GL00623

THE UNIVERSITY OF UTAH

Earth Sciences and Resources Institute

February 15, 1996

Mr. Peter G. Vikre
ASARCO Incorporated
Great Basin Division
510 East Plumb Lane
Reno, NV 89502

Dear Peter:

Transmitted herewith are five copies of our final report on the ASARCO CAR Geothermal Leases. I believe that the report provides a complete documentation of our work on the project, the results obtained, and our current evaluation of the resource. Also transmitted are four USGS geologic maps by Ekren and Byers, Maps I-1576, -1577, -1578, -1579; a ASARCO report on the CAR Claims Drilling Results by F.R. Koutz; and a key to the CAR-8 wellhead padlock. We thank you for providing these materials to us during our evaluation.

Dennis Nielson and Joseph Moore contributed to the report in their areas of interest. We feel there is good potential for a resource with temperatures exceeding 150 degrees C, but this has not been proven due to fluid circulation in the CAR-8 well. Joe Moore notes that the mineralogy of CAR-8 indicates these rocks have probably not seen temperatures above 180 degrees C, so the higher temperature reservoir (if present) is either deeper or displaced laterally. We recognize the economics for geothermal development in this area are not favorable at present, and support your decision to hold the leases without incurring major costs in the near future.

I appreciate your patience with our late delivery of this final report, and thank you for the opportunity to work with ASARCO on this project. If you should wish to interest the geothermal community in this prospect, we would like to participate with ASARCO in the presentation of one or more technical papers at a future Geothermal Resources Council meeting.

Please call Dennis, Joe or I with any questions you may have regarding this report, and let us know if we could be of additional service to ASARCO.

Best Regards,

Howard

Howard P. Ross
Research Professor/Senior Geophysicist

encl.
cc: P.M.Wright

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Earth Sciences & Resources Institute
University of Utah

GEOTHERMAL EXPLORATION

CAR GEOTHERMAL LEASES MINERAL COUNTY, NEVADA

Completed for

ASARCO, Incorporated
Great Basin Division
510 East Plumb Lane
Reno, Nevada 89502

Howard P. Ross, Dennis L. Nielson, and Joseph N. Moore

January 31, 1996

Earth Sciences and Resources Institute
University of Utah
1515 E. Mineral Square
Salt Lake City, Utah 84112

ESRI Technical Report No. 96-5-20580-1

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SUMMARY AND RECOMMENDATIONS

The University of Utah Research Institute (UURI; now ESRI/UU) completed a preliminary aeromagnetic interpretation, a self-potential survey, and designed and supervised an electrical resistivity survey of the CAR geothermal leases for ASARCO in March and April, 1994. A structural interpretation of the aeromagnetic data identified northwest-trending (Walker Lane) structures that project into a low-magnetization area, defined mainly by covered, northeast-trending structures. North- and east-trending structures also project into the CAR lease area, enhancing the probability of substantial fracture permeability. The self-potential (SP) survey defined a broad area of low potential which corresponds to much of the low magnetization area and the AEM resistivity low identified by ASARCO. Specific SP minima of 60 to 80 mV occur near the CAR-1,-2 and CAR-3,-7 drill holes, and these are thought to arise from the upflow of thermal fluids.

Consolidated Geophysical Surveys completed six dipole-dipole resistivity lines across the SP anomalies and the low-magnetization area in April. Numerical models of these data show a near-surface, tabular body of low resistivity (3 to 5 ohm-m) that probably represents an outflow plume of thermal fluids, and may include clay and sulfide minerals. Deeper low-resistivity (1 to 3 ohm-m) zones modeled as dipping or vertical-sided bodies may indicate upflow zones or deeper reservoir areas. The recommended site for CAR-8 tests an SP anomaly and the area above a 1 ohm-m body.

Temperature logs of CAR-8 record temperatures of 130°C at a depth of only 96 m (315 ft), then remain essentially isothermal for the remainder of the hole. The hole was completed to allow for a possible flow test, rather than as a temperature gradient hole, and convection in the casing has precluded obtaining a conductive temperature gradient. The mineralogy of CAR-8 ,as reported by ASARCO geologists, suggests that temperatures have probably never been higher than about 180°C at depths of 1500 feet. There is a possibility of higher temperatures, from 150-200°C , in a deeper reservoir which supplies the fluids in the thermal plume. Hydrogen sulfide gas was observed during the temperature logging on August 22.

The data collected to date are consistent with the presence of a moderate- to high-temperature (150-200°C) geothermal resource at depths less than 5000 feet, which could produce electric power. We recommend that ASARCO maintain its CAR geothermal leases, and extend the lease block to the south and southeast to include the lowest resistivity zones identified by the dipole-dipole survey (if this has not yet been done). Further drilling will be required to enhance the market value of the property. We recommend deepening CAR-8 perhaps 500 feet, and completing the hole as a temperature gradient hole. A second hole should be drilled at one of two sites recommended for CAR-9, again to 1500-2000 feet depth, for completion as a temperature gradient hole.

If additional work confirms a 150°C or higher temperature resource, it may be cost-effective to complete four more dipole-dipole resistivity lines, for better delineation of the possible deep reservoir and fluid upflow zones. At a cost of about $13,000, it may be prudent to complete these additional lines before new drilling. While it is desirable to obtain fluid samples for analysis, extensive lost circulation zones in CAR-8 have made the collection of clean fluid samples unlikely without an extended flow test. A better opportunity may occur in the next phase of drilling. Some useful temperature information may be gained from a new sampling and complete analysis of fluids from Rawhide Hot Springs (Wedell Spring No. 1, entry #313 of Garside, 1994).

INTRODUCTION

During the drilling of seven exploration holes for precious metals in 1991 and 1992 in Gabbs Valley, Mineral County, Nevada, ASARCO intersected thermal water at shallow depth over a significant area (Koutz, 1992). A geothermal lease, the CAR lease of four square miles, was subsequently acquired over the thermally anomalous area. ASARCO expressed an interest in enhancing the marketability of this lease through further exploration. The University of Utah Research Institute (UURI), with a long history of geothermal exploration and development activities, submitted a proposal for further geothermal exploration to ASARCO in November 1993 and this proposal was accepted with modifications in December, 1993. This report describes the exploration completed during 1994 and the results obtained. In January, 1995, UURI was merged into the Earth Sciences and Resources Institute, the University of Utah (ESRI/UU) which assumed responsibility for the completion of exploration and reporting activities.

GEOLOGICAL SETTING

The CAR leases are located on the southwest side of Gabbs Valley within the Walker Lane structural zone, a dextral strike-slip fault system (Figure 1). The geology of the area, presented at 1:48,000 (Ekren and Beyers, 1986), shows the lease area to be covered with Quaternary alluvium probably derived from the faulted Tertiary volcanics which crop out to the south and west. North and northeast-trending faults are mapped to the east, north, and northwest. The Rawhide epithermal gold-silver deposit, about 12 miles to the north, lies along a pronounced northwest-trending structural zone which delineates the northern boundary of the Walker Lane (Black et al., 1991). The Poinsettia Mine occurs in Tertiary volcanics five miles to the southeast. Hardyman and Oldow (1991) describe the Tectonic and Cenozoic history of the Walker Lane in some detail.

The CAR leases are located within an area of high-temperature geothermal potential which includes much of western and northern Nevada (Garside and Hess, 1994; Figure 2). Electric power is produced at ten geothermal areas within the state including Stillwater and Dixie Valley, north of the Car leases. Important resources with electric power potential have been identified at the Fallon Naval Air Station (45 miles northwest) and at Fish Lake Valley (70 miles southeast). A recent compilation of low-temperature resources (Garside, 1994) shows two "hot" wells (unnamed) near the CAR leases, and records a measured temperature of 62.2°C at Rawhide Hot Springs, about 10 miles northeast of the lease block. Extensive low- to moderate-temperature geothermal resources are documented in the Hawthorne and Gabbs areas (Trexler et al., 1983; Garside, 1994).

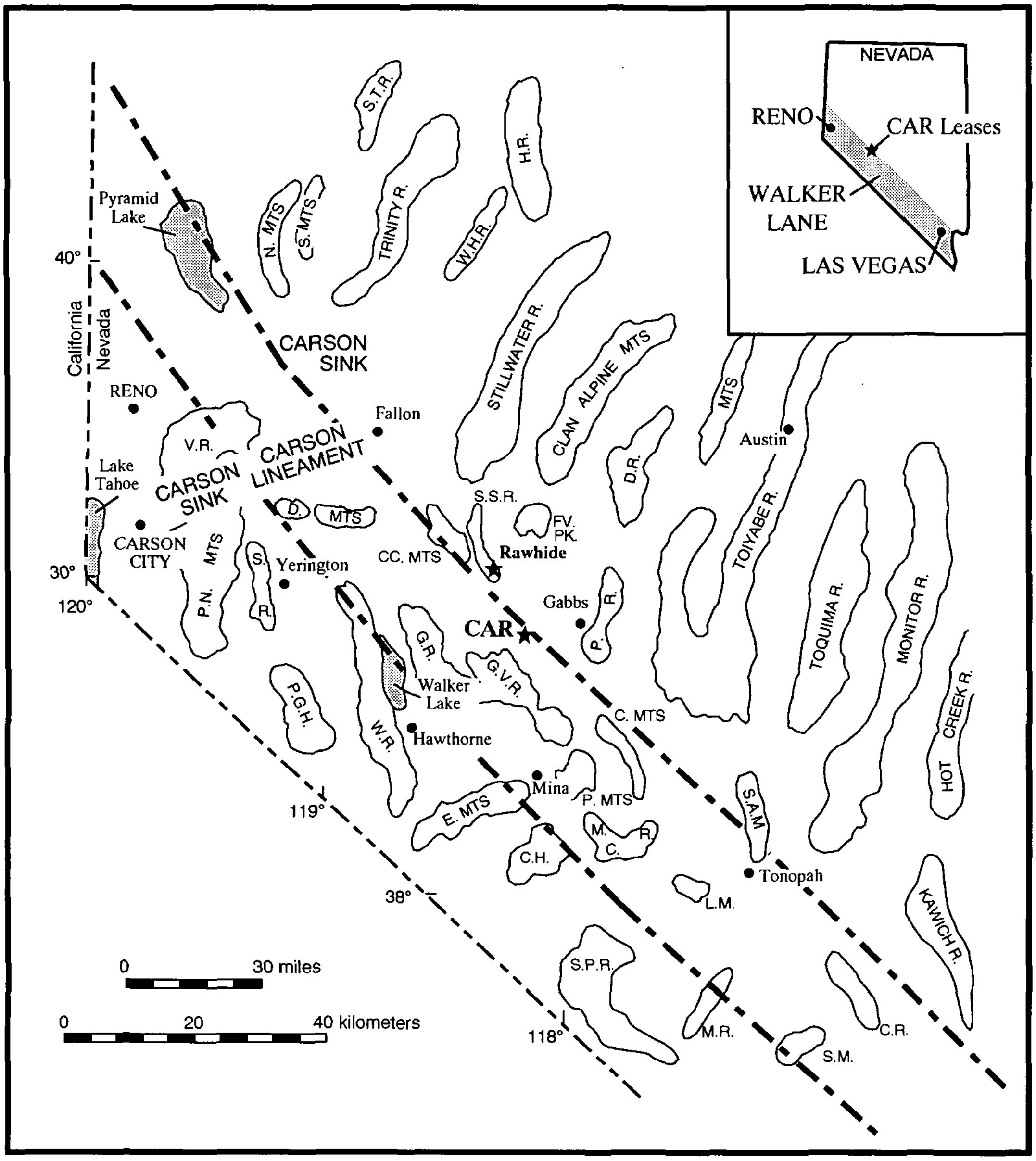


Figure 1. Location of the CAR geothermal leases within the Walker Lane structural zone (modified from Hardyman and Oldow, 1991).

