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GEONOMICS, INC.

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A DIPOLE-DIPOLE RESISTIVITY SURVEY OF THE ROOSEVELT HOT SPRING PROSPECT BEAVER COUNTY, UTAH

submitted to

GETTY OIL COMPANY

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by

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ABSTRACT

A dipole-dipole resistivity survey of 15 line miles was performed over the Roosevelt Hot Springs Prospect, Beaver County, Utah, for the Getty Oil Company by Geonomics, Inc.

Most of the prospect is underlain by high resistive strata corresponding to metamorphic or granitic rock. However, the prospect area is dissected by numerous faults, one of which may be a southern extension of the Dome Fault.

Three highly conductive (low resistivity) zones were located by the survey (Plate III), two of which appear very attractive in terms of geothermal potential. The third zone is not as attractive, but still merits further investigation.

Geonomics recommends that temperature gradient holes be drilled in all conductive zones found, in order to see if any warrant a deep exploration test hole.

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INTRODUCTION

This report describes the results of an electrical resistivity dipole-dipole survey of the Roosevelt Hot Springs Prospect, Beaver County, Utah (see Figure 1). Geonomics, Inc. performed the survey for the Getty Oil Company during the month of June, 1976. The report presents an overview of an area of geothermal interest, combined with an interpretation of the dipole-dipole survey, and presentation of available geological and geophysical data from the area.

The survey consisted of 15 miles of dipole-dipole lines, which were taken on five different sections in T27S, R9,10W (see Plate I). The lines were surveyed using 300 m (984 ft) dipole separations, with an effective probing depth to N = 10.

Description of the Dipole-Dipole Method

Dipole-dipole data provide a two-dimensional cross-section of the resistivity as a function of electrode separation and are presented as a series of pseudo-sections. The method of dipole-dipole presentation is to plot the resistivity value at the pseudo depth, representing the intersection of two 45° lines emanating from the center of the current dipole and the receiver dipole. As a result, the pseudo-section, although convenient, causes a distortion of geologic structure. Thus, a vertical fault is represented on the dipole-dipole pseudo-section as a slanted contact at an angle of 45°. Experience based upon computer modeling must be employed in the interpretation of dipole-dipole data. The five dipole-dipole section locations are shown on Plate I.

