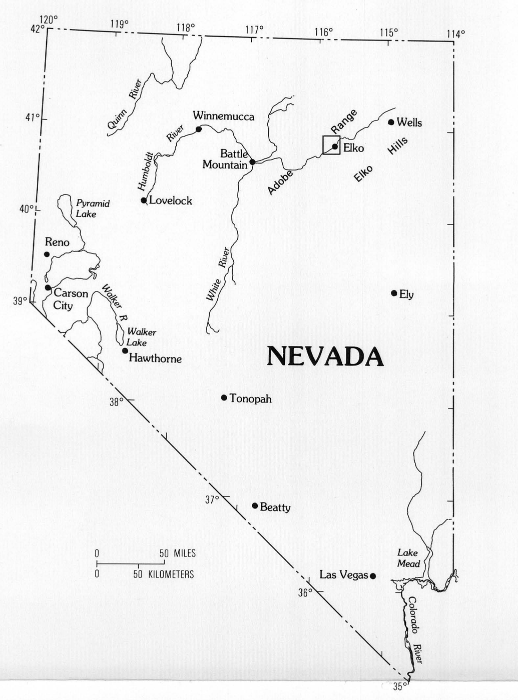

FIGURE 1.—Location of study area

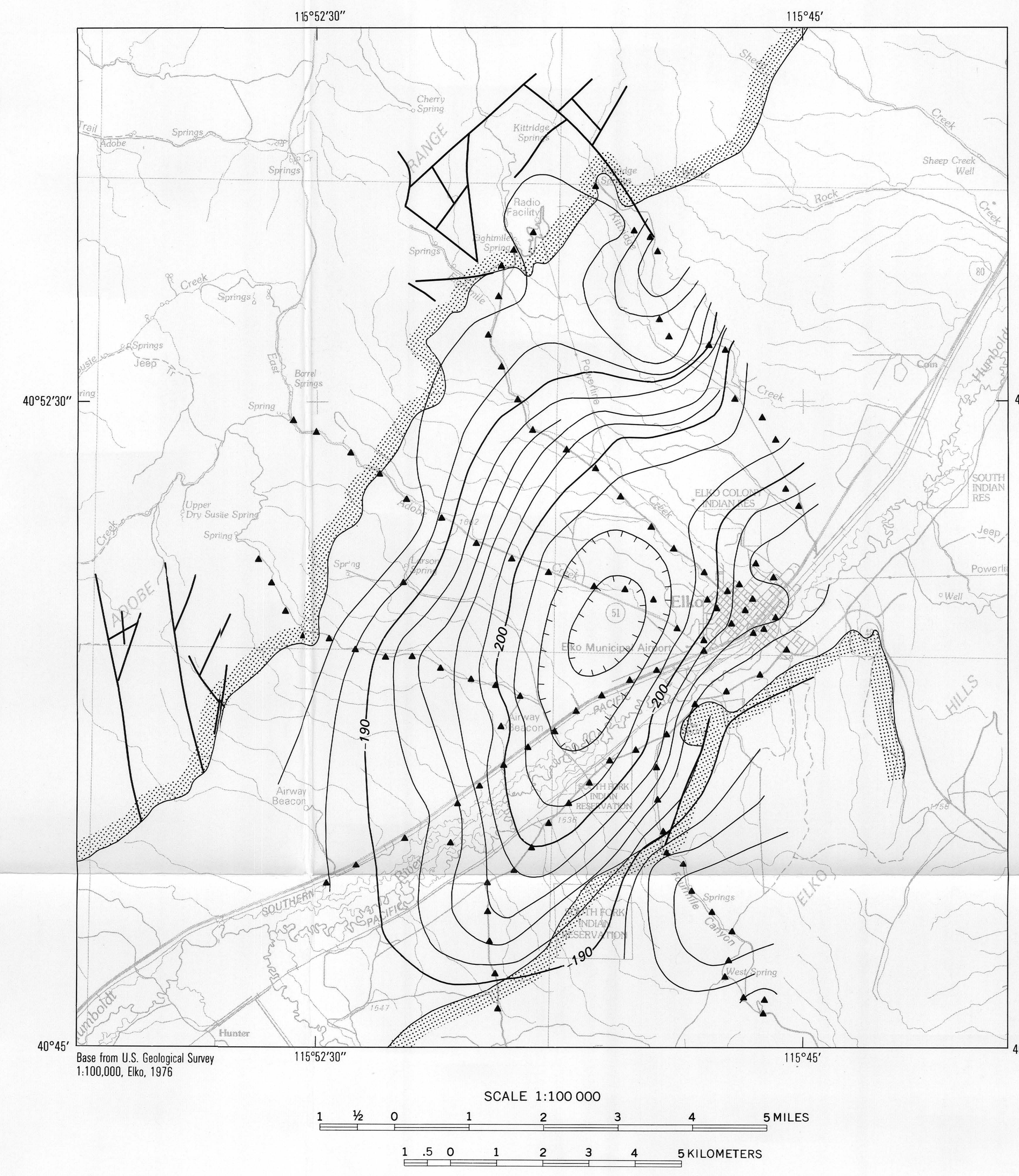

FIGURE 2.—Bouguer gravity values

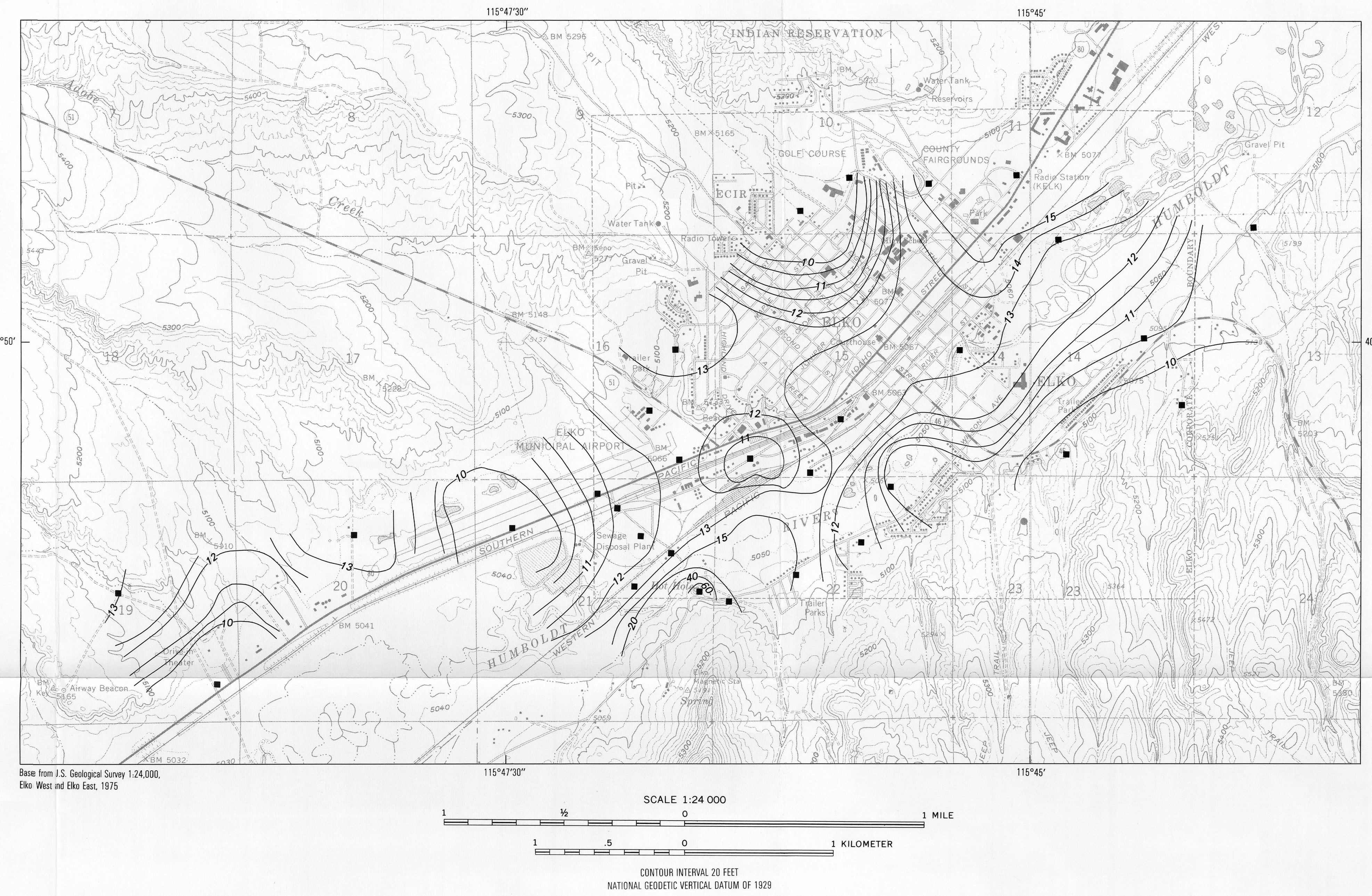

FIGURE 4.—Soil temperature at a depth of 6.6 feet

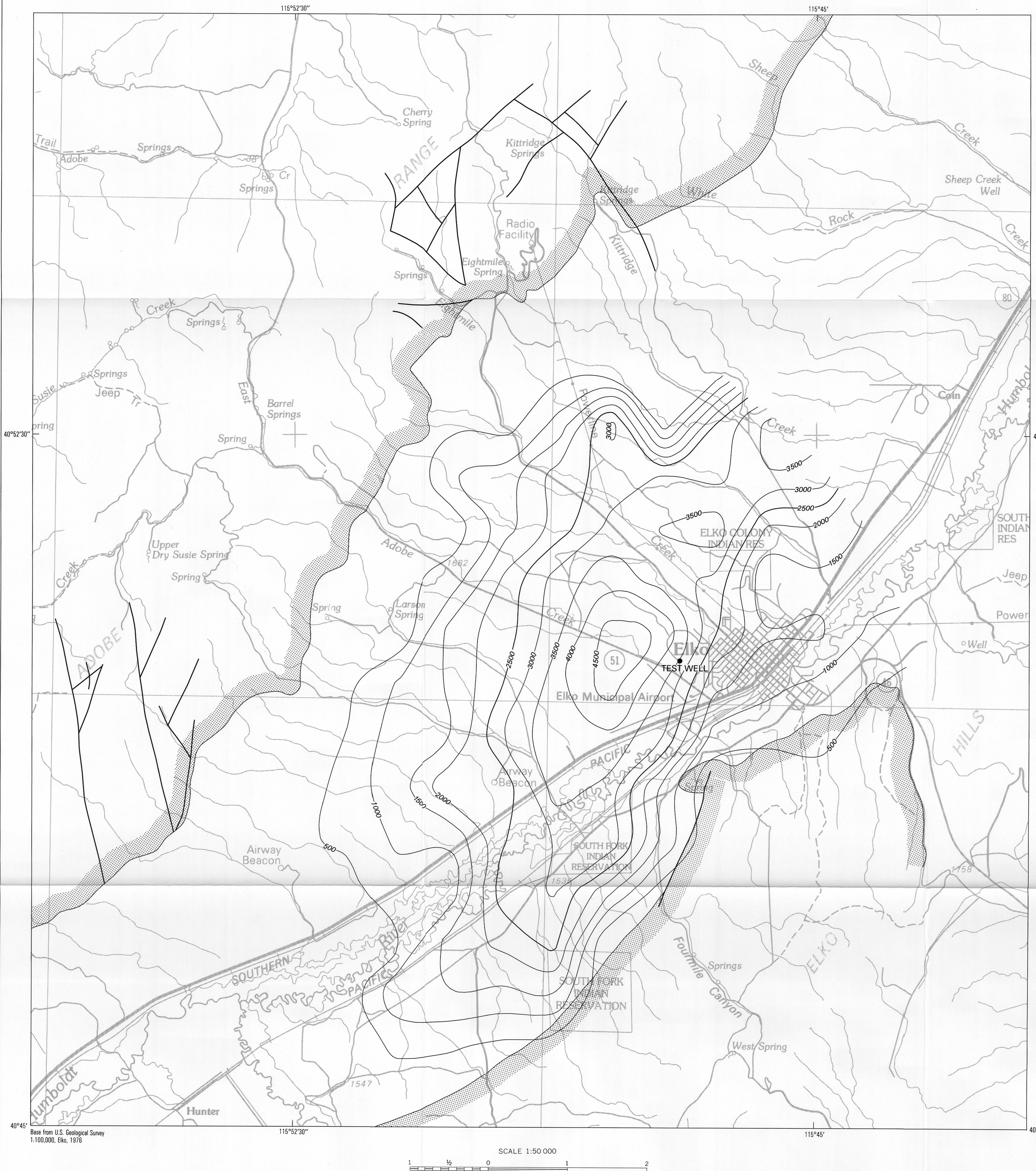

FIGURE 3.—Depth to consolidated rock

EXPLANATION FOR FIGURES 2, 3, AND 4

- **Consolidated rocks**
- **Valley-fill sedimentary rocks and deposits**
- ▲ **Gravity measurement station** (figure 2)
- ■ **Temperature measurement site** (figure 4)
- -200 **Line of equal Bouguer gravity** (figure 2)—Hachured lines indicate enclosed areas of more negative gravity. Interval 2 milliGals
- 500 **Line of equal depth to consolidated rock** (figure 3)—Interval 500 feet. Datum is land surface
- 10 **Line of equal temperature at 6.6-foot depth** (figure 4)—Interval in degrees Celsius, is variable
- **Fault**

CONVERSION FACTORS AND ABBREVIATIONS

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

Multiply	*By*	*To obtain*
Feet (ft)	0.3048	Meters (m)
Miles (mi)	1.609	Kilometers (km)
Square miles (mi^2)	2.590	Square kilometers (km^2)