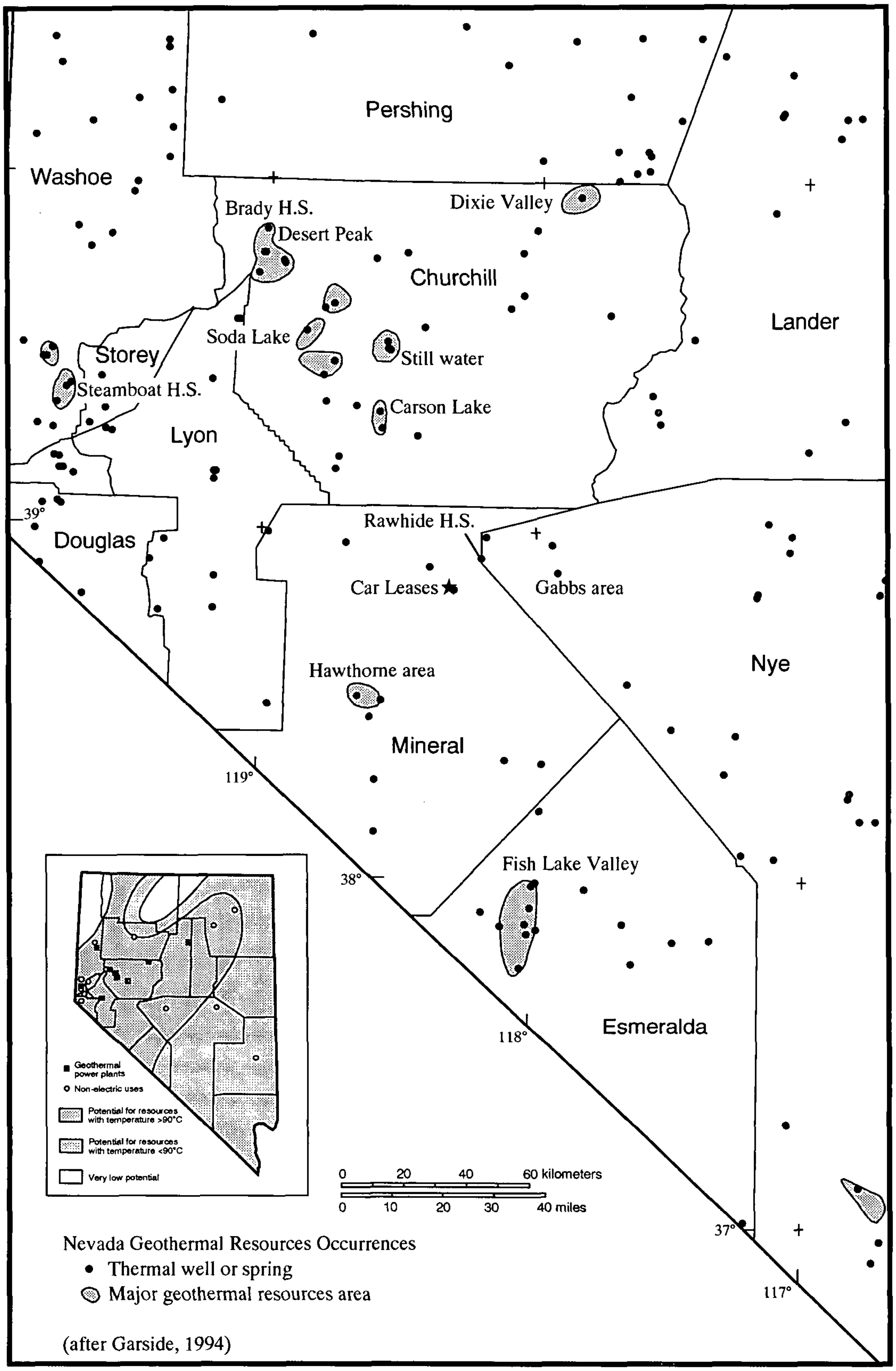


Figure 2. Nevada geothermal resources occurrences and resource potential (modified from Garside, 1994; Garside and Hess, 1994).

SUMMARY OF PREVIOUS WORK

Geology

An internal ASARCO report (Koutz, 1992) summarizes exploration and drilling results on the CAR leases. From October, 1990 to January, 1992, ASARCO completed seven drill holes to depths of 200 to 520 feet. Figure 3 shows the location of the CAR leases and drill holes CAR-1-7. Drilling shows that the area is covered by alluvial gravels that are 100 to more than 500 feet thick. These gravels are underlain by altered fanglomerate and andesitic flows that may be intercalated with a thicker section of alluvium. The water table was usually encountered at shallow depths (60 to 150 feet) near the contact between the gravels and the altered fanglomerate or andesite flows (Koutz, 1992). Figure 4 summarizes temperature observations and water table measurements made by ASARCO. Temperatures to 203°F (boiling) at these shallow depths indicated the presence of a potentially economic geothermal system.

Geophysics

The CAR prospect was originally found during follow-up to airborne electromagnetic (AEM) and magnetic surveys conducted as part of a precious metals exploration program (Koutz, 1992; C. Windels, personal communication). A closed resistivity low of several square miles was discovered which nearly coincided with a pronounced aeromagnetic low of about 100 gammas (Figure 3). Mineral claims were at first staked over the geophysical anomalies, but when drilling revealed thermal waters, a geothermal lease was acquired. The magnetic low is oriented NE-SW, and the drill holes that encountered the highest-temperature fluids are located along the trough of this low (Figure 3).

The resistivity low detected on the AEM survey is believed to be due in part to hydrothermal alteration minerals (clays) and in part to moderate-temperature conductive waters. These waters apparently form a laterally extensive, shallow, sub-horizontal lens in alluvium and volcaniclastic rocks which must be supplied by one or more upflow conduits bringing thermal waters from deeper zones.

EXPLORATION STRATEGY

UURI (now ESRI) proposed a two-phase program of further exploration to help determine the nature of the hydrothermal discovery. The recommendations included a limited amount of surface geophysics followed by intermediate-depth drill testing. The program which was proposed and completed is described below.

Phase 1. Geophysical Program

A semi-quantitative interpretation of the available aeromagnetic data was completed for an

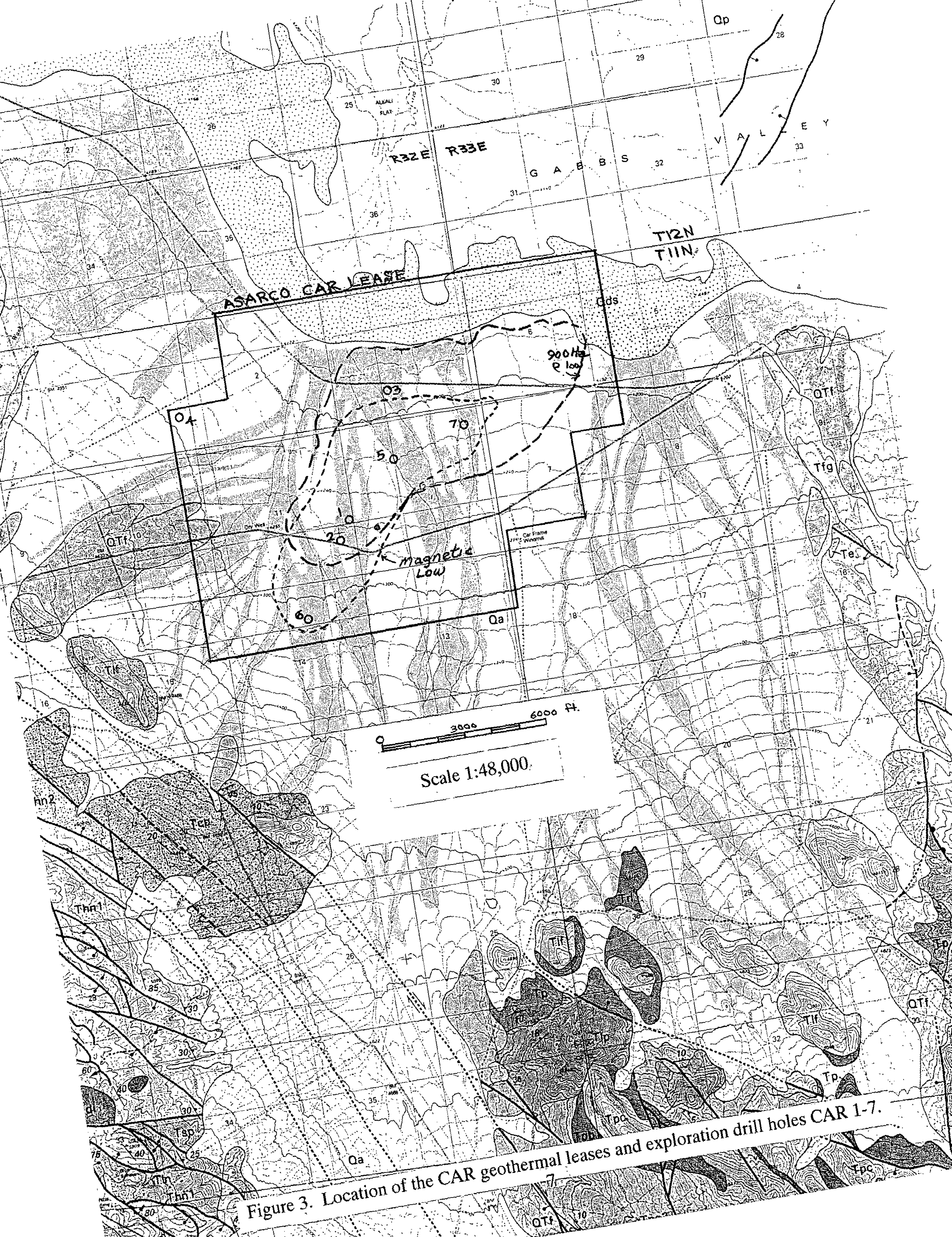


Figure 3. Location of the CAR geothermal leases and exploration drill holes CAR 1-7.

