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ELECTRICAL EXPLORATION FOR GEOTHERMAL RESOURCES NEAR SAN DIEGO MOUNTAIN, NEW MEXICO

FINAL REPORT

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ELECTRICAL EXPLORATION FOR GEOTHERMAL RESOURCES

NEAR SAN DIEGO MOUNTAIN, NEW MEXICO

FINAL REPORT
(7/1/78 - 9/1/79)

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Electrical Exploration for Geothermal
Resources Near San Diego Mountain, New Mexico

ABSTRACT

The area near San Diego Mountain, New Mexico, is considered to have geothermal potential because of nearby recent volcanoes and travertine deposits, high geochemical temperatures, high borehole temperatures and gradients and the Known Geothermal Resource Area of Radium Springs. To further evaluate the geothermal potential of this area, electrical resistivity reconnaissance has been conducted to search for low resistivity zones that might be hot rock or hot water.

Schlumberger profiling and telluric current measurements made near San Diego Mountain have found low resistivity regions immediately north and east of the mountain. These low resistivities may mark high temperature or saline water associated with the high thermal gradients of about 200°C/km, measured in drill holes on San Diego Mountain. Other low resistivity regions were found on the north side of the Sierra de las Uvas and the Mesilla Basin to the southwest. This latter region is probably warm saline water that extends to known warm wells and low resistivities near Kilbourne Hole.

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Resources Near San Diego Mountain, New Mexico

Introduction

High geothermal gradients and travertine deposits mark the area near San Diego Mountain as having potential geothermal resources (Reiter, 1978; Lohse, 1979; Swanberg, 1975). The area was selected for geoelectrical exploration to find possible low resistivity zones that might delineate potential hot water reservoirs. Schlumberger d.c. resistivity found low resistivity zones on the north side of the Sierra de las Uvas, near the north face of San Diego Mountain near a high temperature drill hole, and east of the Rough and Ready Hills. Telluric current measurements found a low resistivity area immediately southeast of San Diego Mountain.

Geologic Setting

This description is summarized from Seager, (1975), Hawley, Seager and Clemons, (1975) and Seager, Clemons and Callender, (1975). The study area, shown on a location outline map of New Mexico, Figure 1, is in the southern portion of the Rio Grande Rift. This part of northern Doña Ana County had undergone considerable faulting and volcanic activity. Major faults, mountains and towns are shown on Figure 2. Direct indications of geothermal potential in the area are hot springs at Radium Springs and high temperatures at San Diego Mountain (Reiter, 1978). Indirect indications

are travertine domes on the northwest face of San Diego Mountain, high geochemical temperatures (Swanberg, 1975) and volcanic structures.

Among major volcanic features of the area is the Goodsight-Cedar Hills Depression, roughly elliptical, about 20 km east-west and 35 km north-south. This depression, which has a maximum depth of about 500 m, is filled with several layers of tuff, and an andesitic basalt. At the center of the depression is the dome of the Sierra de las Uvas, probably formed by deep resurgent magma. On the east side of the depression is the Cedar Hills vent zone, a belt of intrusive rocks and various volcanic features at least 30 km long and 6 km wide.

San Diego Mountain, also known as the Tonuco Uplift, lies a few kilometers north of the vent zone. The tallest part of the mountain has undergone cycles of vertical motion; up in the Laramide deformation, down and up in the Pliocene and up again in the Quaternary.

The Mesilla Basin lies south of the Cedar Hills vent zone and west of Las Cruces. In addition to relatively flat volcanic sediments, there are volcanic hills and craters: Kilbourne Hole, Hunts Hole and Phillips Hole. There is known hot water, high temperatures and low resistivity in the area. Companies and scientific groups have conducted geothermal exploration in this area, as described in several papers in Seager, Clemons and Callender, (1975).

Schlumberger Resistivity Method and Results

The apparent resistivity of the earth is measured by placing four electrodes in a line. Electric current is injected into the ground, at A and B, through the outer two electrodes, and the potential difference is measured between M and N, the inner two electrodes. The earth resistivity calculated by this method represents a weighted average from the surface to an infinity.