For temperature, degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) by using the formula °F = [(1.8) (°C)] + 32.

ABSTRACT

The Elko area, in northeastern Nevada, lies in a northeast-trending structural valley that is filled with Quaternary deposits and Tertiary sedimentary rocks to a maximum depth of about 4,500 feet. The deepest part of the valley is centered west of Elko. The valley-fill deposits in the remainder of the valley have an average depth of about 2,500 feet.

The depth estimates were made from about 200 gravity measurements. Depths were calculated using a three-dimensional gravity inversion model and correlate fairly well with data from an oil test well drilled near Elko.

Soil-temperature measurements, made at a depth of 6.6 feet (2 meters) at 35 locations in the study area, indicate a major thermal anomaly (66 degrees Celsius) southwest of Elko, an area of known hot-spring activity.

INTRODUCTION

The Elko area, approximately 225 miles northeast of Reno, Nev. (figure 1), is a potential site for future geothermal development. The primary area of study covers about 160 mi^2 and lies in the Humboldt River valley. It is bordered on the northwest by the Adobe Range, on the south by an unnamed range of hills, and on the east by the Elko Hills (figure 2).

The area's potential geothermal resources are evident by the presence of hot springs about 1.3 miles southwest of Elko. Except for minor space heating applications, geothermal potential has not as yet (1986) been developed. As more information on the geologic and hydrologic framework of the area becomes available, more interest in using the geothermal resources of the area may develop.

The purpose of this study was to determine geophysical aspects of the area that may control or affect geothermal development. The three properties of significance are the depth to consolidated rocks, the areal patterns of faulting, and the temperature anomalies at a depth of 2 meters (6.6 feet) below land surface.

Depths to consolidated rock were estimated on the basis of a gravity survey of the area. Estimates of depths to consolidated rock were confirmed by drill-hole data.

The presence of faults, indicated by offsets in the consolidated rock surface at depth, can be evaluated by examining the Bouguer gravity anomalies in conjunction with the geologic map of the area (Hope and Coats, 1976). Some faults mapped at land surface in areas of consolidated rock outcrops show evidence of extending beneath adjacent alluvium areas, on the basis of a gravity survey.

Soil temperatures at a depth of 6.6 feet were determined at selected locations in the valley to define areas of higher-than-normal temperature. These areas may be indicative of a deeper thermal source and may be used to delineate possible areas of geothermal potential.

GEOLOGIC SETTING

The study area, shown in figure 2, has a complex geologic setting. To the northwest is the Adobe Range, which is composed of extensively faulted upper Paleozoic limestone, sandstone, and shale (Hope and Coats, 1976). The unnamed range of hills to the south is composed of similar rock types. The valley is filled with a sequence of Tertiary sedimentary rocks consisting of tuff, vitric ash, tuffaceous siltstone and sandstone, conglomerate, and limestone. Overlying these sedimentary rocks is Quaternary alluvial material consisting of coarse sand and gravel along with silt and clay.