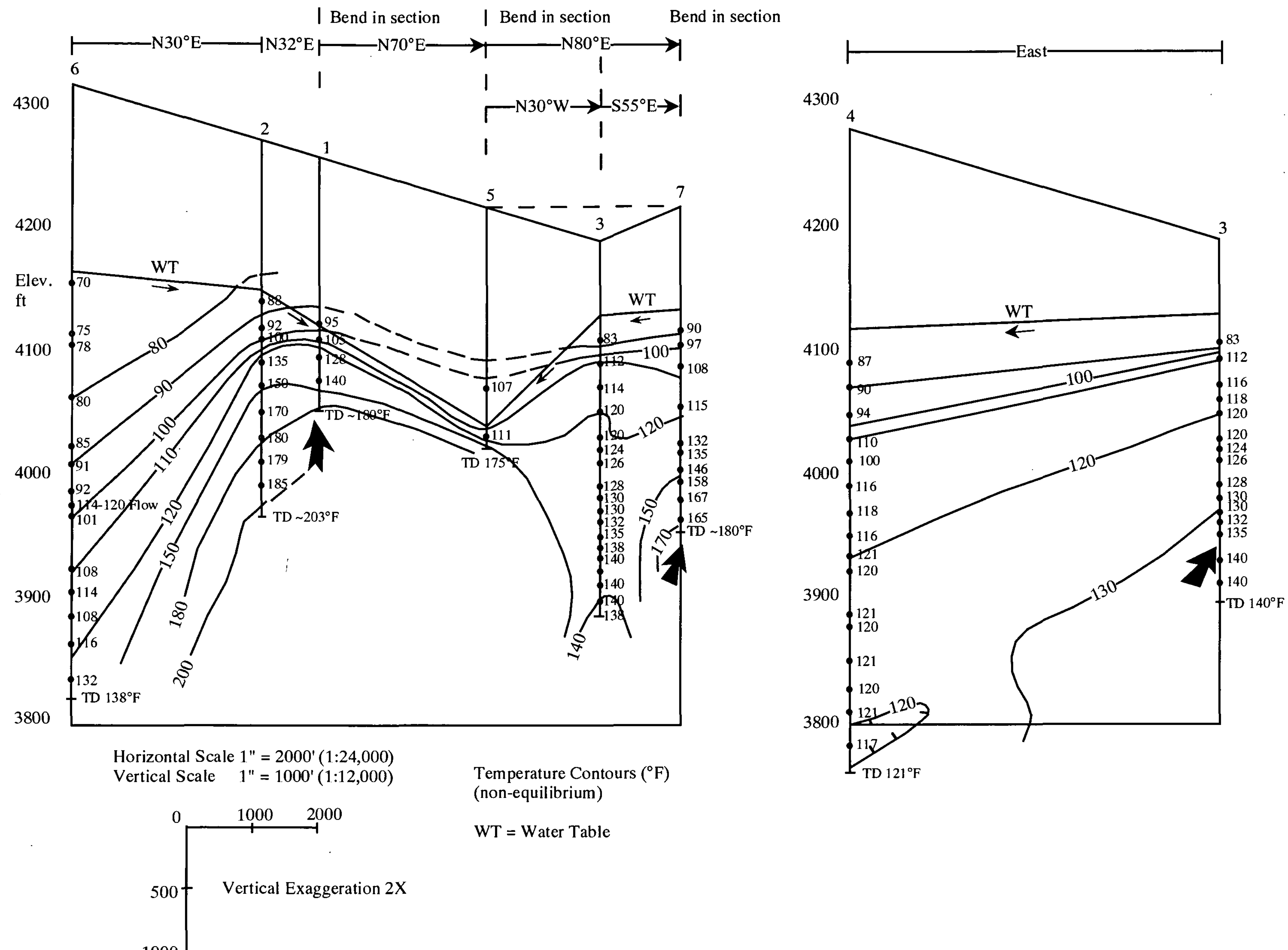


Figure 4. Summary of ASARCO temperature observations, CAR-1,-2,-3,-4,-5,-6,-7. Black arrows indicate proximity to local upflow zones.

area of about 100 square miles to define the geometry of the magnetic low source body, and to locate magnetic discontinuities which might bear on the geologic structure of the area.

A self-potential (SP) survey was then completed for an area of about five square miles, totaling about 67,000 line-ft of surveying with a 200 ft station spacing. The aim of the SP survey was to locate an upflow zone which provides fluids to the near-surface outflow plume detected by the AEM survey and verified by the drilling results.

A dipole-dipole electrical resistivity survey was designed, based on the aeromagnetic interpretation and the SP results, to provide an independent data set suitable for verification of the location and extent of the low-resistivity body detected on the airborne EM survey. UURI proposed a survey of six 7-spreads with electrode spacings of 500 ft and 1000 ft. Numerical modeling was completed for six profiles. The dipole-dipole survey, when numerically modeled, provided a more quantitative location of possible upflow zones and the outflow plume, and may locate an upflow zone(s) with sufficient accuracy to site intermediate-depth slim holes. The numerical modeling results might also give encouragement for the presence of any deeper geothermal reservoir lying within 1,000 to 2,000 feet of the surface. The electrical resistivity survey and numerical modeling could be completed most economically by a geophysical contractor working under the direction of an ESRI geophysicist. After completion of the resistivity work, the aeromagnetic, SP, resistivity and existing geologic data were reviewed and interpreted to determine recommended sites for two intermediate-depth temperature gradient holes.

Phase 2. Intermediate-Depth Drill Testing

The second phase of the program was directed toward confirmation of sufficient temperature of the hydrothermal fluids to determine the feasibility of electrical-power generation. This would require the drilling of one or more intermediate-depth (generally 1,000 to 1,500 foot) temperature-gradient holes. These holes would be smaller in diameter than normal geothermal production wells to minimize drilling and associated costs while allowing measurement of down-hole temperatures and possibly the collection of water samples for chemical geothermometry through production of a limited amount of fluid at the surface for sampling. Subsurface geology, accurate temperature measurements, and uncontaminated fluid samples are the most important items to be obtained from these holes. There was some chance that an appropriately drilled hole could later be turned into a production well, and this possibility would be examined during the drill-hole design task.

UURI geologists have considerable experience in moderate- and high-temperature geothermal drilling in various environments throughout the world. UURI agreed to advise ASARCO on drill hole design, hole completion, and assist in the selection of a drilling contractor. ASARCO choose to log the drill cuttings and core. After the hole(s) were completed and borehole temperatures stabilized, UURI completed a detailed temperature log with a portable, high-precision temperature logging system. UURI would also complete a log during the later stage of drilling, or immediately after, to gain added information on fluid entries before temperature stabilization.

UURI agreed to provide an evaluation of resource potential, and to advise ASARCO of relevant geologic, geothermal and economic considerations as requested. ASARCO obtained the necessary access, surface geophysics, and drilling permits, and contracted directly with the resistivity and drilling contractors.

GEOPHYSICAL SURVEYS

Aeromagnetic Interpretation

Total field aeromagnetic data were acquired over the CAR Lease area as part of the airborne electromagnetic (AEM) of the Paradise-Hawthorne (NV) area reconnaissance survey, completed for ASARCO by Dighem Surveys and Processing, Inc. in March, 1990. The data were made available as blueline prints of total magnetic intensity with flight lines and fiducials superimposed over a screened topographic base at a scale of 1:24,000. The data were plotted as full-value total field (no IGRF or base level removal), with four different contour intervals for an area of high-amplitude and high-frequency magnetic variation. These characteristics made the data difficult to compare with geologic and other data and UURI proposed a preliminary (semi-quantitative) interpretation to obtain more structural information from the aeromagnetic survey.

Magnetic data were obtained on draped flight lines approximately 150 feet above the mean terrain surface. Flight lines were spaced approximately 1000 feet apart and were oriented about N45°E, normal to the dominant Walker Lane structural trend, and very high-frequency variations were noted in this direction. Magnetic field parameters for the area are: inclination 64 degrees, declination 16 degrees E of North. UURI completed a preliminary interpretation which estimated the position of magnetization discontinuities (faults, intrusive body borders, etc.) using a precomputed catalog of magnetic bodies with north-south, east-west, northeast, and northwest orientations. This catalog had been computed for a field inclination of 63 degrees and a declination of 14 degrees east, very similar to the magnetic field of the Paradise area. This interpretation was completed at the scale of the original data (1:24,000) for an area of about 15 miles (east-west) by 13 miles (north-south) centered on the CAR lease area. This structural interpretation is presented as Plate 1 at a scale of 1:48,000, the scale of geologic maps by Ekren and Beyers (1986a; 1986b), and at 1:24,000 in Figure 5.

Overlaying the structural interpretation (Plate 1) on the geology shows substantial agreement with the numerous northwest-trending Walker Lane structures. Some interpreted structures directly overlie mapped faults, and accurately extend these fault locations beneath alluvial cover. Many other interpreted structures disagree slightly or correspond to magnetization contrasts between volcanic units. Some locations probably disagree because of a low dip to the volcanic units. The interpreted structures along the east margin of the Poinsettia Springs quadrangle include north- and northeast-trending faults, several of which agree with mapped features. A northeast-trending structure extends from the CAR lease area toward the Rawhide hot spring area. The structural interpretation contributes considerable insight into the covered areas of the western Ramsey Spring and Mount

