-17-82; temperature logged, 10-6-82 (1:05 pm); total depth, 45 meters; depth of 1½ inch PVC casing, 45 meters; bottom-hole temperature, 23.3°C; bottom-hole depth, 45 meters; bottom-hole temperature gradient, 74°C/km; best estimate heat flow value, 102 mW/m^2 (2.4 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mW/m^2)	(HFU)	Remarks
1	23.71						
2	24.35						
3	23.78						
4	22.42						
5	21.45						
6	20.83		sand, gravel, and clay	1.5			
7	20.54						
8	20.52						
9	20.57						
10	20.63						
15	21.08						
20	21.50						
25	21.92						
30	22.29						
35	22.65	72.7 ± 1.6	sand and clay	1.4	102	2.43	
40	23.01						
45	23.32						

* Estimated thermal conductivity values.

Well Name: TG-85

Location: latitude, 32° 05.97', longitude, 106° 35.34', township & range, T25S.R3E.25.431; elevation, 1,242 meters; spudded, 8-17-82; temperature logged, 10-6-82 (1:35 pm); total depth, 45 meters; depth of 1½ inch PVC casing, 45 meters; bottom-hole temperature, 23.6 °C; bottom-hole depth, 45 meters; bottom-hole temperature gradient, 81°C/km; best estimate heat flow value, 113 mW/m^2 (2.7 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mW/m^2)	(HFU)	Remarks
1	23.81						
2	24.34						
3	24.01						
4	22.55						
5	21.25		clay and sand	1.4			
6	20.62						
7	20.39						
8	20.37						
9	20.38						
10	20.61						
15	21.23		clay, very hard	1.4			
20	21.61						
25	21.98						
30	22.51		clay and sand	1.4	117	2.81	
35	22.96	83.9 ± 3.7					
40	23.36						
45	23.63		clay	1.3	109	2.61	

* Estimated thermal conductivity values.

Well Name: TG-86

Location: latitude, 32° 05.89', longitude, 106° 36.14', township & range, T25S.R3E.26.434; elevation, 1,233 meters; spudded, 8-18-82; temperature logged, 10-7-82 (11:45 am); total depth, 45 meters; depth of 1½ inch PVC casing, 45 meters; bottom-hole temperature, 24.0°C; bottom-hole depth, 45 meters; bottom-hole temperature gradient, 90°C/km; best estimate heat flow value, 115 mW/m^2 (2.7 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mW/m^2)	Estimated Heat Flow (HFU)	Remarks
1	23.86						
2	24.08						
3	23.49						
4	21.83						
5	20.99						
6	20.71						
7	20.67						
8	20.73						
9	20.85		sand and clay	1.4			
10	20.97						
15	21.35						
20	22.00						
25	22.44						
30	22.98						
35	23.33	81.9 ± 3.4			115	2.74	
40	23.70						
45	24.04						

* Estimated thermal conductivity values.

Well Name: TG-87

Location: latitude, 32° 05.38', longitude, 106° 36.82', township & range, T25S.R3E.35.311; elevation, 1,196 meters; spudded, 8-2-82; temperature logged, 10-7-82 (11:15 am); total depth, 45 meters; depth of 1½ inch PVC casing, 45 meters; bottom-hole temperature, 24.6°C; bottom-hole depth, 45 meters; bottom-hole temperature gradient, 102°C/km; best estimate heat flow value, 107 mW/m^2 (2.6 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mW/m^2)	Estimated Heat Flow (HFU)	Remarks
1	23.49		sand and clay	1.4			
2	24.00						
3	24.08						
4	22.17						
5	21.41						
6	21.03						
7	21.05						
8	21.09						
9	21.17						
10	21.43						
15	22.07						
20	22.63	79.1 ± 4.5	clay	1.3	103	2.46	
25	23.04						
30	23.57						
35	23.99		clay and sand	1.4	111	2.65	
40	24.28						
45	24.57						

* Estimated thermal conductivity values.

Well Name: TG-88

Location: latitude, 32° 04.35', longitude, 106° 35.42', township & range, T26S.R3E.1.324; elevation, 1,212 meters; spudded, 8-3-82; temperature logged, 10-7-82 (12:20 pm); total depth, 45 meters; depth of 1½ inch PVC casing, 45 meters; bottom-hole temperature, 24.1°C; bottom-hole depth, 45 meters; bottom-hole temperature gradient, 90°C/km; best estimate heat flow value, 123 mW/m^2 (3.0 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow		Remarks
					(mW/m^2)	(HFU)	
1	24.43						
2	24.79						
3	24.36						
4	22.87						
5	21.65		sand and clay	1.4			
6	21.08						
7	20.83						
8	20.83						
9	20.85						
10	21.04						
15	21.46						
20	21.89						
25	22.30						
30	22.82		clay and sand	1.4			
35	23.28	88.1 ± 2.2			123	2.95	
40	23.67						
45	24.06						

* Estimated thermal conductivity values.

Well Name: TG-89

Location: latitude, 32° 03.47', longitude, 106° 35.84', township & range, T26S.R3E.12.313; elevation, 1,195 meters; spudded, 8-4-82; temperature logged, 10-7-82 (12:55 pm); total depth, 45 meters; depth of 1½ inch PVC casing, 45 meters; bottom-hole temperature, 24.2°C; bottom-hole depth, 45 meters; bottom-hole temperature gradient, 93°C/km; best estimate heat flow value, 125 mW/m^2 (3.0 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mW/m^2)	Estimated Heat Flow (HFU)	Remarks
1	24.32						
2	24.38						
3	23.79						
4	22.79						
5	21.73		sand, gravel, and clay	1.5			
6	20.96						
7	20.75						
8	20.78						
9	20.85						
10	20.91						
15	21.44						
20	22.01						
25	22.50						
30	23.04		clay and sand	1.4			
35	23.52	89.0 ± 4.6			125	2.98	
40	23.90						
45	24.19						

* Estimated thermal conductivity values.