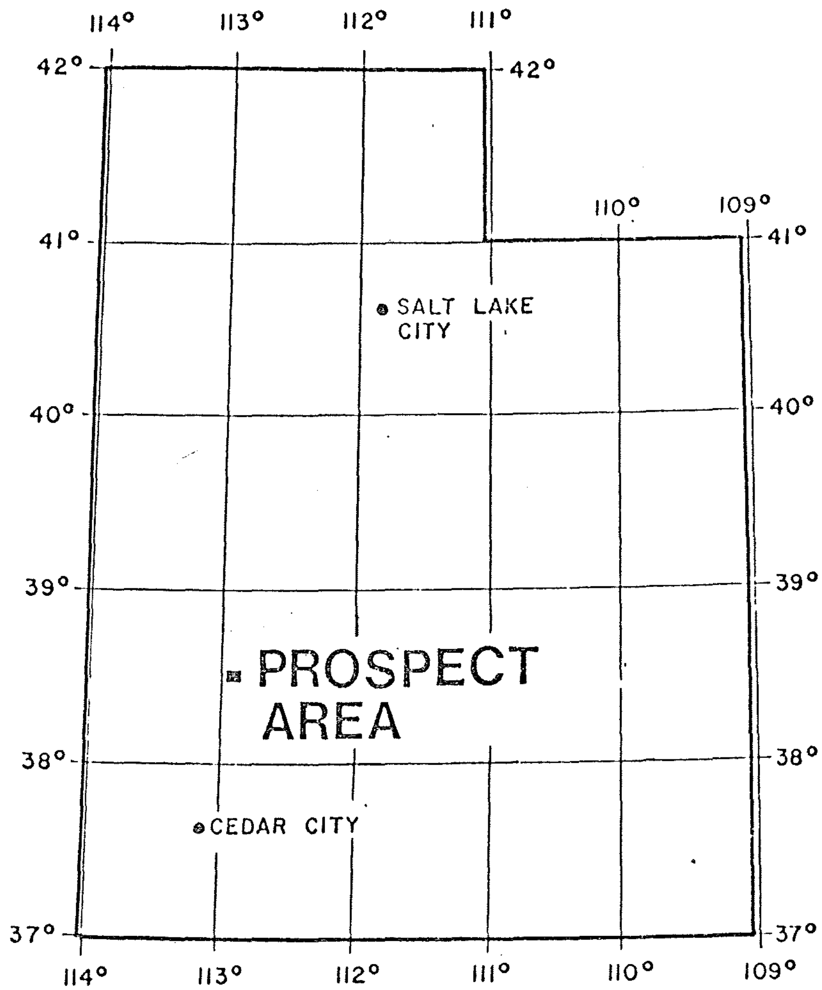

Figure 1. Location map of the Roosevelt Hot Spring Prospect.

GEOLOGICAL AND GEOPHYSICAL SETTING

The Roosevelt Hot Springs Prospect lies in the western foothills of the Mineral Range in Beaver County, Utah (see Figure 1). The town of Milford, Utah is located approximately five miles southwest of the prospect area.

The Roosevelt Hot Springs area is a part of the Basin and Range physiographic province which is characterized by broad sediment-filled valleys flanked by large, north-trending mountain ranges. This present configuration is due largely to Cenozoic block faulting which is primarily responsible for the north-south elongation of the ranges and valleys of Nevada. Thompson (1959) concludes that the faulting must be the result of an east-west extension, which may be on the order of 30 miles.

The most pronounced topographic and geologic feature of the Roosevelt Area is the Mineral Range (see Figure 2 and Plate II), which is an isolated, plutonic horst principally composed of white granite (Liese, 1957; and Earll, 1957). Radiometric age determinations have been made on the Mineral Range, indicating that parts of it are Miocene to early Pliocene (Park, 1968; and Armstrong, 1970). Silicic flows of late Pliocene age cap the Mineral Range, with two flows extending into the immediate area of Roosevelt Hot Springs (see Plate II). Liese (1957) and Earll (1957) have mapped a zone of Precambrian (?) metamorphic rocks at the base of the Mineral Range. Biotite gneiss makes up most of the exposed metamorphic rocks, but some schists and phyllites are also present. The age of Precambrian (?) was assigned to the rocks by Earll (1957) principally because of their metamorphic grade.

Alluvial fan deposits, consisting of granitic, volcanic, and some metamorphic fragments, cover most of the Roosevelt area. These alluvial deposits are probably Quaternary in age (Peterson, 1975).

Elsewhere within the Roosevelt area can be found intrusive granitic, lamprophyric, and aplitic dikes, as well as three large triangular V-embankments. The embankments are composed of gravel, pebbles, and cobbles derived from granitic and silicic volcanic rocks.

