TEMPERATURE GRADIENT DRILLING IN THE MESQUITE-ANTHONY AREA, NEW MEXICO

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ABSTRACT

Thirty shallow temperature gradient holes were drilled on the Las Cruces east mesa southeast of the Las Cruces East Mesa Geothermal Field. Temperature and estimated heat flow data indicate that the thermal anomaly is now as large as 250 km^2. The hydrothermal system is believed to be fault controlled and generally decreases in temperature from the north to the south.

INTRODUCTION

Thirty shallow temperature gradient holes were drilled on the mesa east of Interstate Highway 10 from Mesquite to Anthony, New Mexico (see Fig. 1), to further delineate the Las Cruces East Mesa Geothermal Field (Lohse and Icerman, 1982). The northern boundary of the Mesquite-Anthony area is approximately 6 km south of the southern extent of the area surrounding Tortugas Mountain that was delineated in 1981. As the result of these two exploration programs, detailed temperature data have been collected over a thermal anomaly of about 250 km^2 in eastern Dona Ana County.

TEMPERATURE DATA

The locations of the temperature gradient holes, identified by the label TG, are shown in Figure 1. Twenty-eight of the holes had target depths of 150 ft (∿ 45 m). 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 ft and loss of circulation at 29 ft, respectively. Two of the thirty holes were drilled to a total depth of 315 ft (∿ 95 m). All of the holes bottomed out in Quaternary sediments, ranging from unconsolidated gravels and sands to semi-consolidated clays. Calculated bottom-hole temperature gradients range from 37 to 177°C/km. The highest temperature recorded at 45 meters was 28°C observed in hole TG-68.

Figure 2 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.

HEAT FLOW DATA

Heat flow values for specified depth intervals were calculated for each of the holes based on measured temperature gradients and estimated thermal conductivities. When heat flow values have been estimated for more than one interval in a given hole, the estimated best 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 study area are shown in Figure 3. The heat flow data are hand-contoured at 1 HFU intervals. These best estimates range from 1.6 to 5.3 HFU. Generally, 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 study area.

GEOLOGICAL AND GEOPHYSICAL DATA

Tectonic Features

Surface faults within the study area 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 Mountains 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 general 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, with an associated dip of about 20 to 35° WNW. Paleozoic strata of similar age are also found in the