Well Name: TG-90

Location: latitude, 32° 01.88', longitude, 106° 35.40', township & range, T26S.R3E.24.322; elevation, 1,186 meters; spudded, 8-4-82; temperature logged, 10-7-82 (4:25 pm); total depth, 45 meters; depth of 1½ inch PVC casing, 45 meters; bottom-hole temperature, 24.7°C; bottom-hole depth, 45 meters; bottom-hole temperature gradient, 105°C/km; best estimate heat flow value, 77 mW/m^2 (1.8 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mW/m^2)	(HFU)	Remarks
1	26.09						
2	26.66						
3	26.91						
4	25.49						
5	24.29						
6	23.40		sand, gravel, and clay	1.5			
7	22.90						
8	22.72						
9	22.69						
10	22.70						
15	22.95						
20	23.25						
25	23.56						
30	23.90		clay	1.3			
35	24.21	58.9 ± 1.8			77	1.83	
40	24.46						
45	24.71						

* Estimated thermal conductivity values.

Well Name: TG-91

Location: latitude, 32° 01.63', longitude, 106° 34.71', township & range, T26S.R4E.19.332; elevation, 1,209 meters; spudded, 8-4-82; temperature logged, 10-7-82 (4:05 pm); total depth, 8.5 meters; depth of 1½ inch PVC casing, 8.5 meters; bottom-hole temperature, 22.9°C; bottom-hole depth, 8.5 meters.

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mW/m^2)	(HFU)	Remarks
1	24.63						Drilling was stopped due to lost circulation.
2	25.21						
3	25.51						
4	25.08						
5	24.25		large gravel, fractured				
6	23.59						
7	23.23						
8	22.97						
8.5	22.92						

* Estimated thermal conductivity values.

Well Name: TG-92

Location: latitude, 32° 00.91', longitude, 106° 34.77', township & range, T26S.R4E.30.313; elevation, 1,196 meters; spudded, 8-5-82; temperature logged, 10-7-82 (11:00 am); total depth, 45 meters; depth of 1½ inch PVC casing, 45 meters; bottom-hole temperature, 25.5°C; bottom-hole depth, 45 meters; bottom-hole temperature gradient, 123°C/km; best estimate heat flow value, 128 mW/m^2 (3.1 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mW/m^2)	(HFU)	Remarks
1	24.18						
2	24.69						
3	24.31						
4	23.24						
5	22.07						
6	21.44		clay and sand	1.4			
7	21.33						
8	21.36						
9	21.43						
10	21.56						
15	22.34						
20	23.06						
25	23.68						
30	24.29		clay	1.3			
35	24.73	98.6 ± 5.1			128	3.07	
40	25.15						
45	25.54						

* Estimated thermal conductivity values.

Well Name: TG-93

Location: latitude, 32° 00.25', longitude, 106° 34.17', township & range, T26S.R4E.31.234; elevation, 1,213 meters; spudded, 8-5-82; temperature logged, 10-8-82 (10:35 am); total depth, 45 meters; depth of 1½ inch PVC casing, 45 meters; bottom-hole temperature, 24.9°C; bottom-hole depth, 45 meters; bottom-hole temperature gradient, 109°C/km; best estimate heat flow value, 132 mW/m^2 (3.2 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mW/m^2)	Estimated Heat Flow (HFU)	Remarks
1	24.73						
2	25.03						
3	24.49						
4	23.14						
5	21.91						
6	21.26		sand and clay	1.4			
7	21.07						
8	21.09						
9	21.14						
10	21.45						
15	21.91						
20	22.57						
25	23.11						
30	23.65						
35	24.12	94.3 ± 3.8	clay and sand	1.4	132	3.16	
40	24.57						
45	24.90						

* Estimated thermal conductivity values.

Well Name: TG-94

Location: latitude, 32° 04.84', longitude, 106° 34.88', township & range, T26S.R3E.1.224; elevation, 1,250 meters; spudded, 8-18-82; temperature logged, 10-7-82 (1:35 pm); total depth, 45 meters; depth of 1½ inch PVC casing, 45 meters; bottom-hole temperature, 23.0°C; bottom-hole depth, 45 meters; bottom-hole temperature gradient, 68°C/km; best estimate heat flow value, 85 mW/m^2 (2.0 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Litholgoy	K* (W/m-°K)	Estimated Heat Flow (mW/m^2)	Estimated Heat Flow (HFU)	Remarks
1	24.30						
2	24.56						
3	24.08						
4	22.55						
5	21.63		sand and clay	1.4			
6	20.88						
7	20.55						
8	20.54						
9	20.58						
10	20.63						
15	21.08						
20	21.48						
25	21.80		clay	1.3	82	1.96	
30	22.19						
35	22.49	63.1 ± 2.0					
40	22.78		clay and sand	1.4	88	2.11	
45	23.04						

* Estimated thermal conductivity values.

Well Name: TG-95

Location: latitude, 32° 02.72', longitude, 106° 33.98', township & range, T26S.R4E.18.422; elevation, 1,253 meters; spudded, 8-21-82; temperature logged, 10-7-82 (2:10 pm); total depth, 45 meters; depth of 1½ inch PVC casing, 45 meters; bottom-hole temperature, 21.7°C; bottom-hole depth, 45 meters; bottom-hole temperature gradient, 37°C/km; best estimate heat flow value, 68 mW/m^2 (1.6 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mW/m^2)	Estimated Heat Flow (HFU)	Remarks
1	23.41						
2	23.12						
3	22.44						
4	21.50						
5	20.85						
6	20.37		clay, hard	1.4			
7	20.13						
8	20.04						
9	20.06						
10	20.07						
15	20.22						
20	20.45						
25	20.70		sand and clay	1.4			
30	21.03						
35	21.27	48.8 ± 2.5			68	1.63	
40	21.47		clay and sand	1.4			
45	21.65						

* Estimated thermal conductivity values.