FIGURE I STUDY AREA LOCATION MAP

FIGURE 2. Main geologic features of study area, (from Clemons and Hawley, 1975; Clemons and Seager, 1973; and Stoyer, 1975). Drill hole DH-1, located on the dome of San Diego Mountain has a maximum thermal gradient of 205°C per kilometer at a depth of 80 to 140 meters; DH-2 has a maximum gradient of 218°C per kilometer at a depth of 61 to 140 meters, (from Reiter, Sheaver and Edwards, 1978). DH-3 has a gradient of 66.4°C per kilometer at depths of 110 to 140 meters and a bottom hole temperature of 36°C at 175 meters, (Lohse, 1979).

tive depth. The resistivity of material shallower than one-half the outer electrode separation ($AB/2$) has the greatest effect on the measurement. We usually make measurements with $AB/2$ ranging from 1 to 2000 meters. The values of measured apparent resistivity are plotted against values of $AB/2$ forming a sounding curve which looks like a smoothed graph of the actual resistivity of layers underneath the measurement site. The actual layering may be determined by comparing the data with handbook or computer-generated sounding curves.

For reconnaissance work, instead of making soundings at each station, which would be inefficient, we make profiles by taking only two data at each station. While this does not provide enough information to construct layered models along the profiles, it does indicate subsurface apparent resistivities and locates boundaries. For our work at San Diego Mountain, we took data at $AB/2 = 800$ and 100 meters. These $AB/2$ values are chosen to represent a medium and deep depth of penetration. It is desirable to penetrate as deeply as it might be possible to drill; these $AB/2$ spacings were chosen as a reasonable trade-off between maximizing penetration and maximizing coverage.

Resistivity is used to explore for geothermal resources because hot water conducts electricity better than cold water, and hot rock better than cold rock. There are possible "false alarms" due to saline groundwater, clay and other conductive minerals. Thus, the results of an electrical survey must be combined with other geophysical and geological data to make realistic conclusions.

Figure 3 shows profile lines, data and apparent resistivity contours. Also shown are sounding locations and telluric current stations, which will be discussed later. Apparent resistivities for $AB/2 = 100$ meters and $AB/2$

= 800 meters are given in Figure 2. The two data give a rough idea of the depth of any anomaly. The deeper data, $AB/2 = 800$ m are more relevant to our study. Apparent resistivities for our profiles and Jackson's soundings are tabulated alongside each station on Figure 2.

The contours of apparent resistivity on Figure 2 show several main low resistivity areas: 1) in the northwest portion of the survey area, 2) along the north face of San Diego Mountain, 3) about three miles west of San Diego Mountain, 4) in the south of the survey area in the Mesilla Basin, and 5) southeast of San Diego Mountain, from Smith, (1977). Smith's data are from dipole-bipole mapping. The method is useful for showing geologic structures by lateral variations in resistivity, but is not useful in determining depths to conductors. The results do show that there is low resistivity material present as marked by the contours. Theory for dipole-bipole mapping shows that the depth of this low resistivity could be the same as the low resistivity found by our $AB/2 = 800$ m data.

The resistivity lows near San Diego Mountain in Figure 3 are close to the high temperature reported by Reiter. We also made short-range soundings there, and planned our telluric current survey for this area. The short range soundings allowed us to determine the depth to the top of the conductive material, and with the profile data, we can estimate the minimum depth to the bottom of the conductive material. The location of the soundings are shown as double ended arrows on the map of Figure 4 and the data and models are shown in Figures 5, 6, 7 and 8. We are combining sounding data with $AB/2$ up to 100 meters with the $AB/2 = 800$ m profile data and assuming that for $AB/2$ greater than 800 m the data show a resistive basement. Such data would plot as a line with a 45° slope. Matching models to such data gives a minimum

FIGURE 4. Location of short range Schlumberger soundings. Background map is from an enlargement of USGS 15-minute San Diego Mountain quadrangle. Data and interpretation of these soundings is presented in Figure 5.

SITE SDMT 1 4-LAYERS
 R=240 10 2 100
 T=7 300 250

FIGURE 5. Sounding data and model calculations for sounding S-1, mapped on Figure 4. The continuous line is the model calculation. The accuracy of the data is about 3% at short electrode spacings, limited by the accuracy of the meters, and about 20% at large electrode spacing, limited by signal levels which drop below telluric current voltages. Scatter in the data is usually due to lateral inhomogeneities. There is a low resistivity at this site of resistivity of 2 ohm-meters with a thickness of 250 meters.

SITE SDMT 2 6-LAYERS
 R=68 10 3 20 5 100
 T=1.4 2.2 10 12 600

FIGURE 6. Data and model for sounding S-2 on Figure 4. There are two low resistivity layers here, a shallow layer of resistivity 3 ohm-meters and 10 meters thick, and a deeper layer 5 ohm-meters and 600 meters thick. The symbol key is the same as Figure 5.

SITE SDMT 3 4-LAYERS
 R=130 26 3 100
 T=2.8 18 700

FIGURE 7. Data and model for sounding S-3 on Figure 4. The low resistivity layer here has a resistivity of 3 ohm-meters and a thickness of 700 meters. The symbol key is the same as Figure 5.

