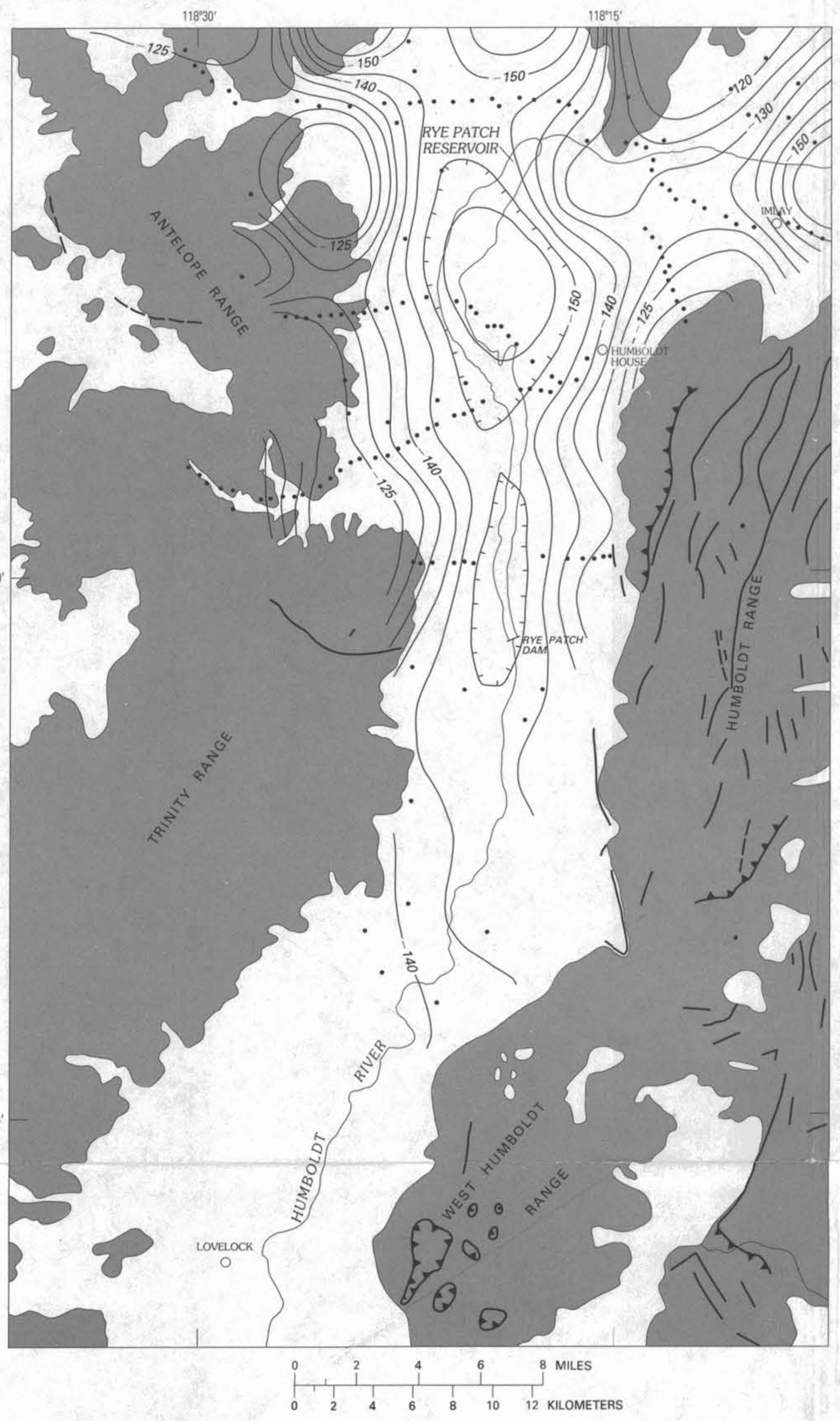

FIGURE 2—Bouguer gravity anomalies.

FIGURE 1—Location of study area.