Well Name: TG-96

Location: latitude, 32° 01.28', longitude, 106° 33.92', township & range, T26S.R4E.30.224; elevation, 1,236 meters; spudded, 8-19-82; temperature logged, 10-7-82 (3:30 pm); total depth, 45 meters; depth of 1½ inch PVC casing, 45 meters; bottom-hole temperature, 23.2°C; bottom-hole depth, 45 meters; bottom-hole temperature gradient, 72°C/km; best estimate heat flow value, 69 mW/m^2 (1.6 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mW/m^2)	Estimated Heat Flow (HFU)	Remarks
1	26.17						
2	26.72						
3	26.34						
4	24.79						
5	23.44						
6	22.67						
7	22.21						
8	21.97		clay and sand	1.4			
9	21.91						
10	21.89						
15	21.83						
20	22.00						
25	22.22						
30	22.48				71	1.69	
35	22.83	50.5 ± 2.1					
40	23.00		clay	1.3	66	1.57	
45	23.23						

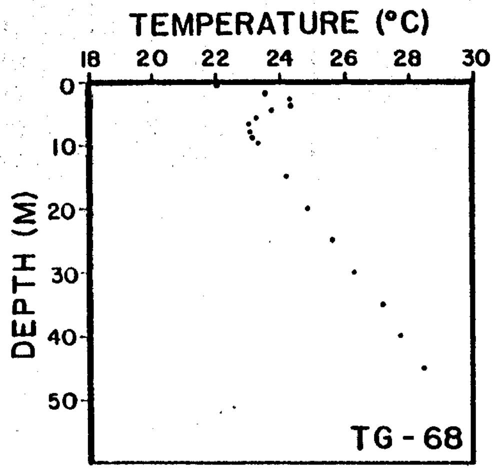
* Estimated thermal conductivity values.

Well Name: TG-97

Location: latitude, 32° 02.97', longitude, 106° 34.98', township & range, T26S.R3E.13.242; elevation, 1,202 meters; spudded, 8-20-82; temperature logged, 10-7-82 (2:50 pm); total depth, 45 meters; depth of 1½ inch PVC casing, 45 meters; bottom-hole temperature, 23.3°C; bottom-hole depth, 45 meters; bottom-hole temperature gradient, 73°C/km; best estimate heat flow value, 92 mW/m^2 (2.2 HFU).

Depth (m)	Temperature (°C)	Temperature Gradient (°C)	Lithology	K* (W/m-°K)	Estimated Heat Flow (mW/m^2)	(HFU)	Remarks
1	24.16						
2	24.36						
3	23.85						
4	22.12						
5	20.89						
6	20.63						
7	20.64						
8	20.67						
9	20.81		clay and sand, very hard	1.5			
10	20.92						
15	21.37						
20	21.75						
25	22.08						
30	22.38						
35	22.73	61.5 ± 1.2			92	2.21	
40	23.00						
45	23.28						