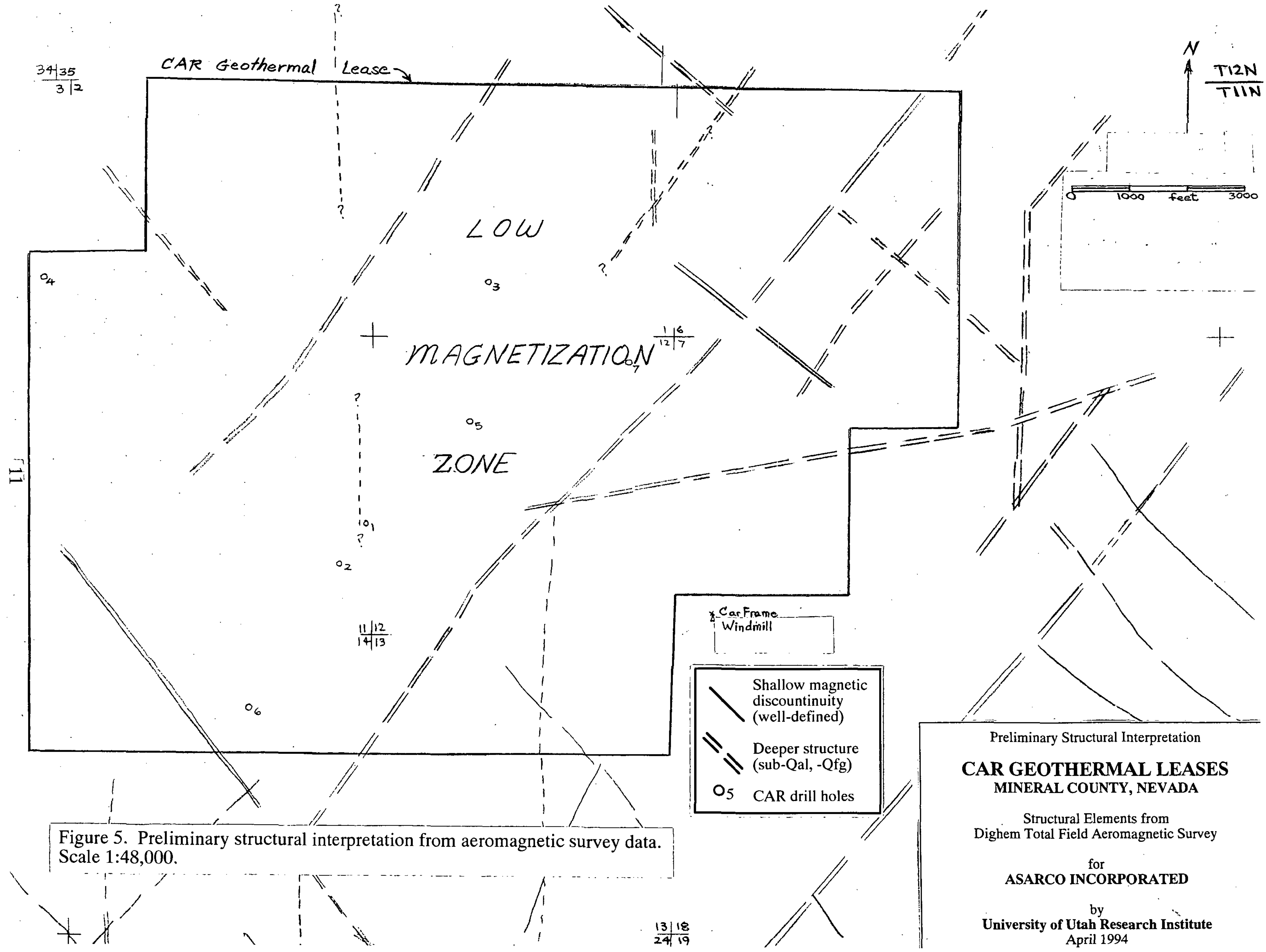


Figure 5. Preliminary structural interpretation from aeromagnetic survey data. Scale 1:48,000.

Preliminary Structural Interpretation

CAR GEOTHERMAL LEASES
MINERAL COUNTY, NEVADA

Structural Elements from
Dighem Total Field Aeromagnetic Survey

for
ASARCO INCORPORATED

by
University of Utah Research Institute
April 1994

Annie quadrangles, including the interpretation of northeast-, northwest- and east-west structures intersecting in the vicinity of Rawhide Hot Springs. We invite the reader's own correlation of interpreted structures and mapped geology.

Northeast-, northwest- and north-trending structures are interpreted within and projected into the CAR lease area (Plate 1, Figure 5). Some interpretations are based on weak magnetization contrasts, as much of the CAR area is a strong magnetic low. The interpretation places relatively accurate borders on the low magnetization area. The low-magnetization area may arise from down-faulted bedrock and increased alluvial fill and slopewash, alteration of these materials and underlying bedrock, or (most likely) both. Koutz (1992) does record considerable alteration and pyrite mineralization in CAR-1 to 7, much of which probably predates the present hydrothermal system. The principal value of the magnetic interpretation is to provide some added insight into structures in this area and to better define the area to be included in SP and resistivity surveys.

Self-Potential (SP) Studies

The application of the SP method in geothermal exploration has been described in detail by Corwin and Hoover (1979). SP anomalies are generated by electrokinetic (moving fluids and ions) and thermoelectric phenomena. The polarity and magnitude of the anomalies are determined by the source phenomena, depth to the source area, the electrical resistivity of the fluids, reservoir, and overburden, and cross-coupling coefficients.

Self-potential surveys have been very successful in locating geothermal fluid upflow zones, especially when these fluid rise within 1000 ft of the ground surface (Ross et al., 1990; 1991). Ross et al. (1995) describe SP surveys in the Basin and Range and southern Rio Grande Rift where significant SP anomalies could be associated with probable upflow zones in 8 out of 10 geothermal areas studied. The surveys are often used in a cost-effective manner to define specific areas of interest that will later be surveyed with more costly and more environmentally sensitive geophysical methods, such as electrical resistivity, prior to drill testing.

Self-Potential (SP) Survey

The Bureau of Land Management, Carson City District Office, approved on February 10, 1994, Notice of Intent N3-03-94 authorizing ASARCO Inc. or their agent to conduct geophysical work on the public lands (CAR geothermal leases) near Gabbs Valley. Short daylight hours and below-freezing morning temperatures dictated delaying field surveys until late March or early April. The SP survey was completed from March 28 to April 1. The substantial driving time from Fallon to the field (about 80 minutes - 65 miles) dictated 12 hour field days for efficient completion of the survey.

A primary base station (B.S.#1) was established approximately 800 ft north of the CAR-2 site and a secondary base station (B.S.#2) was located about 7200 ft N65°E from B.S.#1 (Figure 6). Twelve lines were completed in a radial (spoke-like) fashion from the two base stations, totaling

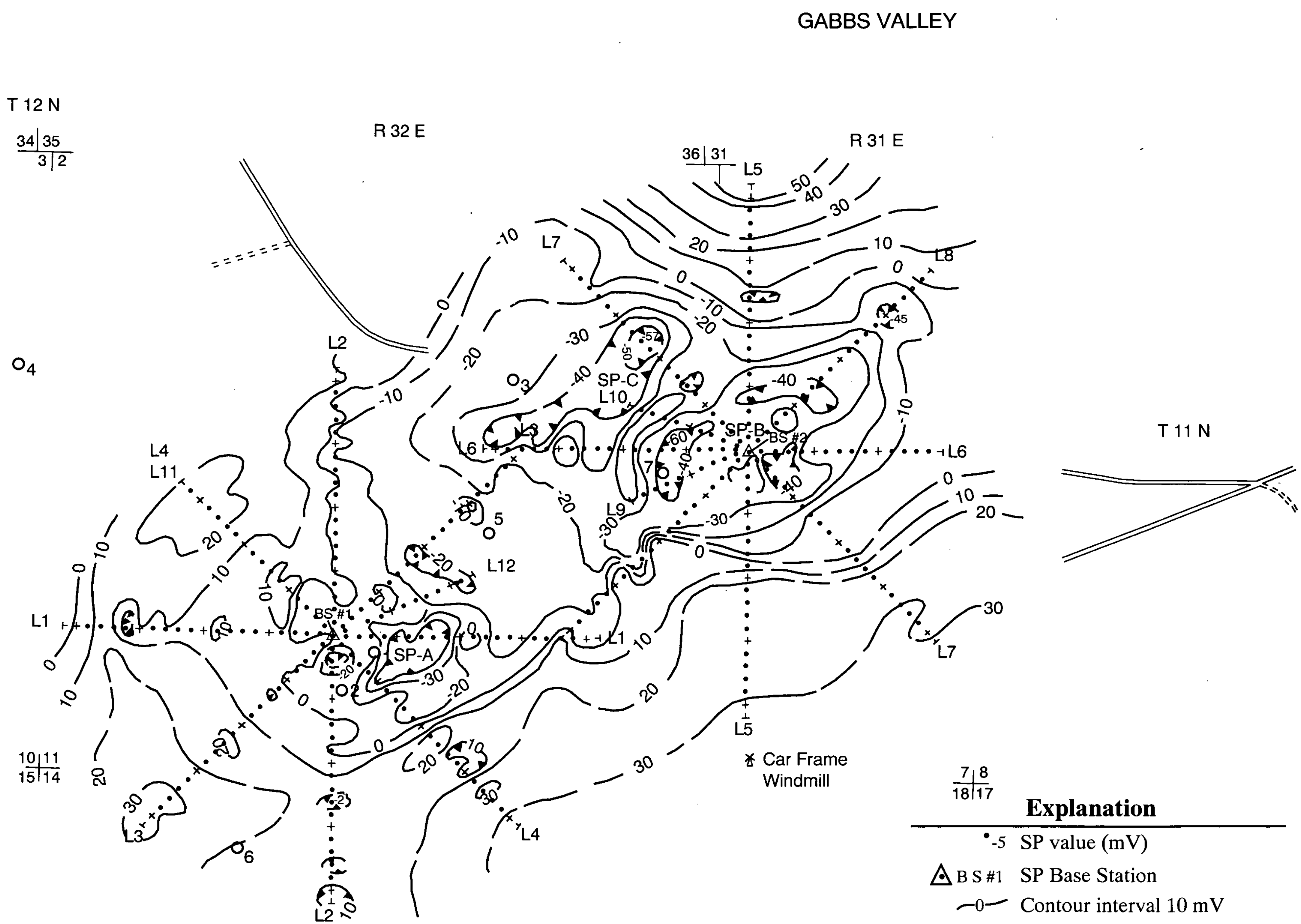


Figure 6. Self-potential survey and contour map, CAR geothermal leases. SP values at specific stations shown in Appendix 1.

approximately 71,000 line-ft (21.64 line-km) of SP traverse. The area covered, approximately 4.0 square miles, includes 356 stations for an average density of about 89 stations per square mile. This provides satisfactory coverage of the low magnetic susceptibility body, its bounding structures, and the overlapping AEM low resistivity area. Base stations were located by Brunton compass and tape from known positions on dirt roads.

Self-potential measurements were completed using the radial or "spoke" technique for efficiency of field operation so that many potential measurements, generally at 200 ft spacings along the line, could be made directly with respect to a central electrode. The surveys were completed using a high-impedance digital voltmeter and copper-copper sulfate porous-pot electrodes. In the typical survey mode, an electrode pair with small potential difference was selected at the base station. A bearing was followed to the end of each line and station locations were measured with a 200 ft tape. Electrode positions were dug and wet with a small amount (about 6-12 oz) of tap water while moving outward from the base station. At the end of the profile it was necessary to wait at least 15 minutes, then monitor infiltration potentials until the electrode hole appeared to be in equilibrium (no potential drift, though telluric effects could be present). Potentials were read to 0.1 mV with the intent of maintaining a 1 mV accuracy at each station. Electrode drift was determined upon the return to the base station and a drift correction, mainly due to pot temperature differences, was determined. Prewatering of electrode holes was required because of the extremely dry (high impedance) surface conditions. Base station #1 was assigned a value of background or 0 mV and tied to B.S.#2 by two common stations on each of two survey lines. On March 29 and 30, B.S.#2 was -22 mV with respect to B.S.#1, but this changed to -30 mV for March 31, and April 1. This difference is considered small compared to the SP variations observed.