EXPLANATION

VALLEY-FILL DEPOSITS

BEDROCK

NORMAL FAULT—Dashed where approximately located

THRUST FAULT—Sawteeth on upper plate

—150— LINE OF EQUAL COMPLETE BOUGUER GRAVITY (FIGURE 2)—Assumes a bedrock density of 2.67 grams per cubic centimeter. Interval 5 milligals

600 / S1 SEISMIC REFRACTION LINE (FIGURE 3)—Estimated depth to bedrock (600), in feet below land surface, and line number (S1) are indicated

—2000— LINE OF EQUAL DEPTH TO BEDROCK (FIGURE 3)—Interval 1,000 feet

—13— LINE OF EQUAL TEMPERATURE AT 6.6 FEET (FIGURE 6)—Interval 1 degree Celsius

• GRAVITY STATION (FIGURE 2) OR TEMPERATURE SITE (FIGURE 6)

○ GEOTHERMAL EXPLORATION WELL AND NAME (FIGURE 6)

INTERIOR—GEOLOGICAL SURVEY, RESTON, VA—1986—W85133

FIGURE 3—Depth to bedrock and location of seismic refraction lines.

CONVERSION FACTORS AND ABBREVIATIONS

Inch-pound units of measure used in this report may be converted to International System of Units (metric) by using the following factors:

Multiply	*By*	*To obtain*
foot (ft)	0.3048	meter (m)
foot per second (ft/s)	0.3048	meter per second (m/s)
inch (in.)	25.40	millimeter (mm)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)

INTRODUCTION

The Humboldt House study area, about 50 miles southwest of Winnemucca and 100 miles northeast of Reno (figure 1), is one of Nevada's many promising geothermal areas. The area of study, about 500 square miles, lies in the Humboldt River valley between Lovelock and Imlay (figure 2). It is bordered on the west by the Trinity and Antelope Ranges and on the east by the Humboldt and West Humboldt Ranges. Rye Patch Reservoir, in the central part of the study area (figure 2), was constructed in 1935 by the U.S. Bureau of Reclamation for impoundment of water for irrigation.

The area's geothermal potential has not been fully determined at present (1982). As more information becomes available on the geologic and hydrologic framework of the area, more interest may be expressed in developing the geothermal resources.

The purpose of the geophysical study reported herein, which was made in cooperation with the U.S. Bureau of Land Management, was to determine aspects of the geology that may control, affect, or delineate the geothermal system in the area. Principal determinations to be made were (1) variations in the gravitational field, (2) depth to bedrock, and (3) temperature anomalies at a depth of 6.6 feet (2 meters) below land surface in the valley fill.

In scope, the field work included (1) a series of gravity profiles and supplementary measurements across the valley (total, 200 sites); (2) six seismic-refraction lines to augment the gravity data interpretation; and (3) temperature measurements at 30 sites.

GEOLOGIC SETTING

Geology in the area is complex. The Trinity and Antelope Ranges to the west are composed of Triassic and Jurassic slate, phyllite, and quartzite, and Cretaceous granodioritic intrusives. Also exposed are Tertiary tuff and sediments (Johnson, 1977). The rocks are not extensively faulted. The Humboldt and West Humboldt Ranges to the east are composed of highly faulted sequences of Triassic mudstone, limestone, dolomite, and rhyolite. The valley-fill deposits, of Quaternary and Tertiary age, consist mainly of alluvial and lacustrine material dominated by sand, silt, and clay. A summary of the geologic and structural history of the area has been presented by Johnson (1977).

For the purpose of this study, the geologic units were generalized to distinguish only bedrock and valley-fill deposits, as shown in figure 2.