* Estimated thermal conductivity values.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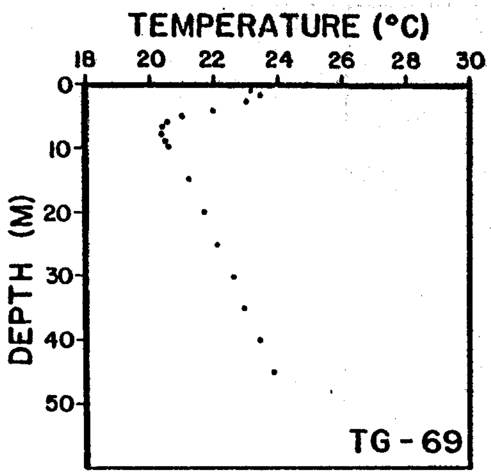
TG - 68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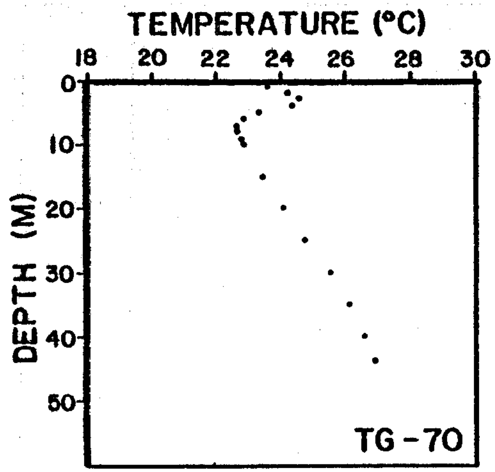
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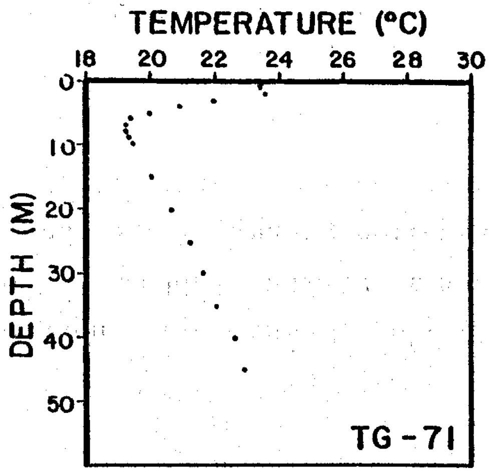
TG - 70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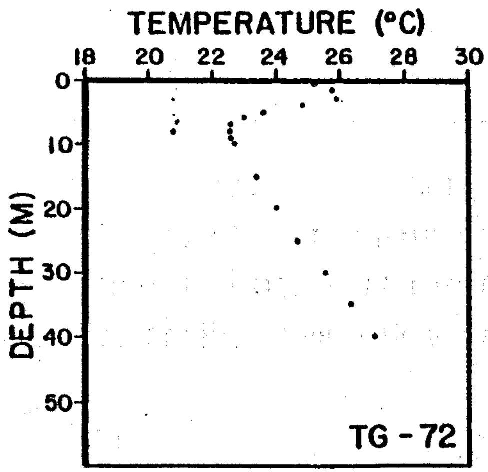
DEPTH (M)
0 10 20 30 40 50
TG - 71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DEPTH (M)
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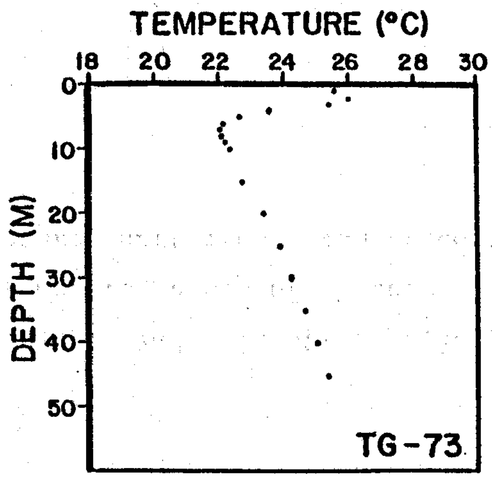
TG - 72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DEPTH (M)
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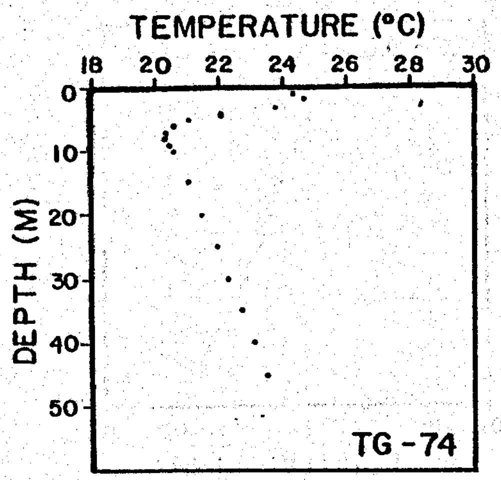
TG - 73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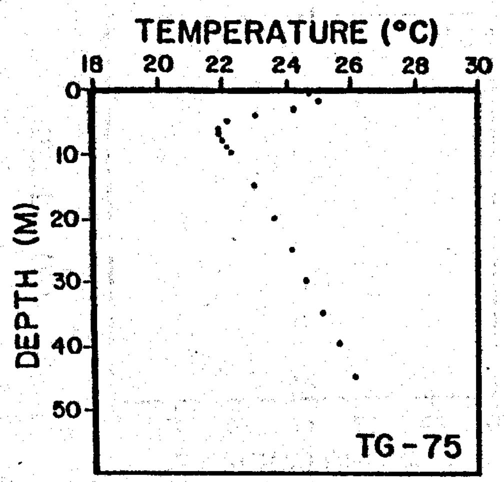
TG-74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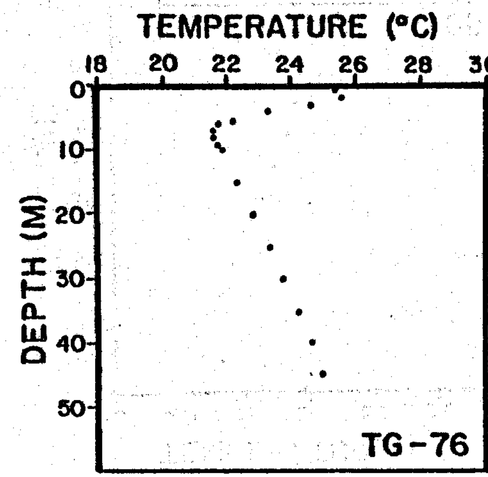
TG-75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DEPTH (M)