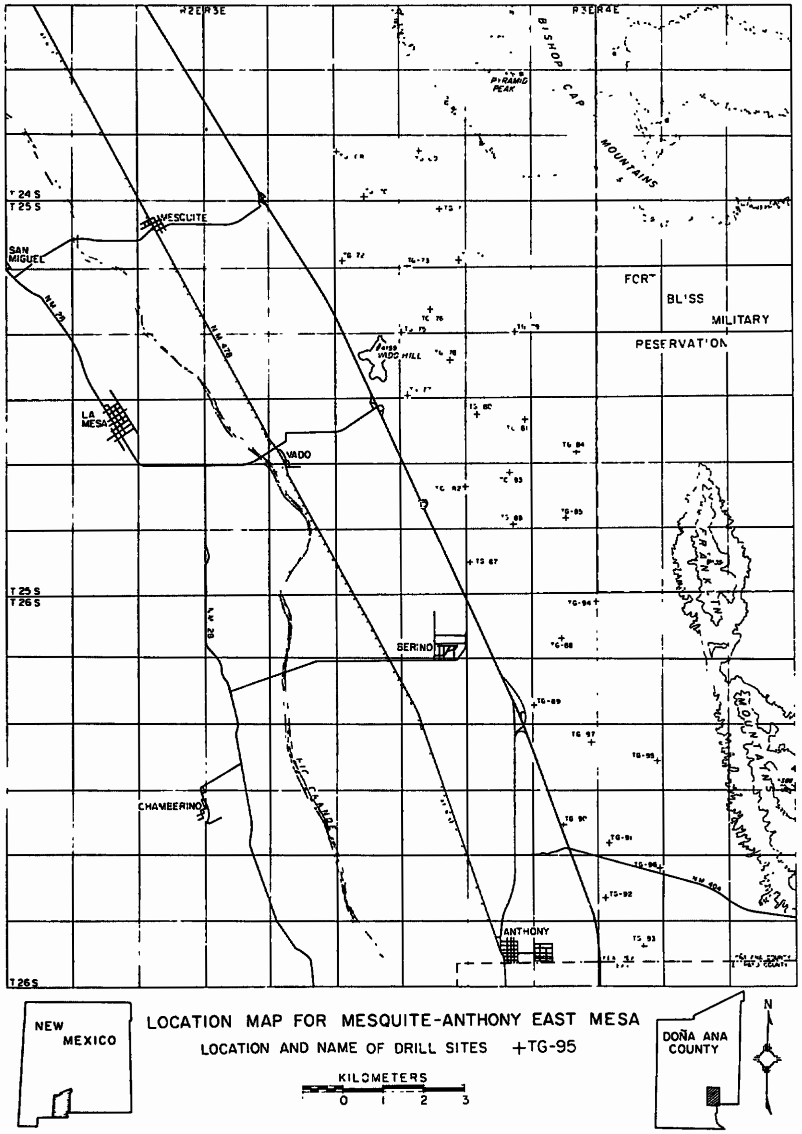

Figure 1. Location of temperature gradient holes (TG) in the Mesquite-Anthony area.

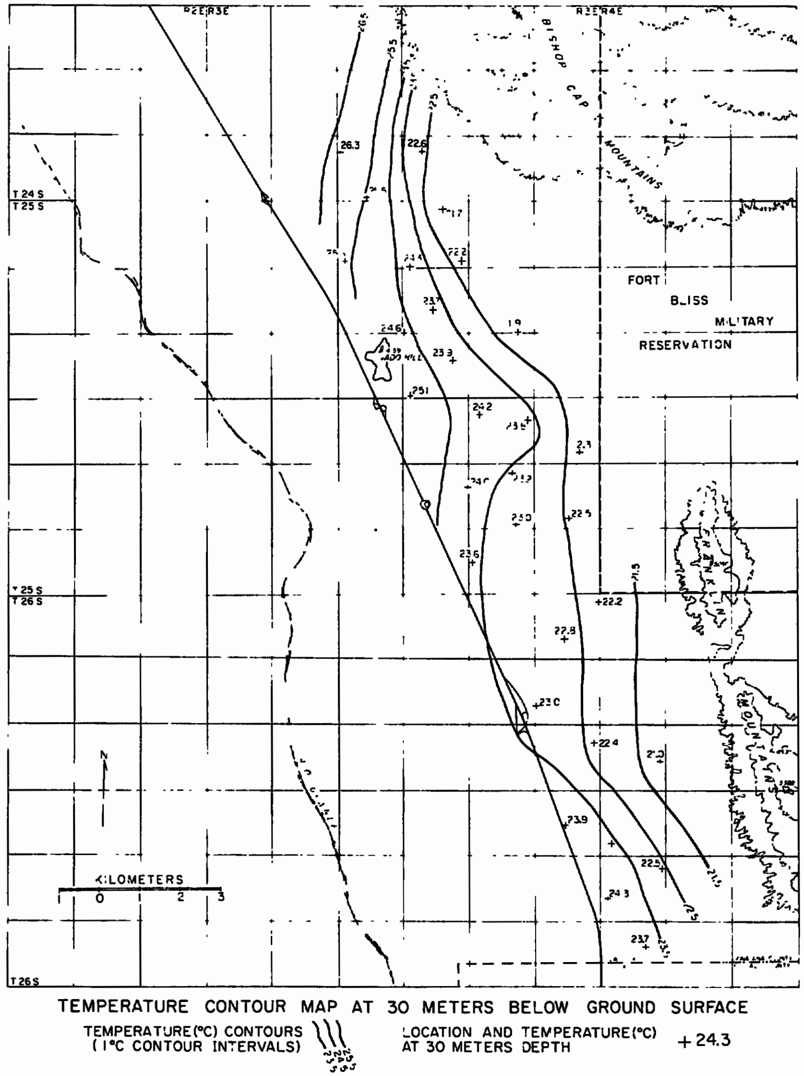

Figure 2. Temperature contours at a 30-meter depth in the Mesquite-Anthony area.

Franklin Mountains, while here the dip is a little larger generally ranging from 35° W to 45° SW. The northern portion of the Franklin Mountains generally strikes 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 km to the north of the study area at Tortugas Mountain, 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 here the dip of the strata ranges from 15 to 25° WSW and the average strike is NNW-SSE. Vado Hill (see Fig. 1) is an andesite or latite flow of early Tertiary age (Kottlowski, 1960), which includes the Orejon Andesite of Dunham (1935) in the Organ Mountains.

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 reveals that 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 (Lohse, 1982).

Gravity and Aeromagnetic Data

The residual Bouguer gravity data of Aiken et al. (1978) show three principal features in the study area. A regional gravity maximum and a local increase in gravity to the northeast are identified. Thirdly, a high gravity gradient trends in a NNW-SSE direction through the center of the study 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) extend only a few miles into the northern end of the study area. However, these data suggest the existence of a magnetic maximum in the north central portion of the area.