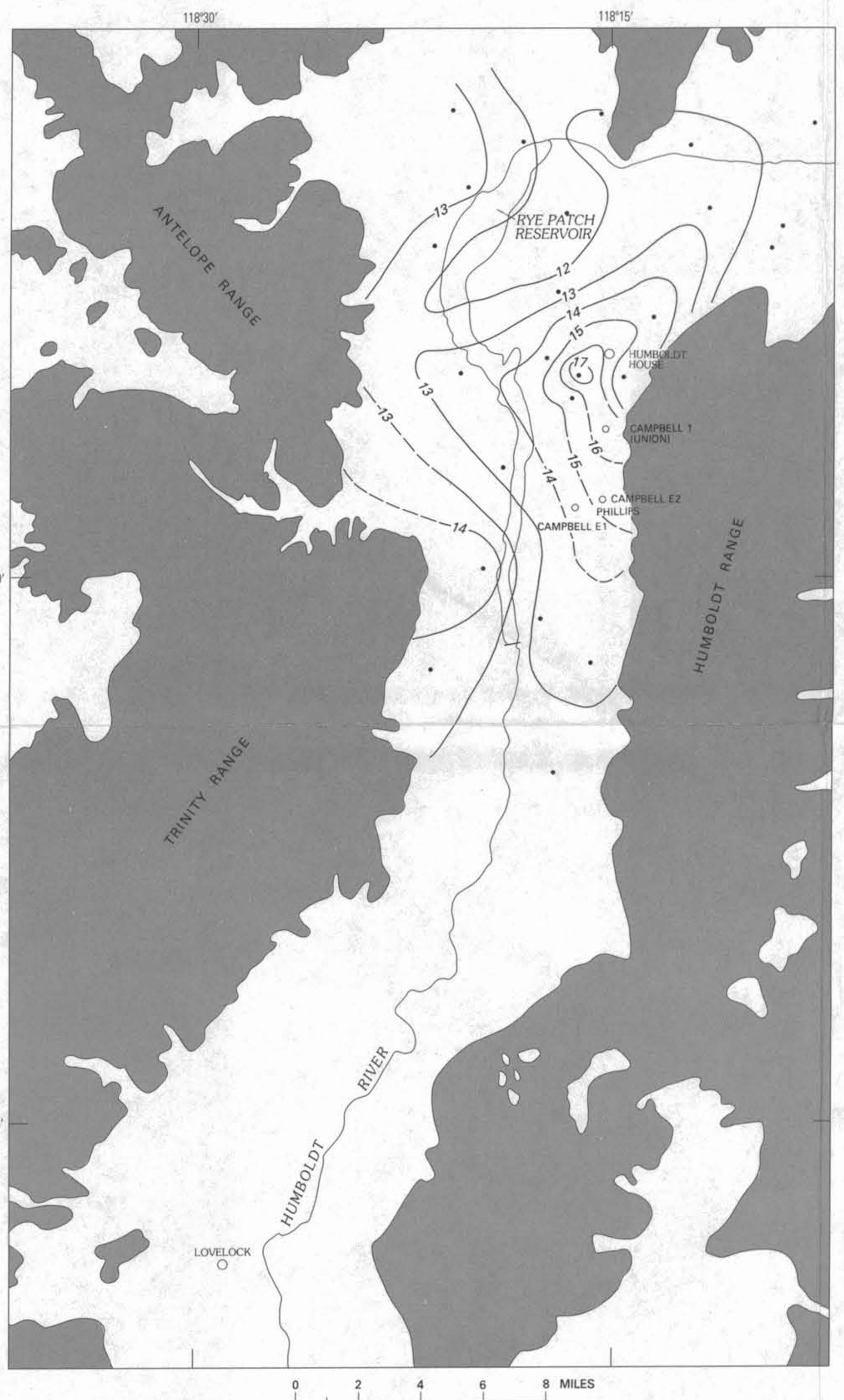

FIGURE 6—Temperature at a depth of 6.6 feet (2 meters).

GRAVITY SURVEY

The purpose of the gravity survey of the Humboldt House area was to estimate the thickness of valley-fill deposits. Commonly, a gravity survey can also be used to identify faulting in an area concealed by such deposits. The theory and uses of gravimetric surveys can be found in most geophysics textbooks, such as that of Dobrin (1976, pages 357–403).

METHOD

Gravity-instrument readings were obtained at about 200 stations in the study area (figure 2). Stations generally were along profiles coincident with roads. In parts of the valley, however, profiles were not feasible, or roads did not exist, so randomly spaced measurements were made to obtain adequate areal coverage.

For purposes of correcting the gravity data for known sources of error, the altitude of an individual gravity station is the single most critical item. Errors in altitude determinations of as little as 5 feet produce an error in Bouguer gravity values of 0.3 milligal. Ideally, station altitudes should be surveyed; however, owing to time limitations and the large areal extent of the study area, altitudes were obtained using a surveying altimeter. The altimeter used was readable to the nearest 2 feet, but errors inherent in the corrections can overshadow this accuracy. With frequent microbarographic corrections and recalibration at sites of known altitude, altimeter readings can be accurate to ±5 feet or less (Schaefer, 1983, page 14), an amount not deemed significant for the purposes of this study.

Whenever possible, stations were located at bench marks, road intersections, and section corners shown on topographic maps. Altitudes of these stations are probably accurate to ±1 foot.