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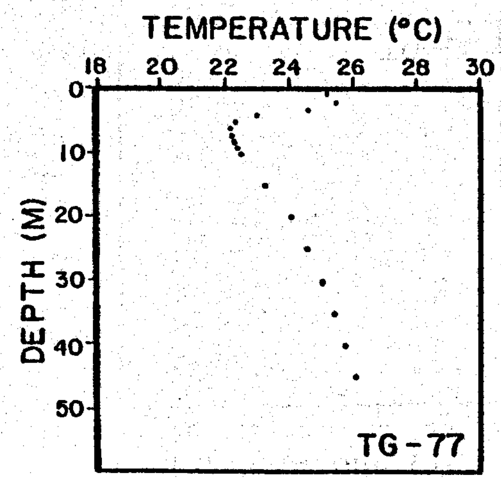
TG-76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DEPTH (M)
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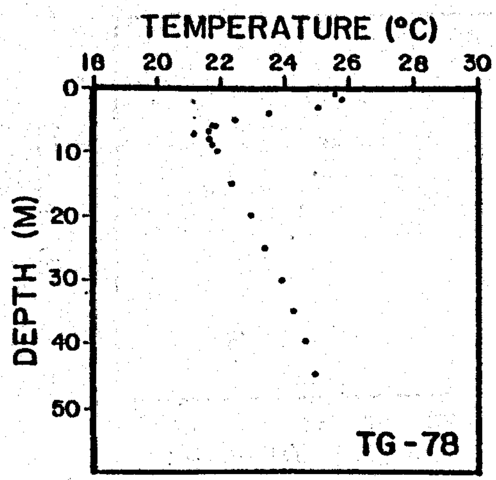
TG-77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DEPTH (M)
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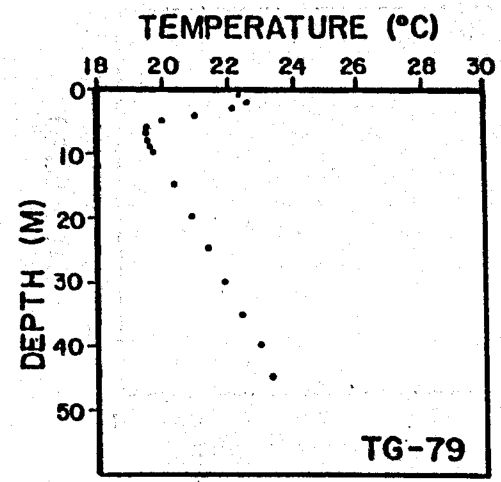
TG-78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DEPTH (M)
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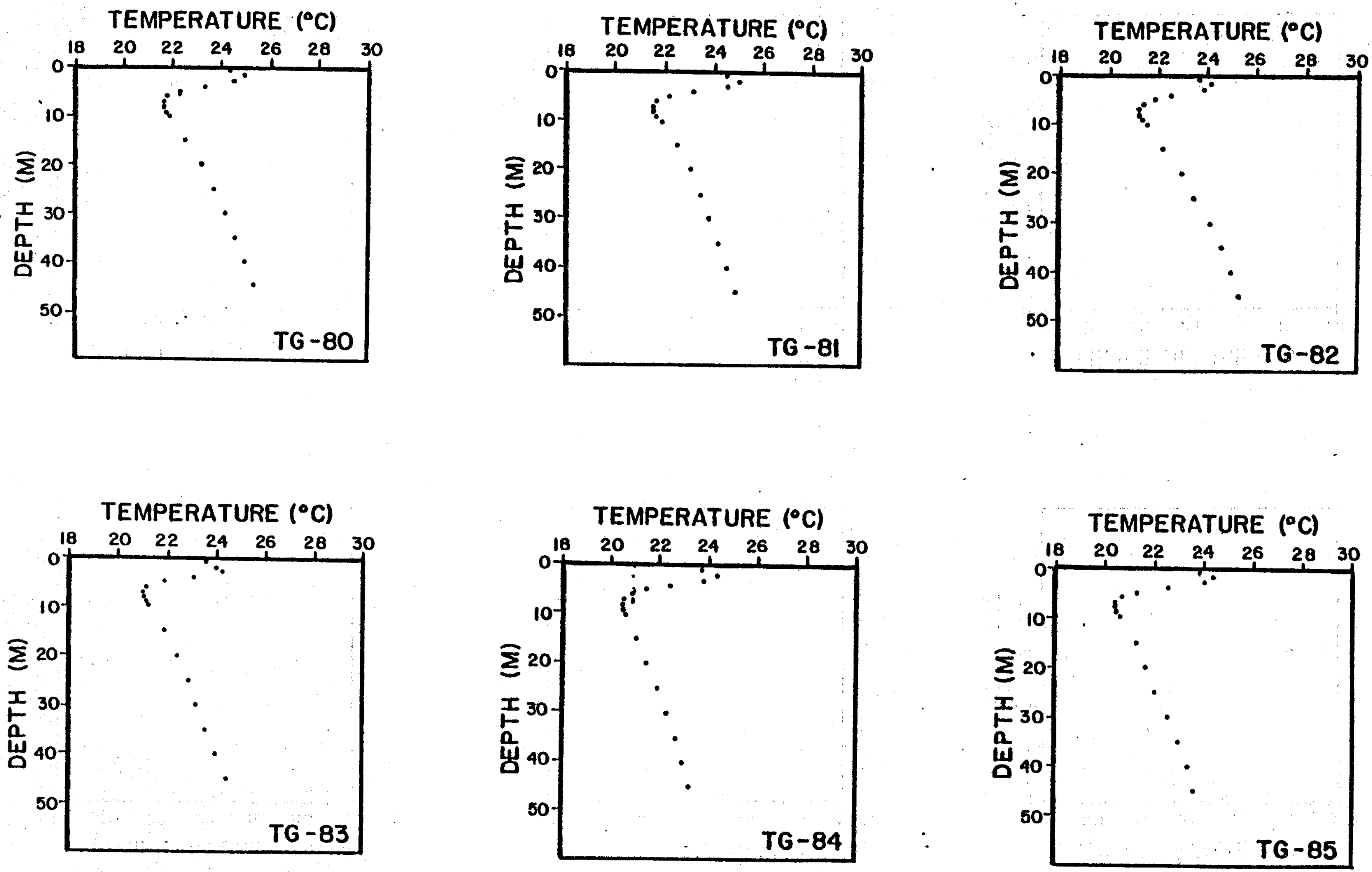
TG-79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DEPTH (M)
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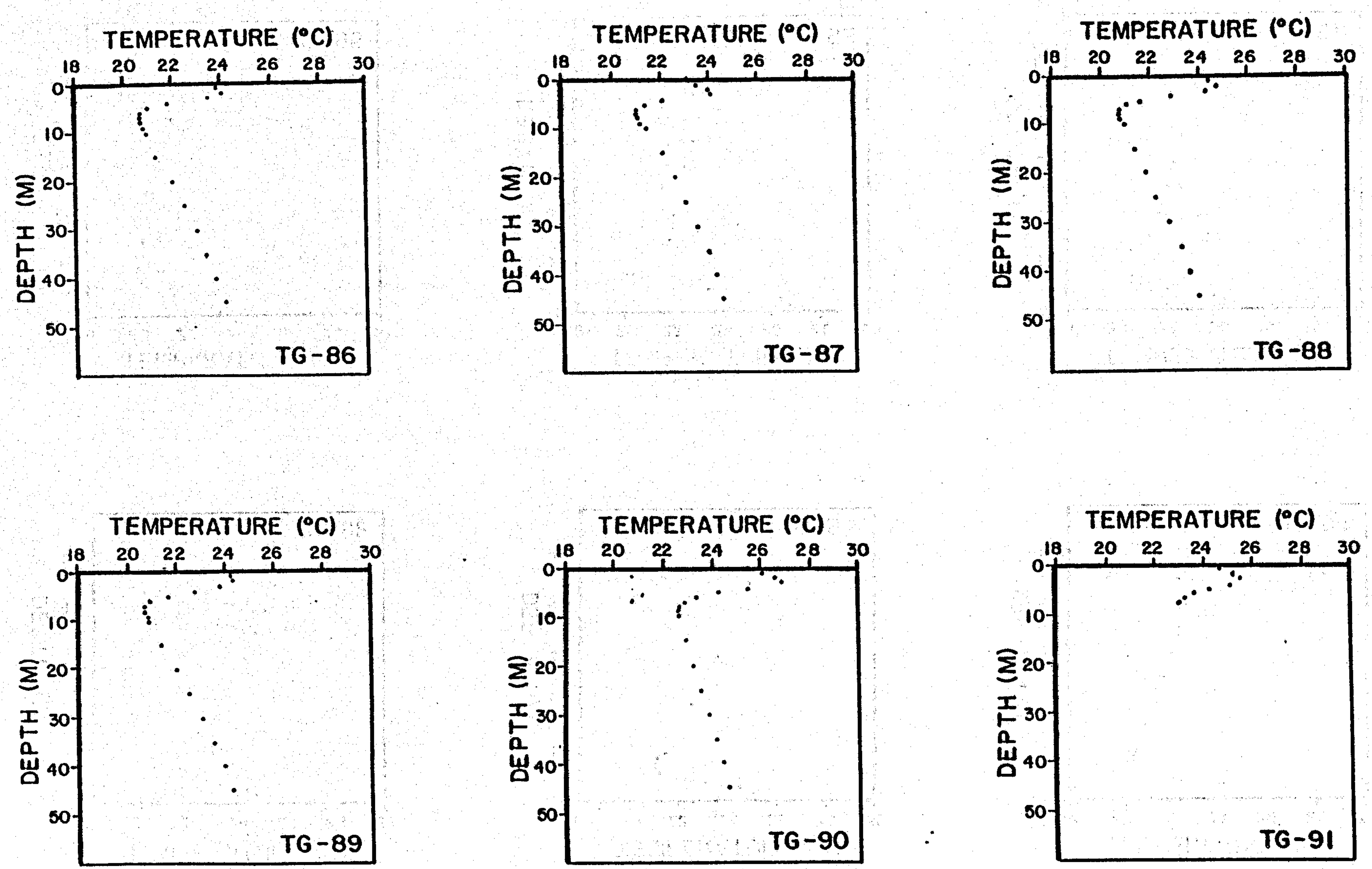
TG-80
TG-81
TG-82
TG-83
TG-84
TG-85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DEPTH (M)
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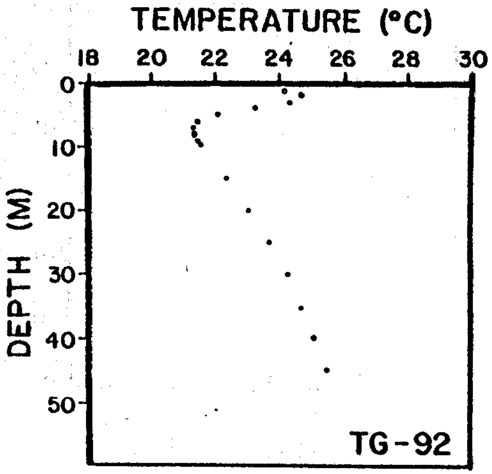
TG-87
TG-88
TG-89
TG-90
TG-91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DEPTH (M)
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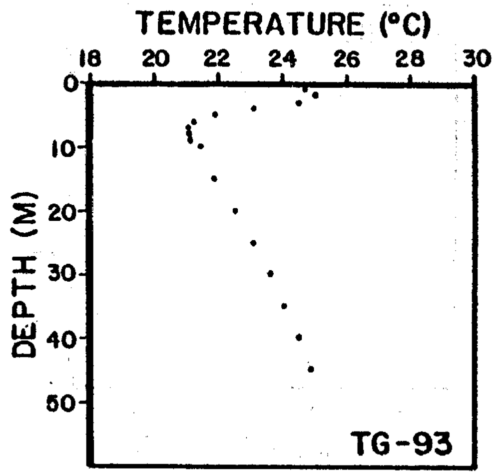
TG-92