For the purpose of this study, the upper Paleozoic section of the surrounding ranges is considered to constitute the consolidated rock (figure 2), and the same types of rocks are assumed to underlie the valley-fill deposits. The Tertiary sedimentary rocks and Quaternary alluvium are herein considered to constitute the valley fill.

GRAVITY SURVEY

The purpose of the gravity survey of the Elko area was to estimate the depth to consolidated rock and, therefore, the thickness of valley-fill deposits. A gravity survey can also be used to identify faulting in consolidated rock concealed by valley fill. A complete description of the theory and uses of gravimetric surveys can be found in most geophysics textbooks, such as that of Dobrin (1976, p. 357–403).

Method

Gravity measurements were made at 123 stations in the study area. Stations were selectively spaced throughout the area, but many were located on roads for ease of access. Eleven of the stations are not shown in figure 2, but are spaced farther out to determine regional patterns.

The altitude of the individual gravity station is the most critical parameter in the reduction of gravity data. Errors in altitude of 5 feet produce an error in final gravity values of 0.3 mGal (milliGals). Ideally, station altitudes should be surveyed; however, because of time limitations and the large areal extent of the study area, some altitudes were obtained from 7½-minute topographic maps. The topographic maps have a contour interval of 20 feet, which gives an accuracy of ±10 feet to altitudes—equivalent to about 0.6 mGal. Most stations, however, were located at bench marks, road intersections, and section corners shown on the topographic maps. These altitudes are assumed to be accurate to ±1 foot (about 0.06 mGal).

Horizontal control for the individual stations was provided by the Loran navigation system. A more complete description of Loran theory and operation is given by Laurila (1976, p. Basically, the Loran navigation system was used in the field to determine latitude and longitude at the gravity stations. Use of the Loran system and the application of corrections to the positional fix of gravity stations allowed an estimated accuracy of about 0.02 minute of latitude and longitude (approximately 120 feet on the ground). Positions need to be within 200 feet to achieve a gravity accuracy of 0.04 mGal.

Corrections

The purpose of corrections is to reduce all gravity measurements to a common altitude datum. The results of these corrections are the Bouguer gravity values, which reflect spatial variations in mass across the study area.

All gravity measurements were referenced to a local base station in the Elko area. At the beginning and end of each day of measurements, this base station was remeasured to determine instrument drift. The base has an adopted observed gravity of 979,745.37 mGal, and from this value the observed gravity values for all stations were computed. The local base was referenced to a network base at the Battle Mountain Airport (about 70 miles to the west). The IGSN 71 (International Gravity Standardization Network, 1971) value for this base is 979,754.79 mGal (Jablonski, 1974).

Gravity data were corrected for tidal variations, latitude, and altitude. Theoretical gravity, free air anomalies, and Bouguer gravity values were computed using the 1967 gravity formula (International Association of Geodesy, 1967), with an assumed consolidated rock density of 2.67 g/cm^3 (grams per cubic centimeter). A computer program developed by Plouff (1977) was used to make terrain corrections to the Bouguer gravity values from 1.4 to about 104 miles radially outward from each station. Corrections from the station radially outward to a distance of 1.4 miles were done manually using the technique described by Hayford and Bowie (1912).

Results

The term "contour" generally refers to a line of equal altitude above or below some datum such as sea level. For the purpose of this report, "contour" refers to a line of equal gravity, a line of equal depth to consolidated rock, or a line of equal temperature depending on the context.

The Bouguer gravity values (figure 2) range from about –206 to about –182 mGal. The less negative values are found near the surrounding mountain ranges. The larger negative values indicate consolidated rock buried under thick valley-fill deposits in the valley. For example, the thickest section of valley-fill deposits is west of Elko (figure 2) near the airport, where Bouguer gravity reaches –206 mGal.

In general, the contours indicate that the valley is a northeast-tending trough. Vertical faulting of consolidated rock is suggested by closely spaced contour lines on the gravity map. Some faulting may be indicated south of the airport (figure 2).

Depth to Consolidated Rock

From the Bouguer gravity map, an estimate of depth to consolidated rock was made by first removing a regional gravity component. All gravity measurements made on consolidated rock—approximately 30 stations on the periphery of the study area—were used to compute this component. These values were fitted to a first-order trend surface to approximate the regional gradient. This surface was then subtracted from the total Bouguer field to yield the residual field.