The completed SP map, corrected for drift and base station ties, is shown as Figure 6. SP values for individual stations are shown in Appendix 1. There is little topographic relief in the survey area and no recent precipitation was recorded which may have induced downslope potential or infiltration differences. Most of the surveyed area maps as a negative potential when referenced to B.S.#1. True background or 0 potential may better correspond to the +20 to +30 mV values observed along the south, west, north , and east margins of the survey, although some of the marginal highs could be due to long-term infiltration potentials. The +30 to +56 potentials recorded at the north end of Line 5N correspond to blown sand and sand dunes, which typically show high positive values when very dry. The positive values above +30 mV to the southeast and west may correspond to generally higher subsurface resistivities. Three significant, coherent SP minima have been mapped.

Anomaly A, with a minimum of -48 mV, occurs 200 to 1200 feet east of drill hole CAR-1 where high temperatures were observed at shallow depth. If true background corresponds to the +20 mV contour, the amplitude of the minimum is about -68 mV.

Anomaly B, a broad, northeast-trending minima, includes many values of -40 to -60 mV and is probably lower by 10 to 20 mV with respect to true background, (i.e. to -80 mV). This anomaly is centered on B.S.#2 and includes CAR-7.

Anomaly C is a secondary minima of Anomaly B with values of -40 to -57, which lies between CAR -3,-5, and-7. This is a broad minima with a northeast trend.

Sharp gradients associated with all three anomalies suggest a shallow source to the SP anomalies. These gradients are only one- to three-station spacings (200-600 ft) in length, and roughly correspond to depths to the water table. A careful, low-frequency filtering of the data might suggest deeper source depths, but this is unlikely and has not been attempted. The electrical resistivity data would provide a specific drilling target.

Well-defined SP anomalies which occur in a mineralized geothermal environment such as the CAR lease could arise from two sources: 1) sulfide mineralization with substantial continuity (vein-type, or massive) which extends beneath the water table; and 2) an upflow zone of subsurface fluids, either hot or cool. Sulfide mineralization in the CAR drill holes is reported by Koutz (1992) but probably not in the massive, continuous deposits necessary to produce the main SP anomalies. The higher temperatures recorded for drill holes CAR-1, -2, and -7, in proximity to SP anomalies A, B, and C, strongly suggest that these anomalies arise from proximity to a thermal fluid upflow zone. Ross et al. (1995) document several SP anomalies in Nevada, Utah and New Mexico which occur in close proximity to thermal fluid upflow zones. UURI recommended that at least four dipole-dipole resistivity lines traverse the main SP minima to obtain additional information regarding structure and the presence of possible upflow zones.

Electrical Resistivity Survey

In the electrical resistivity method, electrical current is introduced into the earth at a series of electrode positions and voltages are measured at the surface about these electrodes with specialized measuring electrodes. The current is introduced as a square wave of varying polarity (time-domain) or as a low frequency sine wave (frequency domain) which permits discrimination from most natural or man-caused current signals. The electrodes may be positioned in any of several established geometric layouts (arrays) depending on the survey aims and circumstances. The dipole-dipole array has been favored for detailed mining, geothermal and environmental studies (Wright et al., 1985) and was selected for this resistivity survey. In the dipole-dipole array, seven current electrodes are placed in a straight line (in line) and at a uniform interval (a), to permit current switching between six transmitting dipoles. Voltages are measured at the surface in line and on either side of the transmitting electrodes; the greater the distance between transmitting and receiving electrodes, the greater the effect of resistivity distributions at depth.

Many geothermal systems are characterized by low electrical resistivity, because of the presence of conductive geothermal fluids (high-temperature and moderate- to high-salinity) and conductive minerals (clays and zeolites) resulting from hydrothermal alteration. In a study believed to be similar to the CAR exploration problem, Ross et al. (1990) were able to define an upflow zone and outflow plume of a similar geothermal system (Newcastle, Utah) using a combination of electrical resistivity and self-potential surveys.

The resistivity survey had several objectives:

1. To verify the location and extent of the resistivity anomaly detected on the AEM survey;
2. To determine the nature and location of the boundaries and internal geometry of the low-resistivity anomaly;
3. To determine the position and extent of any deeper geothermal reservoir lying within 1,000 to 2,000 feet of the surface.

Electrical Resistivity Results

To complete the resistivity survey in a cost-effective manner and on a timely schedule, UURI recommend that ASARCO contract directly with a geophysical contractor who would be supervised by UURI geophysicists. ASARCO accepted a proposal offered by Consolidated Geophysical Surveys, Sandy, Utah, which is owned and operated by Claron E. Mackelprang. Mr. Mackelprang has a long history of excellent resistivity and induced polarization work with Kennecott Exploration and UURI, and was able to complete the survey on a satisfactory schedule. Consolidated Geophysical mobilized to Hawthorne, NV on April 10, 1994, and completed the survey on April 19. Consolidated Geophysical Surveys then demobilized to Sandy, UT and began numerical modeling of selected profiles as supervised by UURI.

The survey included one profile (Line 1) with electrode separation (a) of 500 feet and five profiles with electrode separation a=1000 feet. The locations of dipole-dipole lines were based on the AEM low-resistivity distribution; observed temperatures in CAR-1 to 7; the aeromagnetic interpretation; and the SP survey results. Later lines also considered the earlier resistivity results. The location of all survey lines is shown in Figure 7. The dipole-dipole resistivity data (in ohm-m) are presented as pseudosections in which data from increasing transmitter-receiver separations (n=1 to 7) are plotted as increased distances below the surface (Appendix 2).

Numerical model solutions are our best estimate of the true geometries and intrinsic resistivities which give rise to the observed data on the pseudosections. The numerical modeling was completed using program IP2D developed at UURI, which assumes a two-dimensional resistivity distribution (geometry) perpendicular to the orientation of the resistivity line. This condition was not strictly met during the survey, but the model results still provide our best estimate of true resistivities and to-scale geometric relationships. Initial resistivity geometries and values were assumed and the corresponding apparent resistivities computed for comparison with the observed data. Model geometries and resistivity values were then modified up to six times until a satisfactory "best fit" to the observed data was obtained. The final geometric models must later be interpreted in view of their mapped position, known geologic information, and other geophysical data. The observed resistivity profiles are included in Appendix 2 and the corresponding numerical model solutions are shown as Figures 8,9, and 10. A brief description of each profile follows.

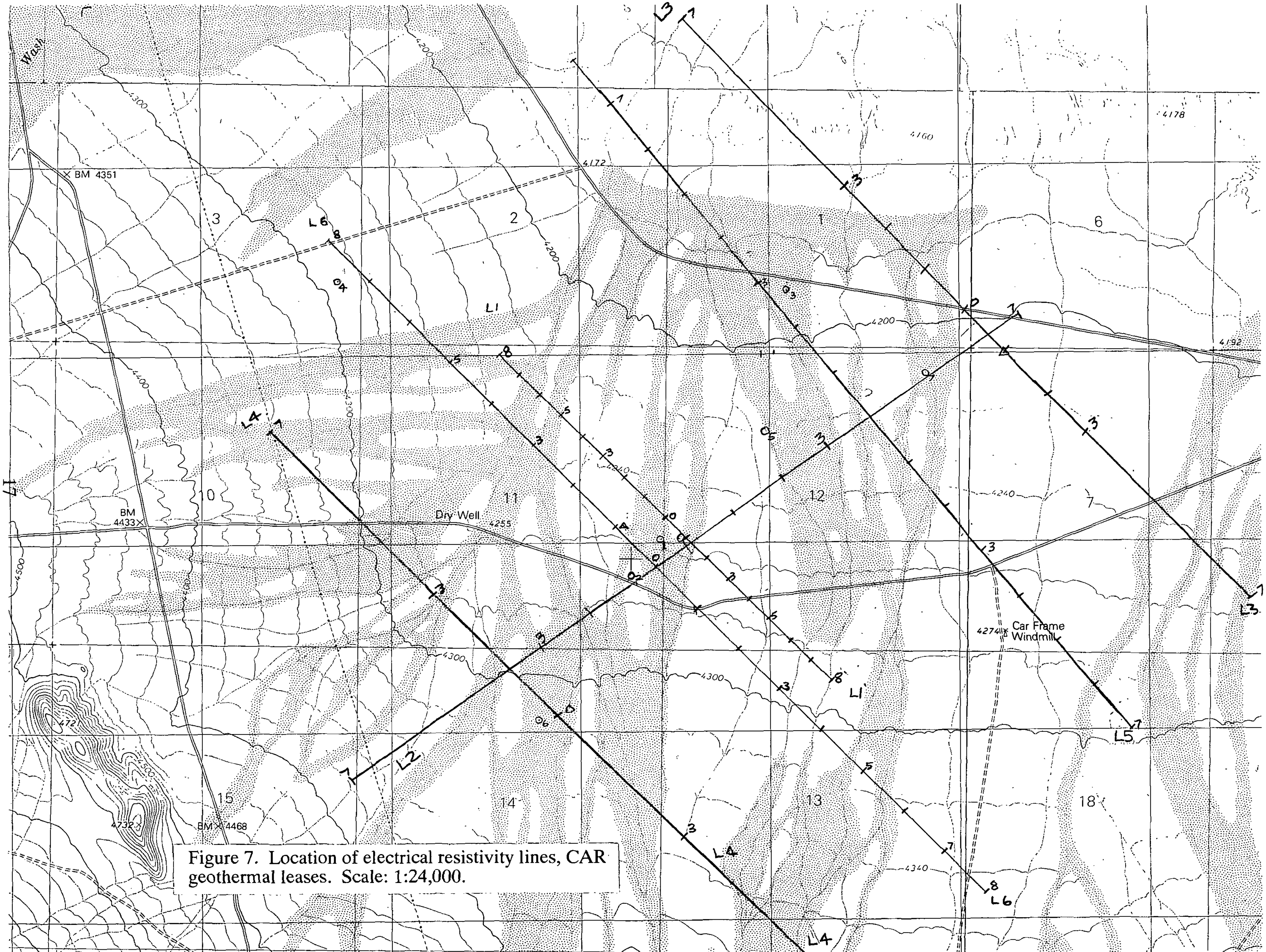


Figure 7. Location of electrical resistivity lines, CAR geothermal leases. Scale: 1:24,000.