Horizontal control for locating the gravity stations was accomplished using the Loran Navigation System. The system can determine latitude and longitude at a position which, after application of certain corrections, is accurate to about 0.01 minute of latitude and longitude (approximately 60 feet on the ground). A more complete description of Loran theory and operation is given by Laurila (1976, pages 419–435).

CORRECTIONS

The purposes of applying corrections to gravity data is to reduce all measurements to a common altitude datum and make compenstaions for stations that lie above or below excessive or deficient mass. Application of these corrections produces Bouguer gravity values, which depict spatial variations in mass across the study area.

All gravity measurements were referenced to two project base stations in the study area. At the beginning and end of each day, one of these base stations was reoccupied to determine net instrument drift. The project base stations were in turn referenced to a primary base station, at the airport in Winnemucca, that has an observed gravity of 979,824.29 mGals (Gravity Services Branch, 1970). The observed gravity values for all stations were computed from this base value.

Gravity data were corrected for tidal variations, latitude, and altitude. Theoretical gravity, free-air anomalies, and Bouguer-gravity values at a bedrock density of 2.67 g/cm^3 (grams per cubic centimeter) were computed for all stations. A computer program developed by Plouff (1977) was used to make terrain corrections to the Bouguer-gravity values radially outward from each station from 1.4 miles to about 104 miles. Corrections from the station radially outward to a distance of 1.4 miles were made manually by using the technique devised by Hayford and Bowie (1912). Principal data for these gravity stations are listed by Duffrin and others (1985).

BOUGUER-GRAVITY ANOMALIES

The Bouguer-gravity values (figure 2) range from about −155 milliGals to about −125 milliGals. The less negative values are associated with the surrounding mountain ranges. The more negative values indicate bedrock buried under thick accumulations of valley fill. For example, the thickest section of valley-fill deposits is near Rye Patch Reservoir (figure 2), immediately west of Humboldt House, where Bouguer-gravity values reach a minimum of −155 milliGals. In general, the lines of equal gravity in figure 2 indicate that the buried bedrock valley is a north-trending trough.

DEPTH TO BEDROCK

From the Bouguer-gravity map, estimates of depth to bedrock were made by synthesizing eight east-west profiles across the study area. These profiles were used to compute the regional gravity trends from which residual-gravity profiles were constructed. A more complete explanation of the procedure used to compute residuals is given by Schaefer (1982, page 10).

Residual-gravity values are used as input to a two-dimensional profile model that is based on a technique described by Cordell and Henderson (1968); depths calculated from the model are shown in figure 3. The depths are based on assumed densities of 2.17 g/cm^3 for the valley-fill deposits and 2.67 g/cm^3 for the underlying bedrock.

The lines of equal depth in figure 3 indicate that the valley is underlain by a north-trending bedrock trough having a maximum depth of almost 9,000 feet below land surface, near Humboldt House (figure 3). A somewhat smaller depression of almost 8,000-foot depth is near the Rye Patch Reservoir damsite.

Because some assumptions must be made to estimate density contrast for the computation of depths to bedrock, errors are possible in the interpretation of gravity data. Other possible errors exist in the altitude and positional data. The effect of these errors on a similar gravity survey is discussed in detail by Schaefer (1982, page 13). In an effort to minimize the errors in depth-to-bedrock determinations, a series of seismic-refraction depth soundings was made in the study area, as discussed below.

SEISMIC SURVEY

Seismic-refraction techniques were used in the study (1) to estimate depth to bedrock and (2) to attempt to determine depths to the water table in alluvial-fan deposits west of Humboldt River (figure 3). Depths to water in the study area could not be determined by using this technique, however, as explained below.

METHOD

Seismic-refraction techniques utilize an energy source to produce a compressional wave that is timed as it travels through subsurface materials. Compressional velocities are then calculated for these materials so that their lithologies and thicknesses can be computed. A more complete explanation of the technique is given by Dobrin (1976, pages 292-339).

Figure 3 shows the location of six seismic-refraction lines. At each of these locations, a string of 12 geophones was emplaced, and explosive charges were set off at progressively greater distances from the geophones. As the shot-point-to-geophone distance is increased, the depth of investigation also increases, but depends on the strength of the return signal and the amount of background noise. Arrival times of the first compressional waves are plotted against the distance between shot point and geophone; the reciprocal of the slope of the plotted line is the wave's velocity in the subsurface material. Two such time-distance plots are shown in figures 4 and 5. From these graphs, the depth to an interface between materials of contrasting seismic velocity (where the slope of the graphical plot changes) can be calculated. Seismic lines are run in both directions to detect sloping surfaces which appear as differing depths for the two directions. Successful application of seismic techniques depends on two prerequisites: (1) Subsurface materials must have increasing seismic velocities with increasing depth; and (2) the difference in the velocity between two adjacent materials must be great enough to be detectable with the equipment being used.