Electrical Resistivity Data

Electrical resistivity data obtained by Schlumberger depth sounding techniques in the study area have been collected by Jackson (1976). 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.

Subsurface Structure

The electrical resistivity layers were correlated to determine cross sections along profile lines from one depth sounding site to another in the study area. 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 Eocene (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 4 is a subsurface fault map produced, in part, from lithologic cross sections. Included in Figure 4 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 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 lithologic cross sections and the 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 km north of the study area.

DISCUSSION

Examination of the temperature and heat flow values shown in Figures 2 and 3, respectively, shows 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 study area. Figure 2 also shows a general increase of temperatures from east to west over the entire area; however, heat flow values (see Fig. 3) indicate a somewhat different pattern of high to low to high again from east to west in the northern part of the study area.

To illustrate this observation, temperature gradient hole TG-79 (see Fig. 1) has one of the lowest temperatures at 30 m in the northern part of the area, but it has a heat flow value which is higher than most of the adjacent holes. One explanation for the apparent discrepancy could be that the high temperatures, temperature gradients, and heat flow values in the northwesternmost

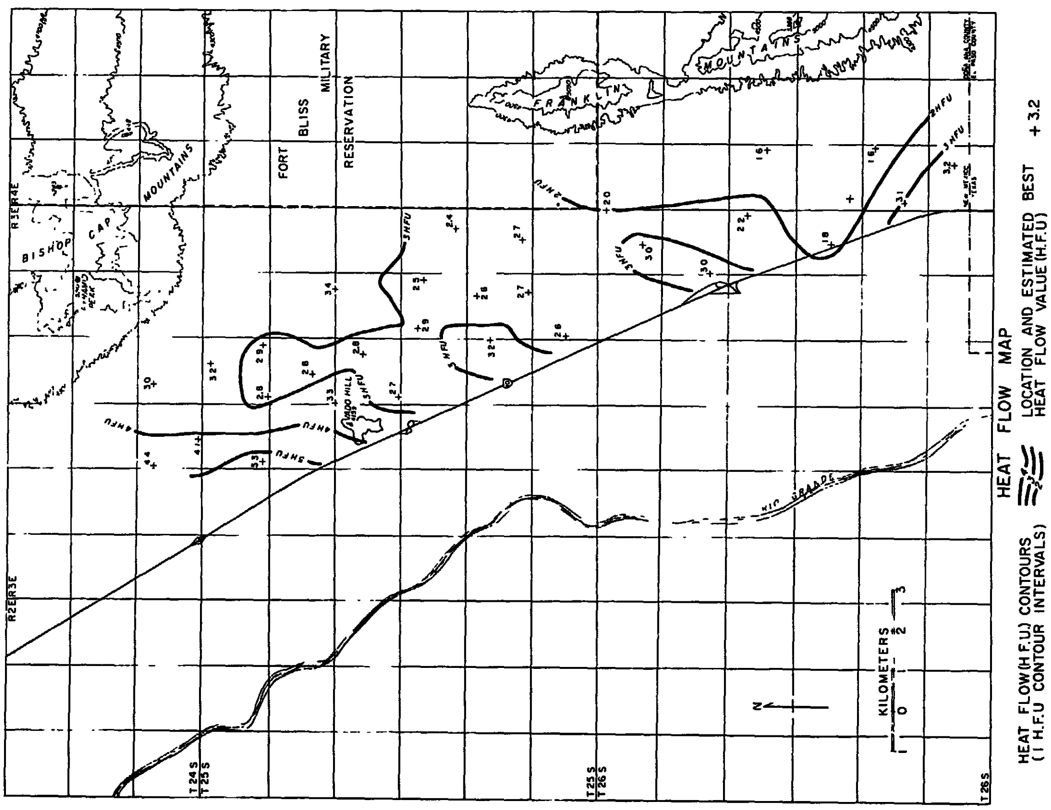

Figure 3. Heat flow map of the Mesquite-Anthony area.