The residual gravity field, in the form of a matrix, was then used as input to a three-dimensional gravity-inversion model described by Cordell and Henderson (1968). The depths calculated from the model are shown in figure 3. The computed depths are based on assumed densities of 2.17 g/cm^3 for the valley fill and 2.67 g/cm^3 for the underlying consolidated rock. The value of 2.67 g/cm^3 is the standard value used for gravity calculations and a density of 2.17 g/cm^3 for the valley fill has been used frequently as a reasonable approximation when no other information is available (Schaefer, 1983, p. 11).

The depth contour lines in figure 3 show that the valley is a northeast-trending trough that has a maximum depth of about 4,500 feet, centered west of Elko. Closure of the contours at the edge of the trough is more a result of lack of data points at the edges of the study area rather than the surface of consolidated rock being bowl-like in these areas. The average thickness of valley-fill deposits in the Elko area is estimated to be about 2,500 feet.

Errors in the interpretation of the gravity data are possible because some assumptions about lithologic composition must be made to develop density contrasts for computation of depths to consolidated rock.

Other possible sources of error exist in the altitude and latitude and longitude values. The effect of these errors on a similar gravity survey is discussed in detail by Schaefer (1983, p. 14): in general, errors in residual-gravity values of 0.1 mGal could result in errors of estimated depth to consolidated rock of as much as about 50 feet.

Depths estimated from the gravity survey were verified using drillers logs from wells in the area. On the basis of the log from a 5,760-foot oil test well that penetrated the valley fill and consolidated rock in the vicinity of Elko (figure 3; Garside and others, 1977, p. 8), the contact between valley fill and consolidated rock was estimated to be at about 4,200 feet. This is the depth where particles of volcanic material were not present in the well cuttings as reported on the log. The gravity survey data indicated depth of about 3,500 feet at this location. The difference between the two estimates is about 17 percent. This can probably be attributed to a small error in the estimated density contrast.

TEMPERATURE SURVEY

Shallow soil-temperature data have previously been used as a geothermal exploration technique in the Basin and Range province (Olmsted, 1977). The advantage of this method for a reconnaissance-level survey is that many measurements can be made quickly in an area to determine temperature patterns.

Method

Temperatures were taken at a depth of 6.6 feet (2 meters) at 35 selected locations in the Elko area. Of these, 30 yielded what are considered reliable temperatures. As a first step, a hole 6.2 feet deep was drilled using a small, powered auger. A 6.6-foot length of small-diameter plastic casing was inserted in the hole, and native material was used to fill the annulus. The holes were allowed to "rest" for at least a month before temperatures were taken. A temperature probe was then inserted into the casing and pushed into the ground the final 0.4 foot. The temperature was measured and recorded to the nearest 0.1 °C. Temperature readings were made at regular intervals after insertion of the probe into the ground. The readings then were extrapolated to a temperature at infinite time using a graphical method described by Parasnis (1971). The accuracy of the final temperature values is probably within ±0.3 °C. A map of areal soil-temperature variation is shown in figure 4.

Results

The average soil temperature in the study area is about 12 °C (figure 4). The map also shows a pronounced high (66 °C) centered near the hot springs (labeled Hot Hole on figure 4) south of Elko. The high temperature does not appear to be related to any mapped faults in the area but may be related to a possible boundary fault on the southeast edge of the valley (figure 2). Furthermore, consolidated rock does not appear to be particularly shallow in the vicinity of the temperature high (about 1,000 feet, figure 3).

CONCLUSIONS

Based on gravity data, Elko and vicinity appear to overlie a structural basin. The estimated thickness of valley-fill deposits reaches a maximum of about 4,500 feet west of the town but averages about 2,500 feet throughout the valley. The configuration of the Bouguer anomaly field along the southeast edge of the valley indicates a bordering fault because of closely spaced contour lines in this area.

Temperature measurements at a depth of 6.6 feet indicate a major thermal anomaly southwest of Elko, an area of known hot spring activity. This area also coincides with the faulting inferred from the gravity survey.

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Geology modified from Hope and Coats (1976)

GRAVITY, DEPTH TO CONSOLIDATED ROCK, AND SOIL TEMPERATURE IN THE ELKO AREA, NORTHEASTERN NEVADA

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Donald H. Schaefer
1988

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