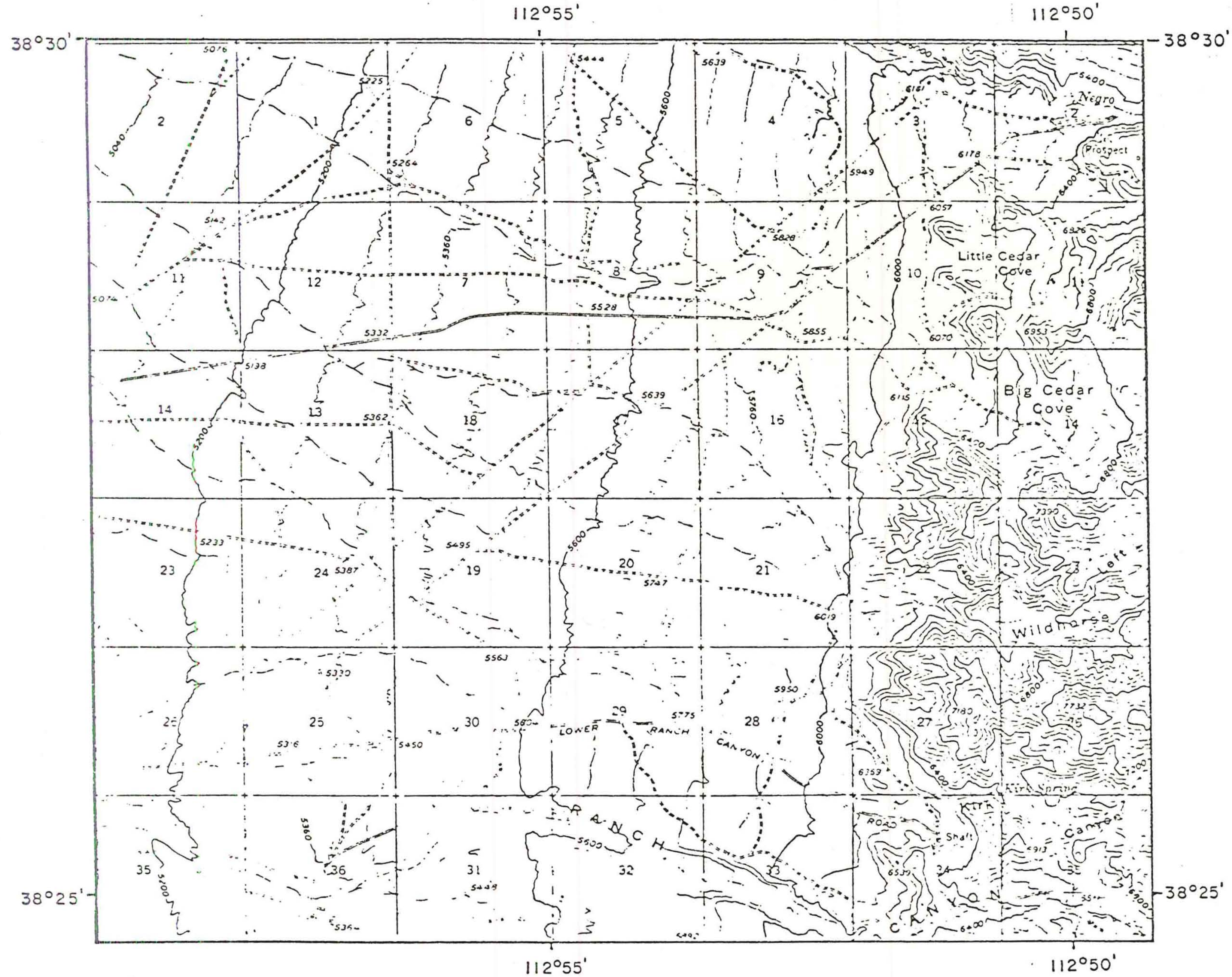

Figure 2. Topographic map of the Roosevelt Hot Spring prospect area.

Structural Setting

The Mineral Range is flanked on the east by Beaver Valley and on the west by the Escalante (or Milford) Valley. According to Cook and Mudgett (1966) the eastern side of the Escalante Valley graben contains a maximum of about 5,000 ft of valley fill.

The Roosevelt Hot Springs area is cut by numerous east-west and north-south trending faults, with the latter being the most predominant type of faulting (see Plate II). The Dome Fault, so named because its maximum offset is in some domed, siliceous hot spring deposits, is the most conspicuous fault in the Roosevelt area, extending in a north-northeasterly direction. The vertical displacement of the fault is at least 15 feet, with the west block moving up relative to the east block (Peterson, 1975).

Another north-trending fault (shown on Plate II in Secs. 11, 14 and 23, T27S, R9W) is inferred from the alignment of small valleys that cross (or nearly cross) the foothills of the Mineral Range. The direction of fault movement is unknown. A third north-trending fault is mapped in Sec. 13, T27S, R9W (see Plate II); the direction of movement is again unknown.

East-west trending faults have been mapped in Secs. 5 and 6, T27S, R8W; in the southern part of Sec. 15; and the northern part of Sec. 22, T27S, R9W. These last two faults are inferred from the outcrop patterns of the Precambrian metamorphic rocks.

Hot Springs

There is evidence that hot springs flowed during historic times at various locations within the Roosevelt Hot Springs area. Roosevelt Hot Springs proper is an abandoned resort that consisted of a hotel, several bathhouses, and a swimming pool. However, at some time about 1963, the hot springs stopped flowing. Peterson (1975) proposes two explanations for the decline in discharge:

1. the deposition of dissolved solids (especially silica) in the water gradually sealed the channelways through which the water reached the surface, or

2. the hot springs dried up because the water table within the Escalante Valley has lowered in recent time.

The second explanation assumes that the shallow groundwater system of the Escalante Valley was in close hydraulic connection with the subsurface channelways feeding Roosevelt Hot Springs. This assertion, however, has not been proven.