TEMPERATURE (°C)
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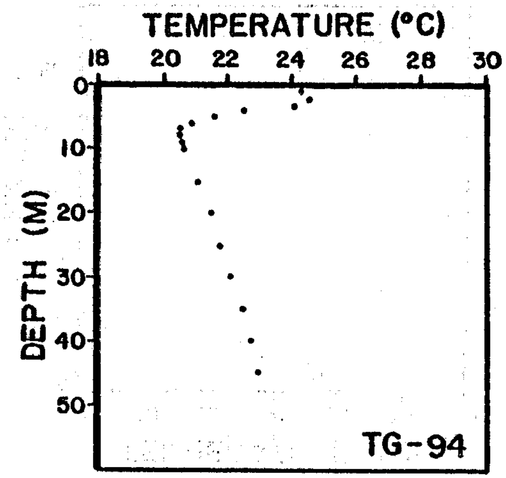
DEPTH (M)
0 10 20 30 40 50
TG-93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DEPTH (M)
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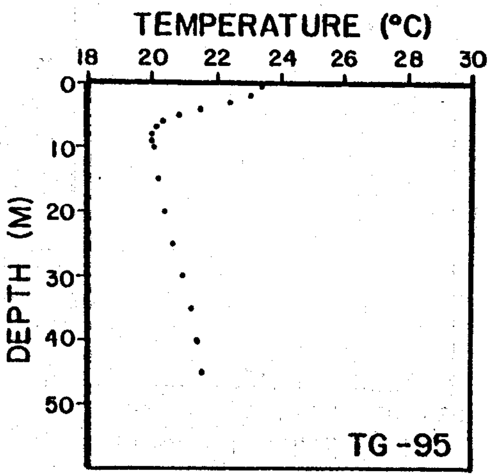
TG-94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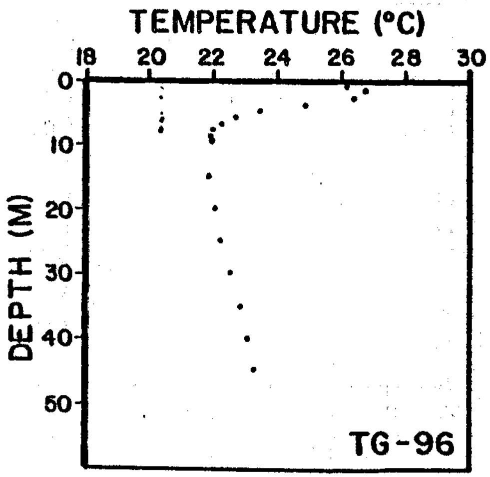
TG-95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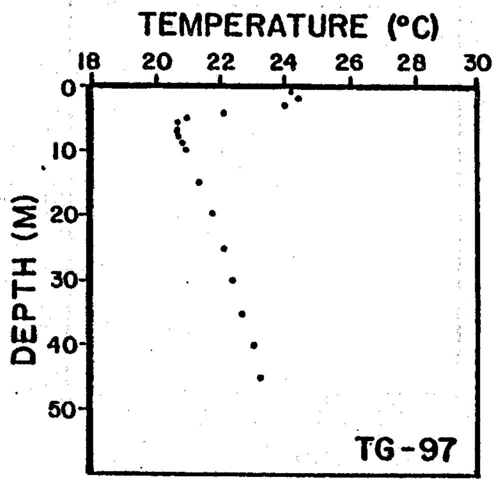
TG-96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18 20 22 24 26 28 30
DEPTH (M)
0 10 20 30 40 50
TG-97