SITE COR+1 4-LAYERS
 R=38 90 4 500
 T=2 180 1200

FIGURE 8. Data and model for sounding located in lower center of Figure 3. The low apparent resistivity at AB/2 1000 m is modelled by a 4 ohm-meter layer of thickness 1200 m. The symbol key is the same as for Figure 5.

possible depth to the resistive basement. The model for S-1, Figure 6, shows a 2 ohm-meter layer 250-m thick; S-2, Figure 7, shows a 5 ohm-meter layer 600-m thick. The model for Schlumberger sounding, S-3, Figure 7, which is located in the center of the low resistivity zone north of San Diego Mountain, shows a low resistivity layer of resistivity 3 ohm-meters and thickness of 700 meters. The reader should be cautioned that these thicknesses are based on sparse data.

Figure 8 is data and model for the Schlumberger sounding in the lower center of Figure 3. The low resistivity layer here has a resistivity of 4 ohm-m and a thickness of 1200 m. The relation of this data to other geologic and geophysical data is discussed in the conclusion of this report.

Telluric Current Method and Results

This method of exploration uses extremely low frequency natural alternating currents to search for low resistivity zones. We use signals with frequencies between .01 and .1 Hz which penetrate several kilometers. The signals are recorded simultaneously at a base and remote stations. The recorded signals may be analyzed several different ways. One of the simplest methods, which we used in this report, consists of calculating the signal power at base and remote stations. Lower values of signal power indicate low resistivity at the remote station.

In electrical geophysical terms, the telluric current power ratios between base and remote stations are proportional to the ratio of magnetotelluric apparent resistivity at a base and remote site. Magnetotellurics refers to an exploration technique that measures natural magnetic and electric fields. The method can determine the layering of the earth underneath whereas telluric currents alone cannot. We are not doing magnetotellurics at this time because of the extra equipment and computing required.

We occupied nineteen telluric current sites around San Diego Mountain. Our telluric records were between fifteen and thirty minutes long. We digitized these data on a digitizing table, punched the data on cards and plotted the data, calculated broadband power ratios (BPRs) for the entire records, using the formula for raw energy ratio given in Hermance, Thayer and Björnsson, (1975).

The BPRs for each site are plotted in Figure 9. Two stations with low BPRs lie just south and east of San Diego Mountain. This could be due to a deep hot zone which causes the high temperatures. This zone of

FIGURE 9. Telluric current broadband power ratios. B is the base station.

weak telluric currents is marked by only two stations, so it is not possible to make an accurate estimate of the size of the anomaly.

It is interesting to notice that none of the western stations toward the center of the Sierra de las Uvas is low. We have not detected any deep conductive structure there.

Conclusion

Figure 10 presents a summary of the low resistivity regions found by this research. The shaded areas represent regions where the Schlumberger apparent resistivities at $AB/2 = 800$ m are less than 10 ohm-m or the telluric current broadband power is less than 0.5 than that of the base station.

The telluric current low near San Diego Mountain only partly overlaps the d.c. resistivity low. The telluric current low could be the deep source of heat for the high temperatures immediately north of San Diego Mountain, offset by about 3 kilometers from the d.c resistivity low.

The d.c. resistivity low in the south central part of the study area is probably a northward extension of low resistivities found by Jackson and Bisdorf, (1975). The Mesilla Basin is know for low resistivities, high salinities and high water temperatures. Our profile data crossing east-west through the pass between the Rough and Ready Hills and Sleeping Lady Hills shows an abrupt increase of resistivity from about 5 ohm-meters to the east and to 12 ohm-meters to the west. This transition may be a northward extension of a fault with a similar geophysical signature west of Kilbourne Hole, about 75 kilometers to the south. Many parts of the Mesilla Basin have low-temperature geothermal potential but potential users are too far away for development. Our study shows that the lands in the

northern part of the basin probably also have geothermal potential.

The low resistivity area in the northwest part of the survey area is a new and interesting area. The most optimistic interpretation is that the anomaly is due to high salinity from irrigation in the area. Well water chemical temperatures and chemical analysis may give a clue as to the cause of the low resistivities. The data within about 2 kilometers of San Diego Mountain, combined with temperature gradient and geological data suggest considerable geothermal potential. The resistivity and telluric content measurements could be continued over the anomalies to delineate the boundaries of the potential resource.

FIGURE 10. Summary of low resistivity areas found by d.c. resistivity and telluric currents. The shaded regions represent areas where the Schlumberger apparent resistivity at $AB/2 = 800\text{m}$ is less than 10 ohm-meters, or where the telluric broadband power ratio is less than .5.

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