Line 1. Line 1 is centered about 400 feet north of CAR-1 and trends S45°E across the center of SP-A. The line was completed with 500 ft dipoles (a=500 ft) with the intent of good definition of an upflow source for the SP anomaly. Low apparent resistivities, 3.4-6.5 ohm-m, were observed for most of the line. Only two values on larger separations exceed 10 ohm-m. The data suggest low (3-5 ohm-m) resistivities overlying somewhat higher values. The numerical model solution (Figure 8) was reached with an excellent fit to the observed data. It shows 3- and 5- ohm-m resistivities dipping to the northwest from stations 1-2 SE with a near-vertical 3-ohm-m zone between stations 3-4 SE. It suggests a plume of thermal fluids above moderate-resistivity (15 ohm-m) colluvium or bedrock.

Line 2. This line, and all subsequent lines, were completed with 1000 ft dipoles (a=1000 ft) to cover more area and to attempt to look for indications of a reservoir beneath the thermal plume. The line trends N55°E across SP anomalies SP-A and SP-B, along the long dimension of the AEM and aeromagnetic lows. The northeast half of the line shows lower resistivities at the near surface, with a possible low resistivity zone at depth. The model solution (Figure 9) suggests a deep, 1 ohm-m zone near CAR-1 and SP-A which rises to the southwest. This body is a good candidate for an upflow zone of thermal fluids, although the model is less reliable below a depth of 2000 feet.

Line 3. Line 3 is centered on the dirt road and trends S45°E across SP-B and B.S.#2. Low resistivities are observed throughout the line, with the lowest extending to depth along the 2-3 SE and 6-7 SE diagonals. The numerical model (Figure 10) suggests a low-resistivity (1 ohm-m) zone rising to a depth of 1000 ft between 2-3SE, along the southeast margin of anomaly SP-B, but also present to the northwest.

Line 4. Line 4 trends N45°W across the southwest part of the low-magnetization body and low resistivity zone mapped on Line 2. Somewhat higher apparent resistivities (10-20 ohm-m) are observed beneath the southeast part of the line. The model solution (Figure 8) shows a complex resistivity distribution, including possible 1 ohm-m zones, above much higher resistivities (50 ohm-m). Low resistivities believed to be typical of the outflow plume, 3-5 ohm-m, continue to the northwest.

Line 5. This line is centered between anomalies SP-B and SP-C within the AEM and magnetic lows, and crosses south of CAR-3. The observed apparent resistivities are slightly higher throughout this line, at 4 to 7 ohm-m. The numerical model (Figure 10) does suggest a lower resistivity zone on the southeast end of the profile.

Line 6. Line 6 is a line of 1000 ft dipoles which trends N45°W about 700 ft southwest of Line 1. The numerical model (Figure 9) shows 15 ohm-m resistivities at depth except for a modeled 1 ohm-m zone southeast of the CAR-1,-2 area.

Figure 11 summarizes the main results for all resistivity models in plan form, for depths to about 1000 feet. Figure 12 summarizes low-resistivity zones for the 1500-2000 ft depths. Low resistivities, 3 to 7 ohm-m, occur as tabular bodies from the surface to 1000 ft depths throughout

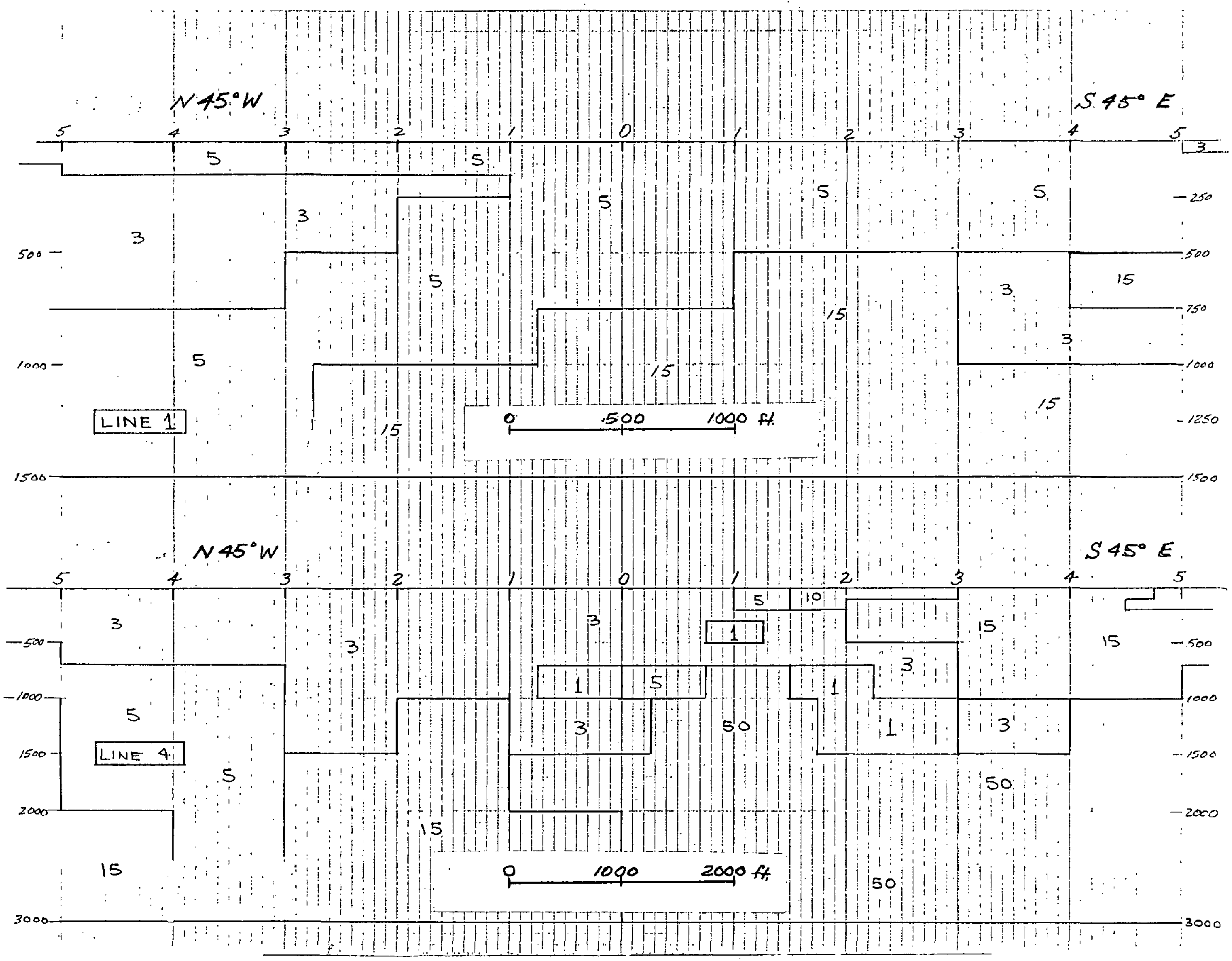


Figure 8. Numerical model solutions, dipole-dipole lines 1 and 4.

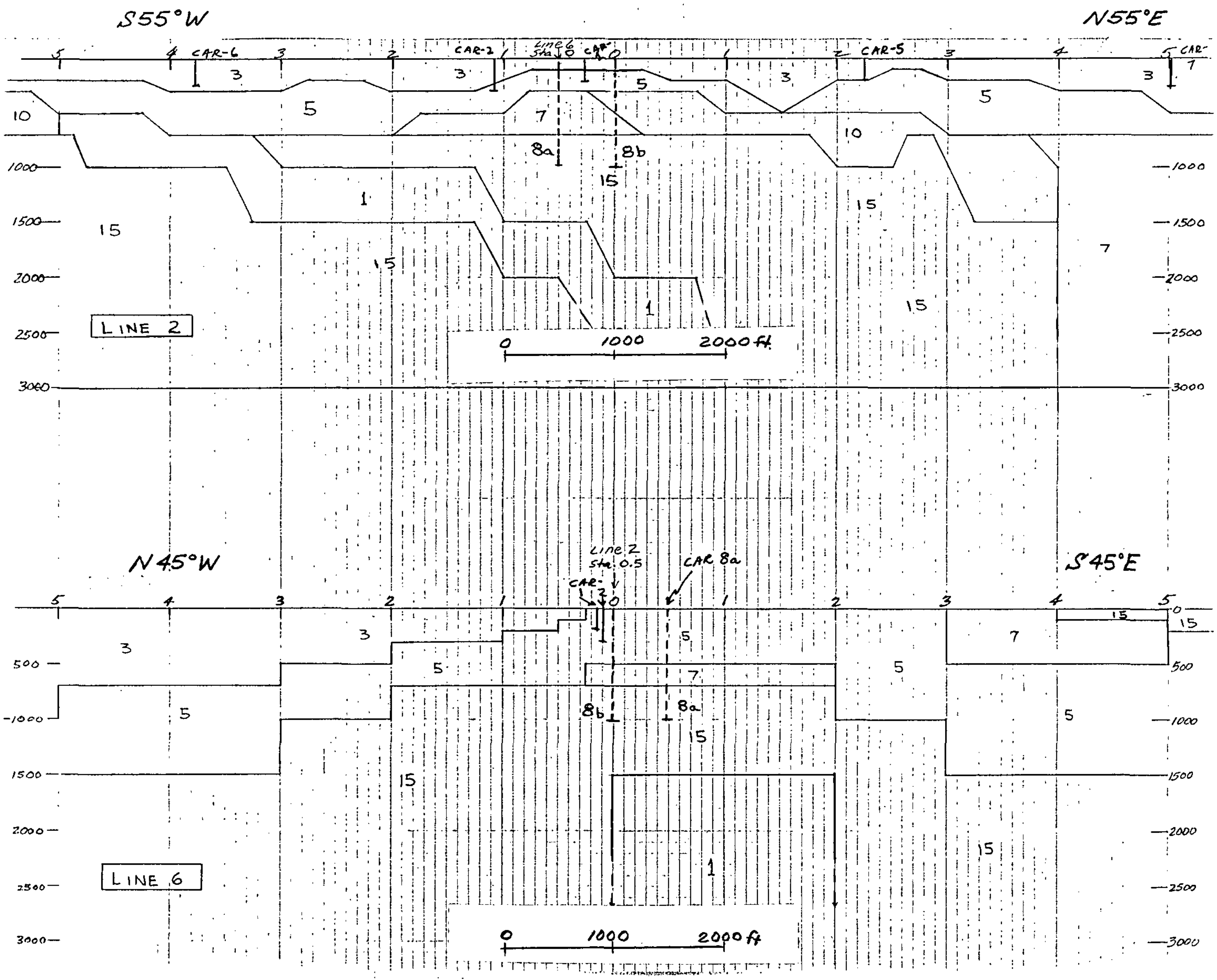


Figure 9. Numerical model solutions, dipole-dipole lines 2 and 6.