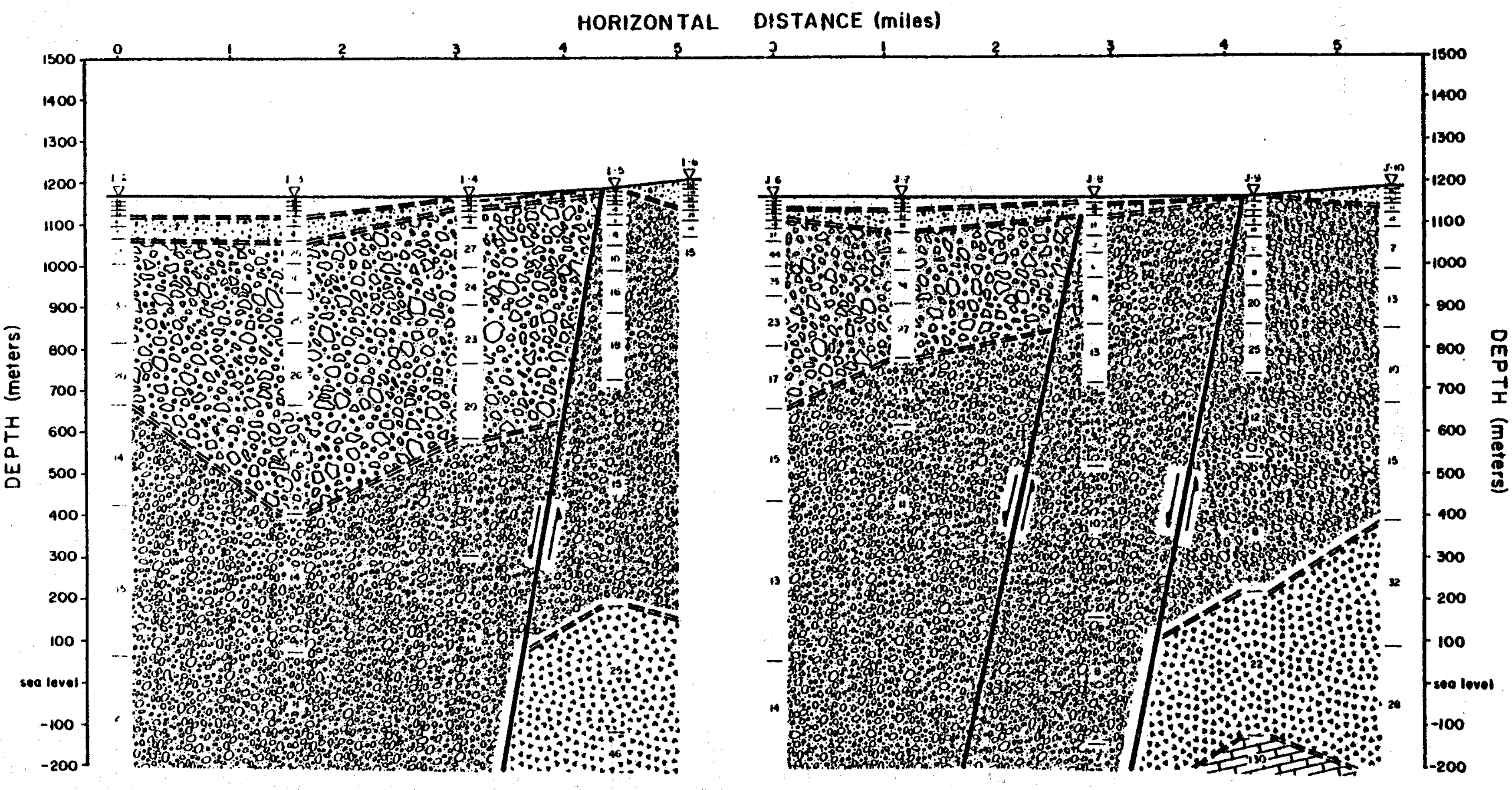
Appendix E

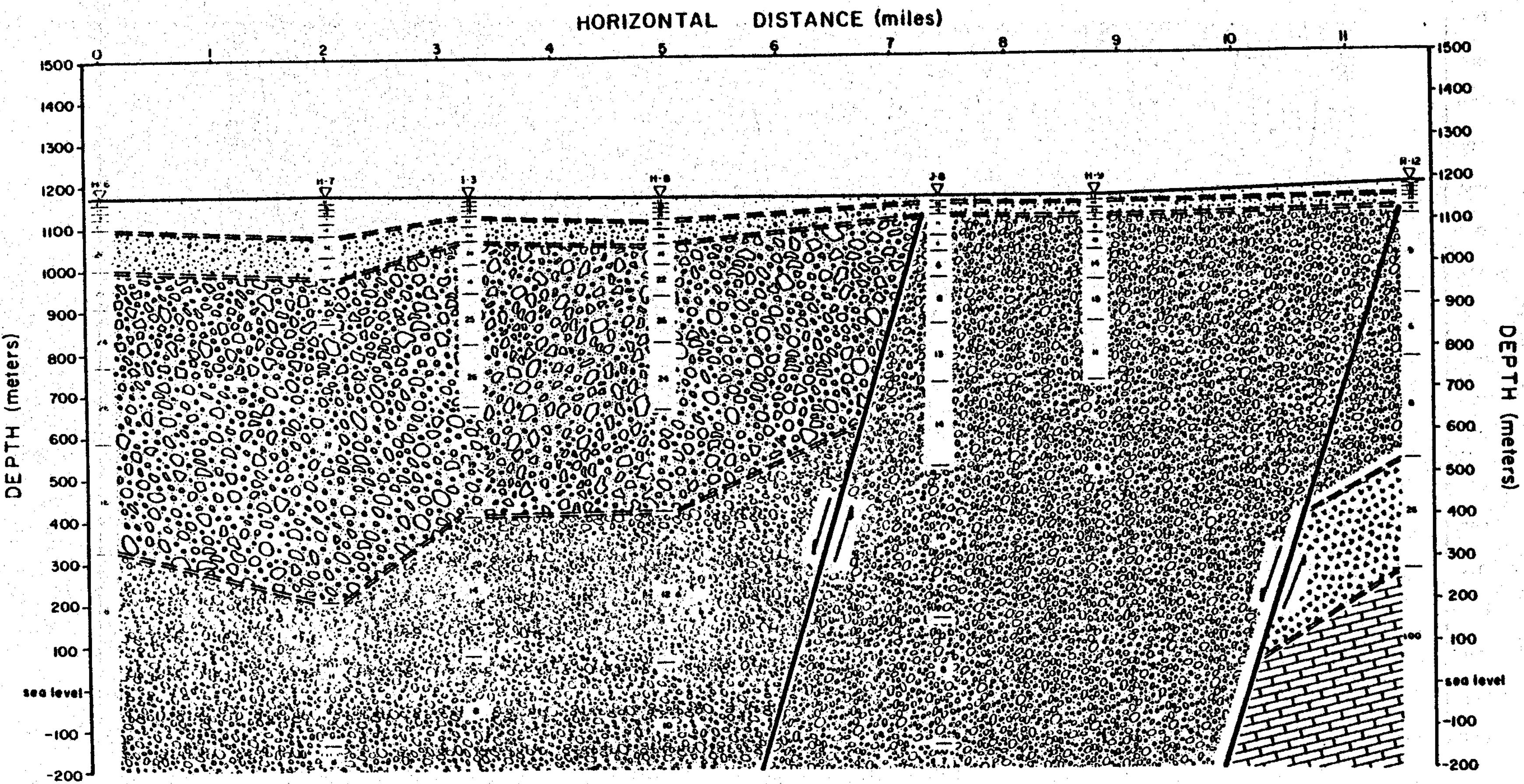
Lithologic Cross Sections for the Mesquite-Anthony Area