DEPTH TO BEDROCK AND WATER TABLE

Figure 3 shows the seismic-profile locations and depths to bedrock as calculated from a combination of gravity and seismic data. In general, most of the seismic- and gravity-derived depths compare fairly well. They are usually within ±1,000 feet—a difference that probably can be attributed to problems in defining a proper density contrast for the gravity survey.

Seismic line S3 (figure 3) was unsuccessful in locating bedrock. As the figure shows, depth to bedrock in this area is probably greater than 7,000 feet. To detect bedrock at this depth would have required a large amount of explosives, which could have caused unacceptable damage in the area of the seismic test.

The seismic survey was not successful in locating the water table. Apparently, the difference in seismic velocities between unsaturated and saturated valley-fill materials is not sufficient to be detected with the resolution attainable by the equipment used in this study.

TEMPERATURE SURVEY

Shallow-temperature data have been used previously as a geothermal exploration technique in the Basin and Range Province (Olmsted, 1977; Schaefer and others, 1983). Although the temperatures were measured at 3.3 feet (1 meter) in most of the previous work, a 6.6-foot (2-meter) depth was selected for this study in an attempt to minimize the effect of seasonal temperature fluctuations. The advantage of this shallow-temperature method for a reconnaissance survey is that many measurements can be made quickly in an area to determine areal patterns.

METHOD

Temperatures were obtained at a depth of 6.6 feet at 30 locations throughout the Humboldt House area. Initially, a hole 6.2 feet deep was drilled using a small powered auger. A 6.6-foot length of 3/4-inch-diameter plastic tubing was inserted in the hole, and native material was used to backfill the annulus. The holes were allowed to equilibrate for at least 9 months before temperature were measured. In December, at the time of measurement, a temperature probe was inserted into the casing and pushed into the underlying sedimentary deposits an additional 0.4 foot. The temperature was then measured and recorded to the nearest 0.1 °C (degree Celsius). The accuracy of the final temperature, however, is probably not better than ±0.3 °C. Temperature readings were made at regular time intervals over a period of about 20 minutes after insertion of the probe. The readings were then extrapolated to a temperature at infinite time by using a graphical method described by Parasnis (1971).

TEMPERATURE DISTRIBUTION AND ANOMALIES

The lines of equal temperature in figure 6 show a well-defined thermal high centered near Humboldt House, where measured values reach a maximum of almost 18 °C. Figure 6 also shows the three geothermal test wells drilled in the study area near this temperature anomaly as part of an ongoing geothermal exploration project.

SUMMARY

The Humboldt House area, in a north-trending valley between Lovelock and Imlay, is filled with alluvial and lacustrine sediments having a maximum thickness of almost 9,000 feet. The deepest part of the valley is centered under Rye Patch Reservoir, with a shallower depression to the south, near Rye Patch Dam. The depth estimates were based on about 200 gravity measurements in the area and checked with data from six seismic-refraction lines.

Temperature measurements made at a depth of 6.6 feet (2 meters) at 30 locations in the study area indicate a maximum of almost 18 °C, near Humboldt House. This thermal high is slightly north of three recently drilled geothermal test holes.