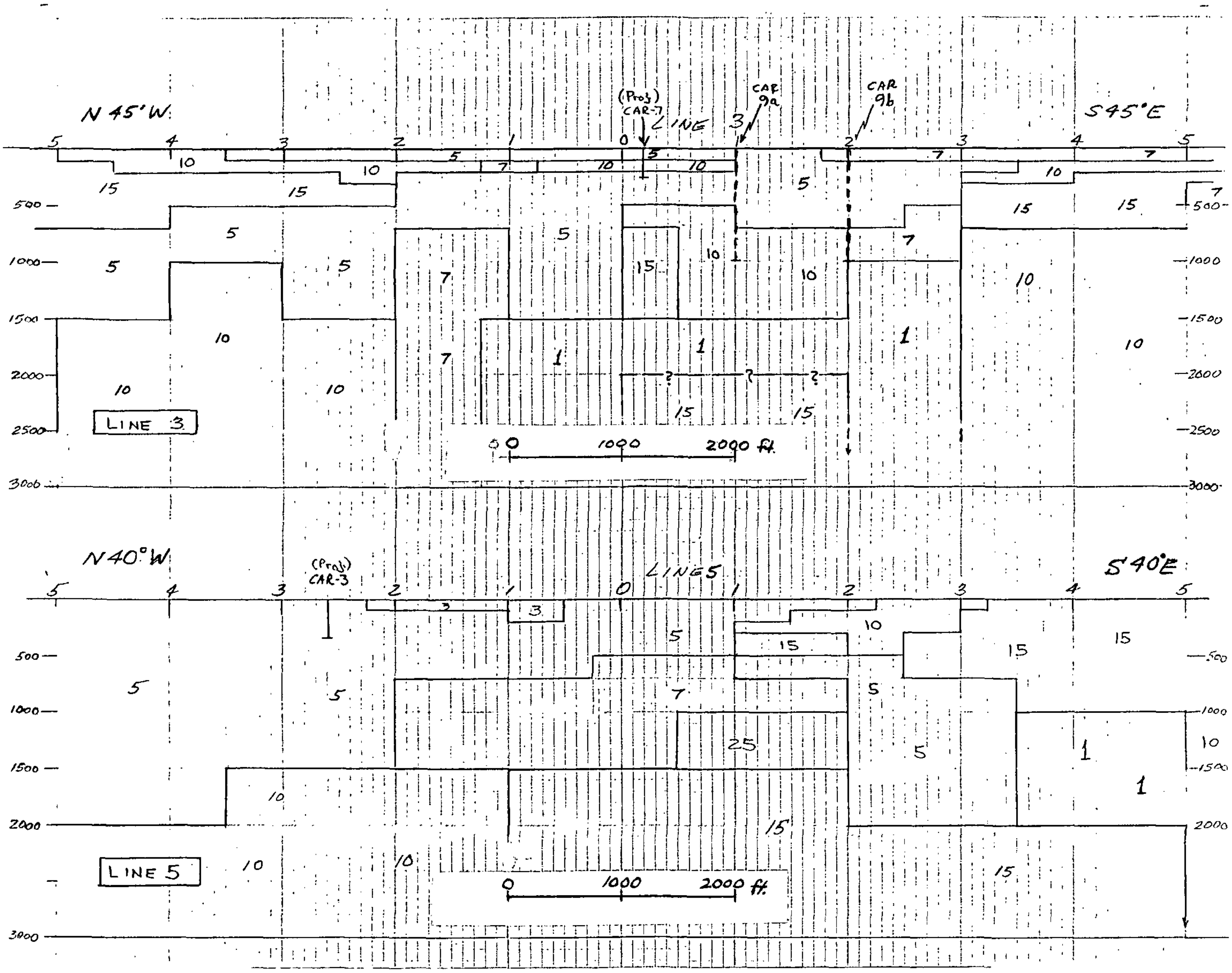


Figure 10. Numerical model solutions, dipole-dipole lines 3 and 5.

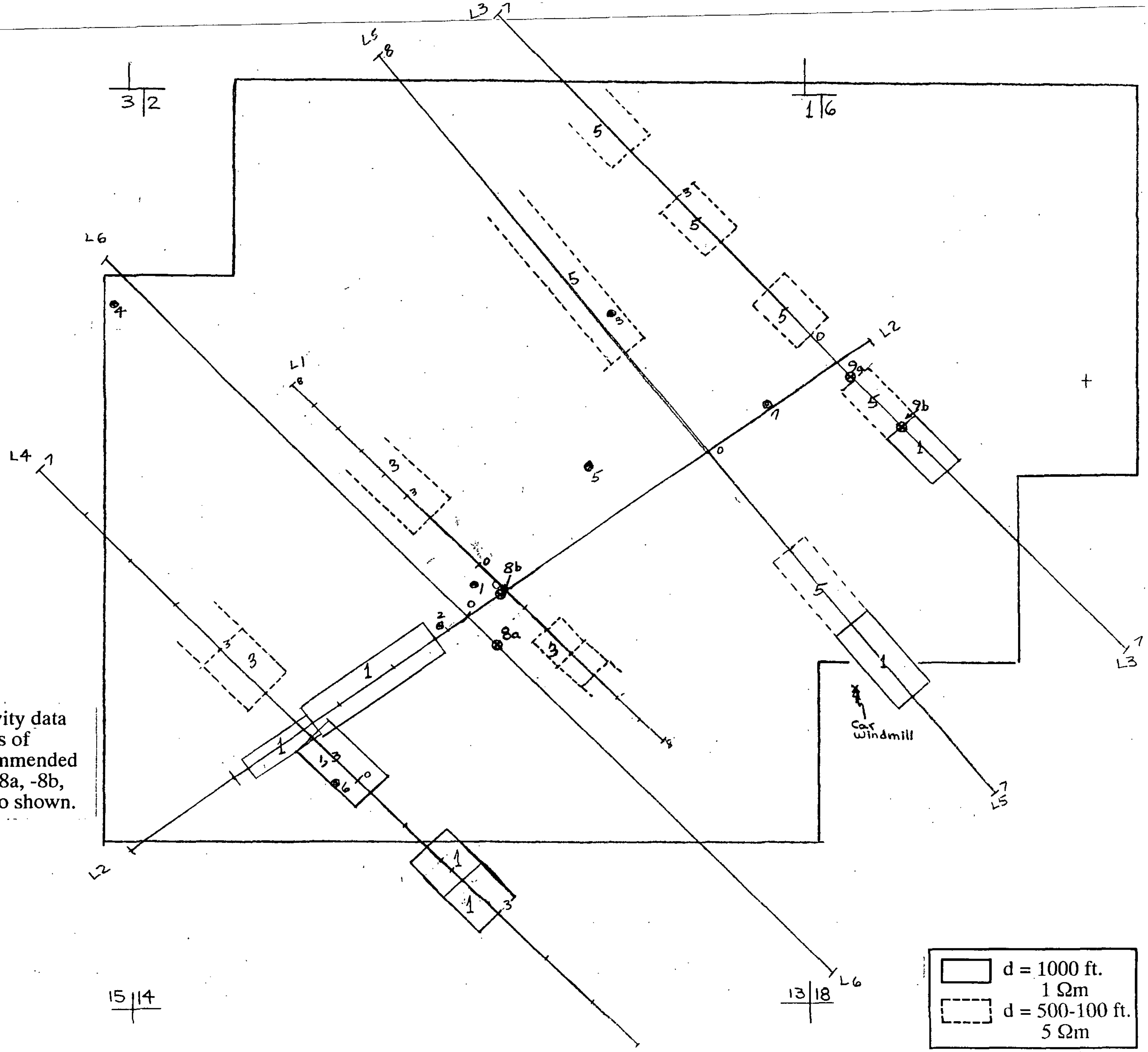


Figure 11. Resistivity data summary for depths of 0-1000 feet. Recommended locations for CAR-8a, -8b, and -9a, -9b are also shown.

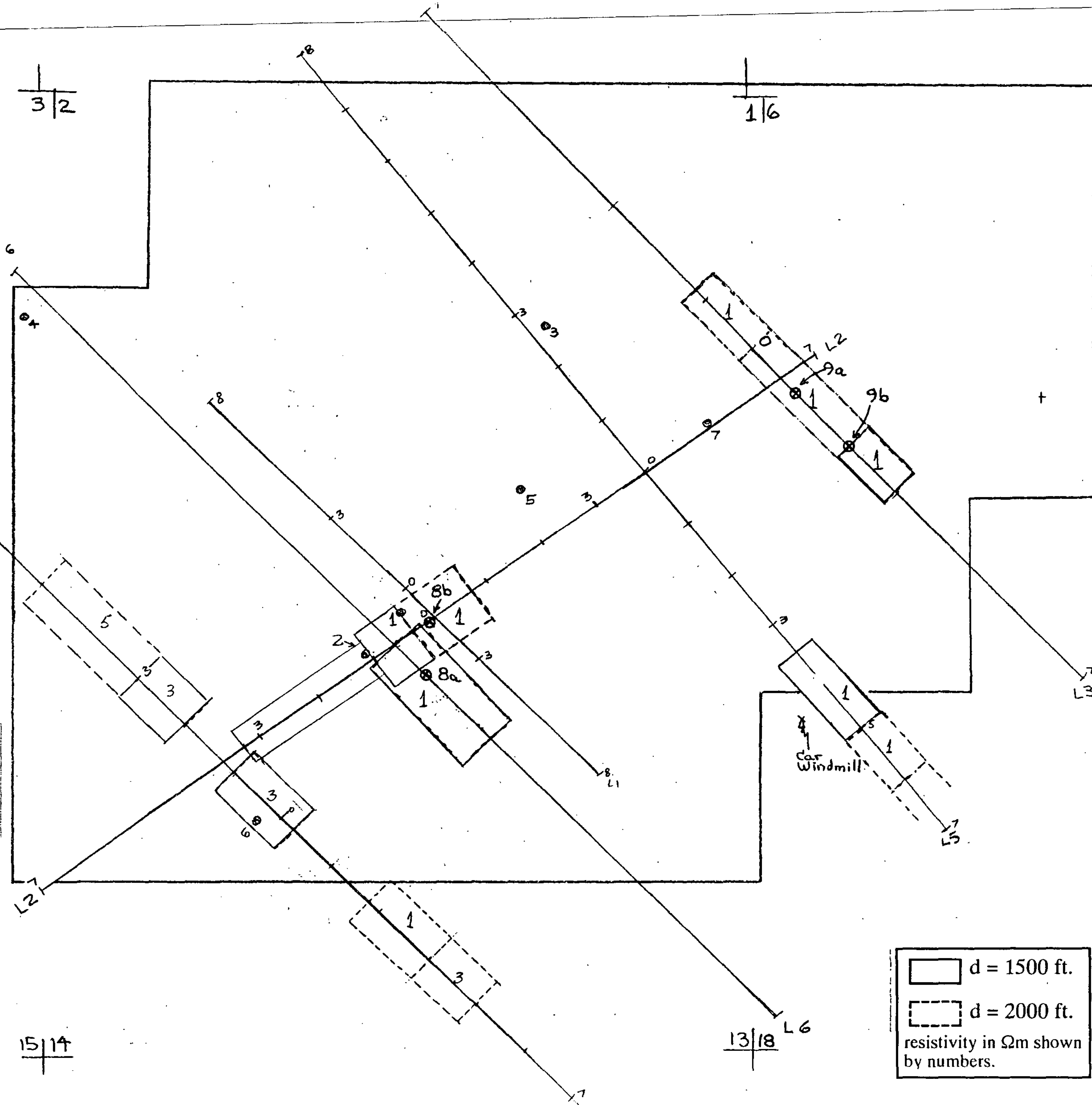


Figure 12. Resistivity data summary for depths of 1500-2000 feet. Recommended locations for CAR-8a, -8b, and -9a, -9b are also shown.

much of the area. Only lower resistivity zones, or zones with possible vertical depth extent, more consistent with upflow zones, are indicated on the maps. Low-resistivity bodies of 1-3 ohm-m possibly extending to some depth are indicated mainly south and east of CAR-1,-2 by lines 1,2, and 4. A 1 ohm-m body may extend to depth either side of SP-B, east of CAR-7.