Hot Springs deposits are also found in Negro Mag Wash in Sec. 3, T27S, R9W (Plate II). There is evidence that these springs may have been active in modern times, since temperatures as high as 130°F have been measured very near the surface at these deposits.

Geochemistry

Lee (1908) first described and analyzed the waters of Roosevelt Hot Springs. Water tests were also performed in the area between 1950 and 1957, with the results displayed in Table I. It is believed, but by no means certain, that the waters analyzed by Lee, as well as the later tests compared in Table I, are from the same springs. Peterson (1975), however, notes the possibility that the springs which Lee analyzed may be located in Negro Mag Wash.

Silica and sodium-potassium-calcium geothermometry have been applied to the data in Table I by the technique described by Fournier and Rowe (1966) and Fournier and Truesdell (1973). The results of these analyses indicate that the subsurface temperatures may be as high as 298°C.

Drill Holes

A hole drilled to a depth of 273 feet in the NW 1/4 NE 1/4 of Sec. 16, T27S, R9W encountered steam under some pressure with a temperature of 270°F. Two other drill holes are located on the upthrown block of the Dome Fault. One hole, which is still open to a depth of 50 feet, has a measured temperature of 140°F. The other, which was drilled to a depth of 80 ft, was known to have boiling water associated with it at depth.

Temperature gradient wells have been drilled in the Roosevelt Area by Phillips Petroleum Company, Thermal Power Company, and others. Available temperature gradient data indicate that the gradients range from 2.5°F to 26.8°F per 100 ft. The location of these wells, as well as the measured thermal gradients, are shown on Plate II.

Phillips Petroleum Company drilled a well in Sec. 3, T27S, R9W, in July, 1974 (see Plate II). The well was drilled

TABLE I

Analyses of Water from Roosevelt Hot Springs
(concentrations in parts per million)

	Analysis A	Analysis B	Analysis C
Date of collection	1906	11-4-50	9-11-57
Temperature (°F)	190	185	131
Silica (SiO_2)	101	405	313
Calcium (Ca)	31	19	22
Magnesium (Mg)	9.7	3.3	0
Sodium (Na)	102	2,080	2,500
Potassium (K)	102	472	488
Bicarbonate (HCO_3)	30	158	156
Sulfate (SO_4)	90	65	73
Chloride (Cl)	87	3,810	4,240
Fluoride (F)	[1]	7.1	7.5
Nitrate (NO_3)	1.83	1.9	11
Boron (B)	[1]	[1]	38
Lithium (Li)	[1]	[1]	0.27
Iodide (I)	[1]	[1]	0.3
Residue on evaporation at 180°C	645	[1]	[1]
Calculated dissolved solids	[1]	7,040	7,800
pH	[1]	[1]	7.9
Location	sec.? T27S, R9W	sec.34 dcb, T26S, R9W	sec.34 dcb, T26S, R9W
Sampled and analyzed by	USGS	USGS	USGS
Source of data	Lee, 1908 p.50	Mundorff, 1970, p.16-17	Mundorff, 1970 p.16-17

[1]Not determined
dcb = SE 1/4 SE 1/4 NW 1/4

(from Peterson, 1975)

to a depth of 2,728 ft (762 meters), and encountered initial flows of steam in excess of 200,000 pounds per hole at a temperature of over 400°F.

Electrical Surveys

An extensive dipole-dipole survey was performed in the Roosevelt Hot Springs area by Ward and Sill (1976). They reported that the area immediately north of this prospect area is extensively cut by numerous north-south and east-west trending faults (see Interpretation Map, Plate III). In their conclusions they state that the heat source of the convective hydrothermal system of Roosevelt Hot Springs area may lie to the west of the area. They also conclude that the hydrothermal system must be leaking westward along some unmapped east-west fractures. They have concluded this by the use of thermal gradients (see above) and the extremely low resistivities that were encountered in the western foothills of the Mineral Range.

THE PRESENT SURVEY

Five dipole-dipole lines, totaling over 15 miles, were surveyed for the Roosevelt Prospect (see Plate I). The lines, labeled Line 1 through Line 5, used 300 meters (984 feet) dipole spacings, and were surveyed in a manner allowing the greatest delineation of subsurface structure. An intuitive interpretation for each of the five dipole-dipole lines (or pseudo-sections) is shown on figures in the following order: Line 1 on Figure 3; Line 2 on Figure 4; Line 3 on Figure 5; Line 4 on Figure 6; and Line 5 on Figure 7. The Interpretation Map (Plate III) is a combination of the results of this survey, with the findings of other geological and geophysical studies.