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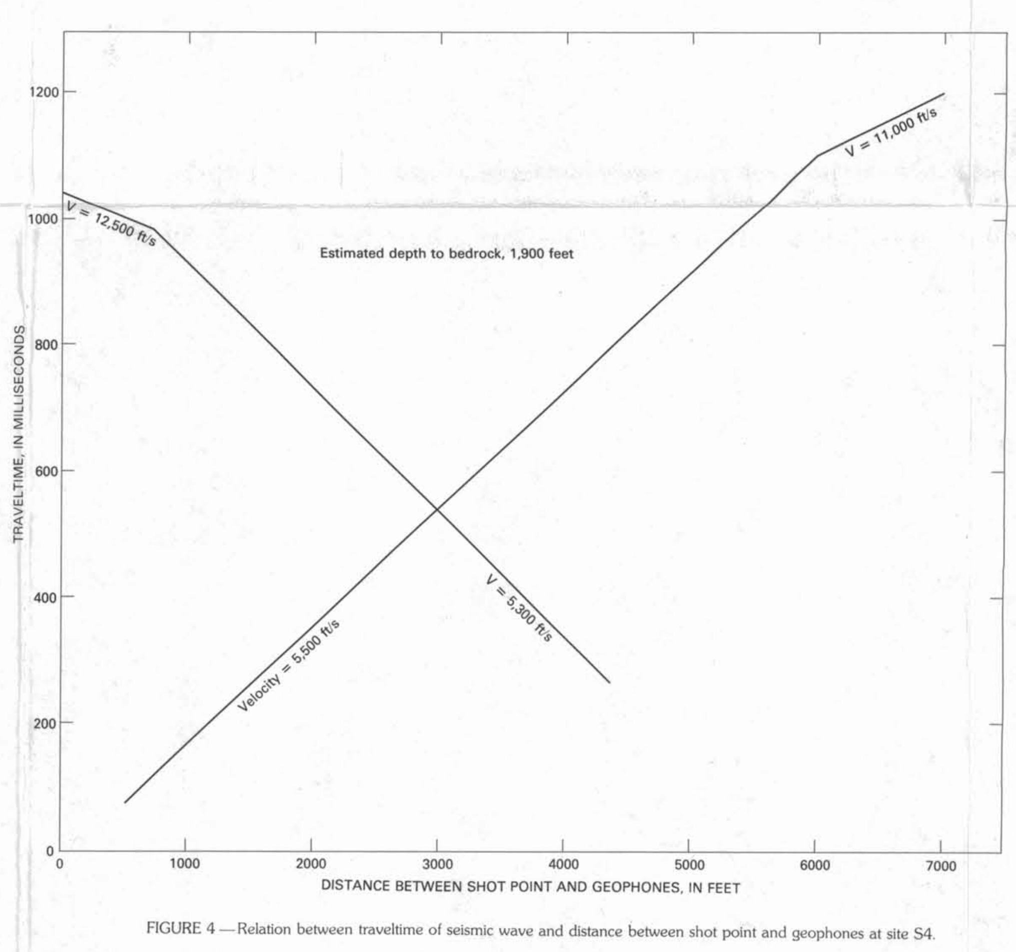

FIGURE 4 — Relation between traveltime of seismic wave and distance between shot point and geophones at site S4.

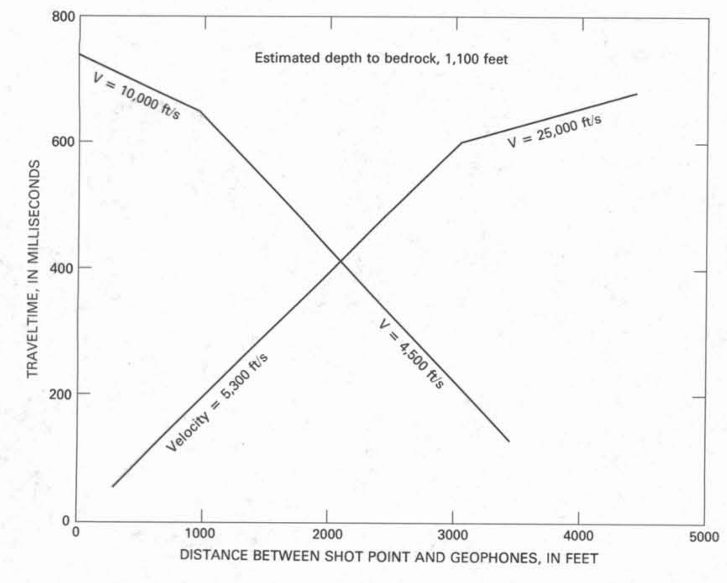

FIGURE 5 — Relation between traveltime of seismic wave and distance between shot point and geophones at site S5.

BOUGUER GRAVITY ANOMALIES, DEPTH TO BEDROCK, AND SHALLOW TEMPERATURE IN THE HUMBOLDT HOUSE GEOTHERMAL AREA, PERSHING COUNTY, NEVADA

By
Donald H. Schaefer

1986

Bases from U.S. Geological Survey, Lovelock, 1:250,000, 1955

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