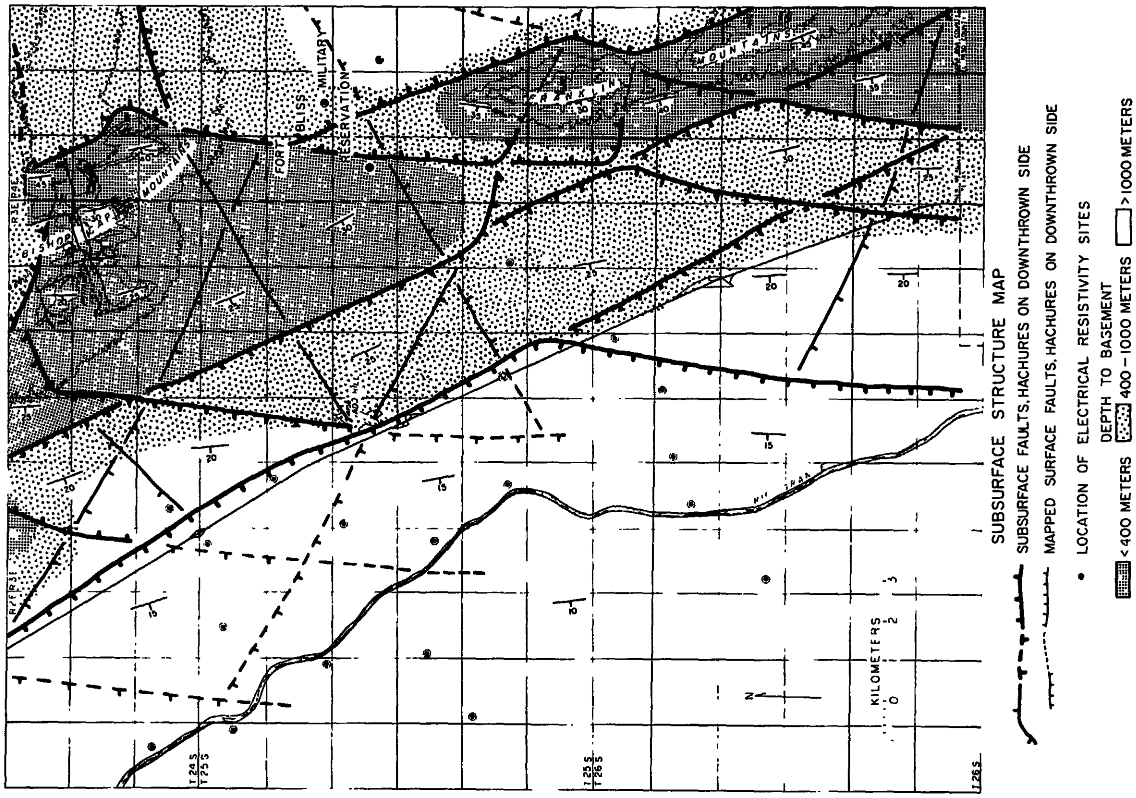

Figure 4. Subsurface structure of the Mesquite-Anthony area.

part of the study area are due to near-surface lateral or vertical hot water flow on the far west side, which would be expected to result in less elevated temperatures, temperature gradients, and heat flow values for those areas to the immediate east of this strongly convective area. Further to the east, away from the local effects of the convective system, the near-surface (i.e., 30-m) temperatures are still lower, but the temperature gradients and heat flow values increase, which would be expected if this area were returning to a more conductive mode of heat transfer. In this respect, the heat flow value of hole TG-79 would be more representative of the background heat flow for the northern part of the study area. The thermal anomaly may be characterized generally 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 study area.

Residual gravity data (Aiken et al., 1978) 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 increases in a more northerly direction. 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 Fig. 4) suggests that the strong convective system in the northwest part of the study area is fault controlled. Whether the geothermal fluids are flowing vertically up the faults, or laterally within a small graben created by the faults, is uncertain. Possibly, especially in light of the dip of the bedrock, both conditions are occurring, that is, the hot water ascends the faults and then, confined within the graben, flows laterally over the top of the bedrock.

CONCLUDING REMARKS

Including the temperature gradient holes drilled from 1978 through 1981, approximately 100 test holes have now been 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. Elevated temperature and heat flow data suggest that the thermal anomaly is approximately 45 km long, with a width ranging from 4 to 8 km. The highest temperature and heat flow values, 54°C and 19 HFU, respectively, are found in the northern part of the anomaly surrounding Tortugas Mountain, about 8 km north of the study area.

Sharp contrasts in temperature and heat flow values over relatively short distances of approximately 1 km, plus a spatial relationship between suspected subsurface faults and the thermal anomaly suggest the existence of a near-surface, fault-controlled hydrothermal system, which extends into the northwest corner of the study area. The geothermal fluids are believed to ascend via the basement fault structure prior to flowing laterally to the southwest over the top of the southwestern dipping bedrock and through the overlying sediments, gradually mixing with the cooler southerly flowing groundwaters of the Mesilla Basin. With the exception of some localized perturbations, the thermal anomaly generally decreases from the north to the south.

ACKNOWLEDGMENTS

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