The Interpretation Map (Plate III) and the interpreted pseudo-sections can be summarized as follows:

1. The study area is dissected by numerous faults or discontinuities that appear to trend in a predominantly northerly direction. Two major faults, one of which appears to be a southern extension of the Dome Fault, are seen intersecting Line 1 (Figure 3) and Line 2 (Figure 4). Other major faults or discontinuities are shown on Line 5 (Figure 7); two of these coincide with faults mapped by Ward and Sill (1976).

2. Three highly conductive subsurface zones have been located within the study area (Areas I, II, and III, Plate III) Area I occurs at the intersection of Line 1 and Line 5. Area II occurs near the northeast end of Line 5, and Area III is located at the northern end of Line 4.

3. A near surface resistive block intersects approximately 500 m of Line 3 and appears to intersect a portion of Line 1. The resistive block has the electrical expression of a subsurface dike (see Plate II), but the true nature of the block will be unknown until further work is accomplished in the area.

DISCUSSION

The results of the dipole-dipole electrical survey are presented as apparent resistivity pseudo-sections in Figures 3 through 7. Significant resistivity contrasts are denoted as faults or discontinuities on the pseudo-sections, with the approximated surface extension of the faults or discontinuities also denoted.

Line 1 and Line 5 (Figures 3 and 7 respectively), the longest dipole-dipole lines, along with Line 2 (Figure 4) indicate that the apparent resistivity values decrease to the southwest, and that the lowest apparent resistivity values (<15 ohm-meters) lie beneath the intersection of the two lines (Area I, Plate III). The highly conductive strata of this area can be caused by a variety of factors, including salinity variation, temperature variation, clay content, and water saturated sediments. Because of the close proximity of Area I to the Escalante Valley, all these factors have a probable influence on the resistivity of the area, with clay and water-saturated sediments considered to have the greatest effect. The effect of temperature on the apparent resistivity values of this area cannot be determined from the pseudo-sections. The highly conductive zone of Area I lies to the west of a major fault or discontinuity. The effects of this fault or discontinuity are most clearly seen from Line 1 (Figure 3) and Line 2 (Figure 4); further, the Interpretation Map (Plate III) indicates that it could be a southern extension of the Dome Fault. In any case, this fault or discontinuity appears to divide the highly conductive rock of the west from the highly resistive rock to the east in this area. Undoubtedly, the highly resistive strata is that of the Mineral Range, and is either granitic or metamorphic in character.

Area II (Plate III) is a near-surface conductive zone. It is located near a well drilled in opal deposits in the NW 1/4 NE 1/4 of Sec. 16. This well hit steam at a depth of 275 feet (see section on Geological and Geophysical Setting), at a temperature of 270°F. It is possible, therefore, that the conductive zone of Area II is an electrical expression of geothermal resource, although it is nearly one mile from the steam well. The hot water of this area could be migrating westward along unmapped east-west fractures.

Area III is a conductive zone which is found deeper in the subsurface. Since the northern limit of this area was not defined, it is possible that this zone is a southern extension of Area II. If this is the case, the entire area surrounding Area II and Area III may be considered as a possible geothermal area warranting further evaluation.

CONCLUSIONS AND RECOMMENDATIONS

Three areas of highly conductive strata have been found within the Roosevelt Hot Springs Prospect (Areas I-III, Plate III). Areas II and III appear to be the most attractive targets for further geophysical work because of a well-defined electrical expression and close proximity to a steam-producing well (NW 1/4 NE 1/4 of Sec. 16, see Plate II). Shallow thermal gradient holes in the immediate area of these two anomalies will give a more clear, and inexpensive, interpretation of the geothermal potential of the area.

Area I appears to expand toward the Escalante Valley and is probably due to water-saturated valley fill. However, the Dome Fault appears, from previous drill hole surveys, to be a channelway for migrating geothermal fluids. With this in mind, one or two shallow thermal gradient holes drilled along the Dome Fault in this area (see Plate III) may prove extremely profitable. The client would have to assess the economic feasibility of such a survey.

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