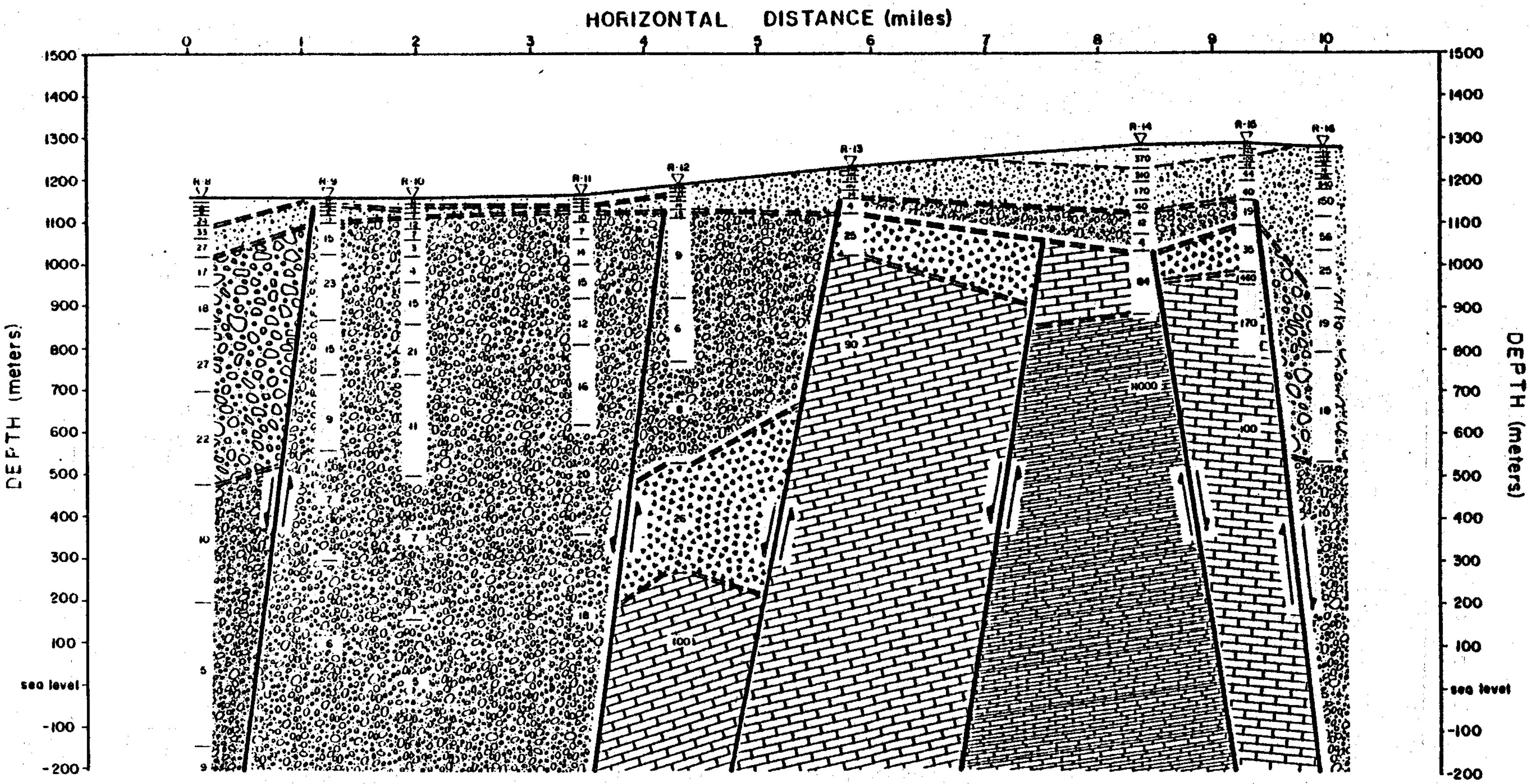
Note: Locations of the profile lines are given in Figure 30. The resistivity data are given in units of ohm-meters.

Legend:

- Late-Quaternary sands and gravels
- Upper Santa Fe group of early-Quaternary age
- Upper Division of the Lower Santa Fe group of late-Tertiary age
- Lower Division of the Lower Santa Fe group of late-Tertiary age
- Volcanic sequence [Orejon Andesite of middle-Tertiary age (?)]
- Paleozoic strata [Permo-Penn (?)]
- Paleozoic strata [Mississippian-Devonian (?)]


HORIZONTAL DISTANCE (miles)
DEPTH (meters)
DEPTH (meters)
sea level
sea level


HORIZONTAL DISTANCE (miles)
0 1 2 3 4 5 6 7 8 9 10 11
DEPTH (meters)
1500 1400 1300 1200 1100 1000 900 800 700 600 500 400 300 200 100 sea level -100 -200
DEPTH (meters)


HORIZONTAL DISTANCE (miles)
0
1
2
3
4
5
6
7
8
9
10
DEPTH (meters)
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
sea level
-100
-200
R-8
R-9
R-10
R-11
R-12
R-13
R-14
R-15
R-16