DRILLING RECOMMENDATIONS

UURI evaluated electrical resistivity model results, self-potential anomalies, and structures interpreted from aeromagnetic data in the context of temperature and geologic data from CAR-1 through CAR-7, using a series of transparencies as overlays. UURI recommended drilling two temperature-gradient holes to depths of 1000 to 1500 feet, with hopes for obtaining fluid samples after flushing drilling fluids from the hole.

CAR-8. This hole was given highest priority because of proximity to CAR-1 and CAR-2 which have high temperatures at shallow depths. Two sites, 8a and 8b were suggested (Figures 11,12). CAR-8a specifically tests the area above a very low-resistivity (1 ohm-m) body well-defined by Line 6, and less well-defined on Line 2. The field data are excellent, the match between modeled and observed resistivities is excellent, and a sharp SP anomaly (SP-A) suggestive of fluid flow occurs immediately to the north. Three structures interpreted from aeromagnetic data intersect 500 to 1000 feet north of the proposed CAR-8a site. An alternative site, CAR-8b was suggested about 750 feet north of CAR-8a to provide a better test of the interpreted structural intersections and the SP-A anomaly, but a less favorable test of the low resistivity body.

CAR-9. This site (Figures 11,12) was proposed to test the large northern SP anomaly (SP-B,-C) and low resistivity zone, approximately 1500 feet east of CAR-7, which also showed encouraging temperatures at shallow depth (Figures 11,12). The numerical model for resistivity data of Line 3 showed a low-resistivity body (1 ohm-m) about 4000 feet wide (SE) at a depth of 1000 to 1500 feet. Proposed site 9a would test the center of the interpreted body (but above it), while 9b would test the northwest edge of the upper part of the body. Site 9a lies well within the center of the -50 to -60 mV SP anomaly while 9b would lie at the southeast edge of the anomaly. Aeromagnetic data suggested NW-, NE-, and north-trending structures which would intersect within the SP minimum.

CAR-8 RESULTS

CAR-8 was drilled at proposed location CAR-8a, approximately 900 feet SSE of CAR-1. The location had not been surveyed in at the time of this writing. CAR-8 is located in the SW/4, SW/4 Sec. 12, T11N, R33E at an approximate elevation of 4270 feet. UURI geologists provided recommendations for the drilling program, and reviewed and commented on a drilling proposal submitted by Tonto Drilling Services, Inc. The hole was drilled by Tonto Drilling Services, Inc., June 14-30, 1994 using a Longyear 55 Hydro rig. The hole was drilled with 6-3/4 in. tricone bit (0-275 ft), 3-15/16 in. tricone bit (275-330 ft), and then NCHQ to total depth at 1502 feet. NCHQ rods (casing) were suspended at the collar to 1498 feet. Numerous lost circulation zones and silicified zones resulted in difficult drilling conditions.

Geologic Summary

ASARCO geologists completed a Drilling Monitor Log (D. Willis, P. Vikre, R.J. Morgan) and a Geologic Log (P. Vikre) and made these available to UURI for a more complete evaluation of CAR-8 drilling and temperature results. This summary is based on those logs.

CAR-8 was drilled in alluvium (0-110 ft), and colluvium/fanglomerate to total depth. The colluvium/fanglomerate varies through clay, silt, sand, boulders and conglomerate derived from (Tertiary) volcanic rocks. The fanglomerate is variably silicified, with non-quartz fine-grained minerals often altered to clays. XRD shows montmorillonite to be a common clay mineral. The core is variably mineralized, and pyrite estimated at 2-4% is common. Assays by ASARCO show Au, Ag, As, and Hg to be present is small and variable amounts. Lost circulation is first noted at 290-300 feet, and again at 320-330 feet. Watercourses or potential watercourses (open fractures) were noted at 314, 420, 447, 475, 495, 501-504, and 570-590 feet in upper parts of the hole. Watercourses are common between depths of 660 and 1150 ft and from 1350-1400, and 1444-1460 feet. The core was noted as "entirely silicified" from 1250-1502 ft and no watercourses were noted below 1460 feet. Lost circulation zones and open fractures are indicated as watercourses on the temperature log summary, Figure 13.

Temperature Measurements

UURI provided ASARCO with several Taylor maximum-reading thermometers for taking unequilibrated temperatures during breaks in the drilling. ASARCO geologists recorded 23 temperature measurements, generally with a time-on-bottom (wait) time of 10 minutes. These data are shown in Table 1 and summarized with two temperature logs in Figure 13. These temperatures are likely disturbed by the circulation of drilling fluids and can be expected to be low compared to equilibrated temperatures, but provide a useful record of temperature changes while drilling. The first anomalous temperature, 163°F (72.8°C) was observed at a depth of 400 feet (153 m), well below the water table. Below 950 feet the maximum temperature measurements closely approach the final temperature log. A maximum temperature of 129.4°C was observed after 30 minutes at a depth of 1000 feet.

UURI completed two temperature logs of CAR-8. Logging was completed with the URRI N.P. Instruments high-precision thermistor probe and temperature logging equipment. Instrument characteristics and on-site calibrations result in a temperature measurement precision of 0.01°C, but hole observation conditions, and convection within the hole may sometimes reduce the measurement accuracy to +/- 0.05°C. The first log was completed June 22 when hole depth was 920 ft. Temperature measurements began at 10:15 am, about 75 min after drilling (circulation) stopped. As such, this was a non-equilibrium log. Borehole fluid level indicated by the UURI Soiltest Water Level Indicator was 134 feet. P. Vikre and D. Willis, ASARCO, assisted H. Ross in completing the survey. The N.P. logging cable is calibrated in meters and temperatures are observed in degrees Celsius (°C). Temperatures were observed at 10 m (32.8 ft) intervals above the water level, and at 5 m (16.4 ft) intervals below water level. A detailed log is included in Appendix 3, and Figure 13

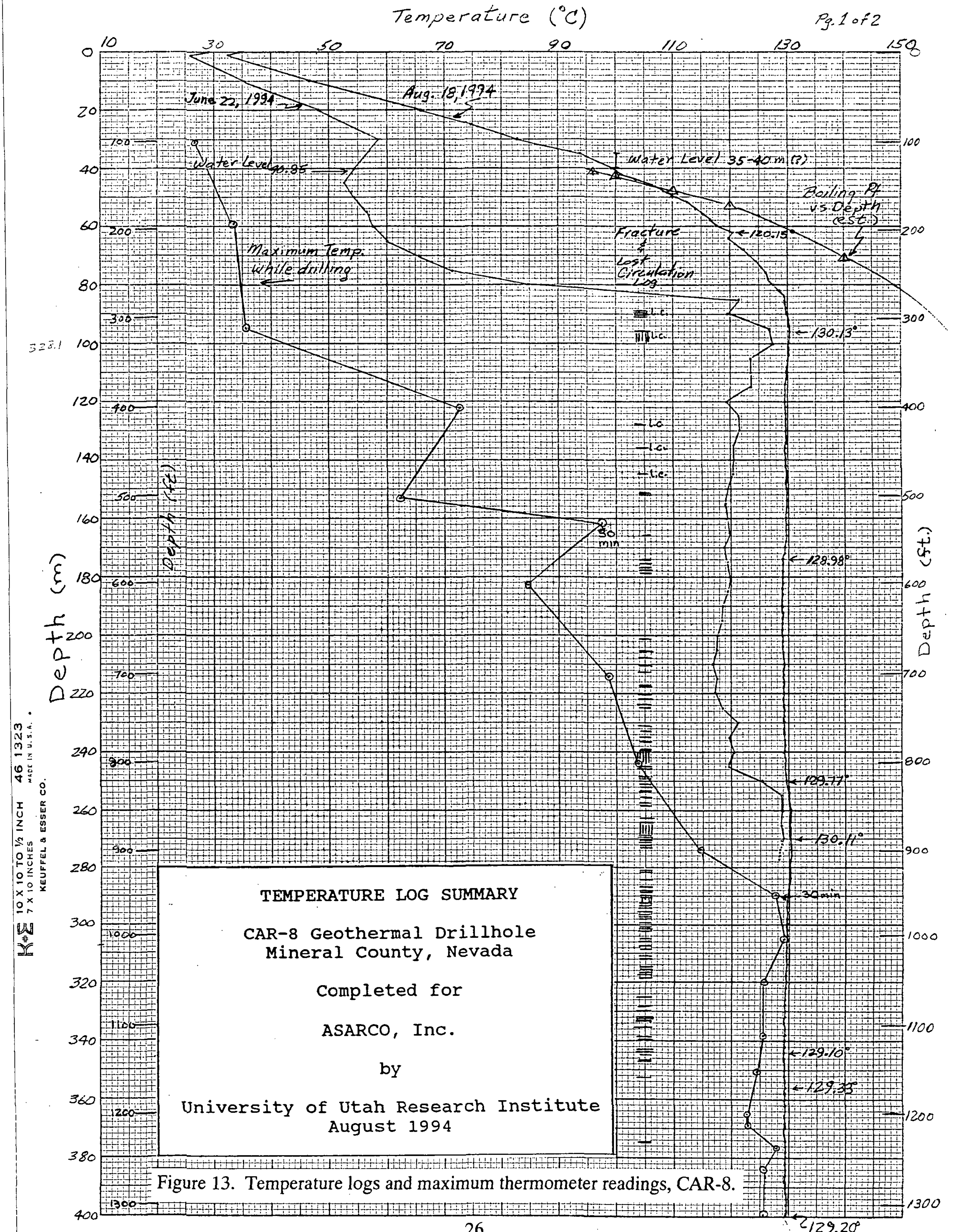
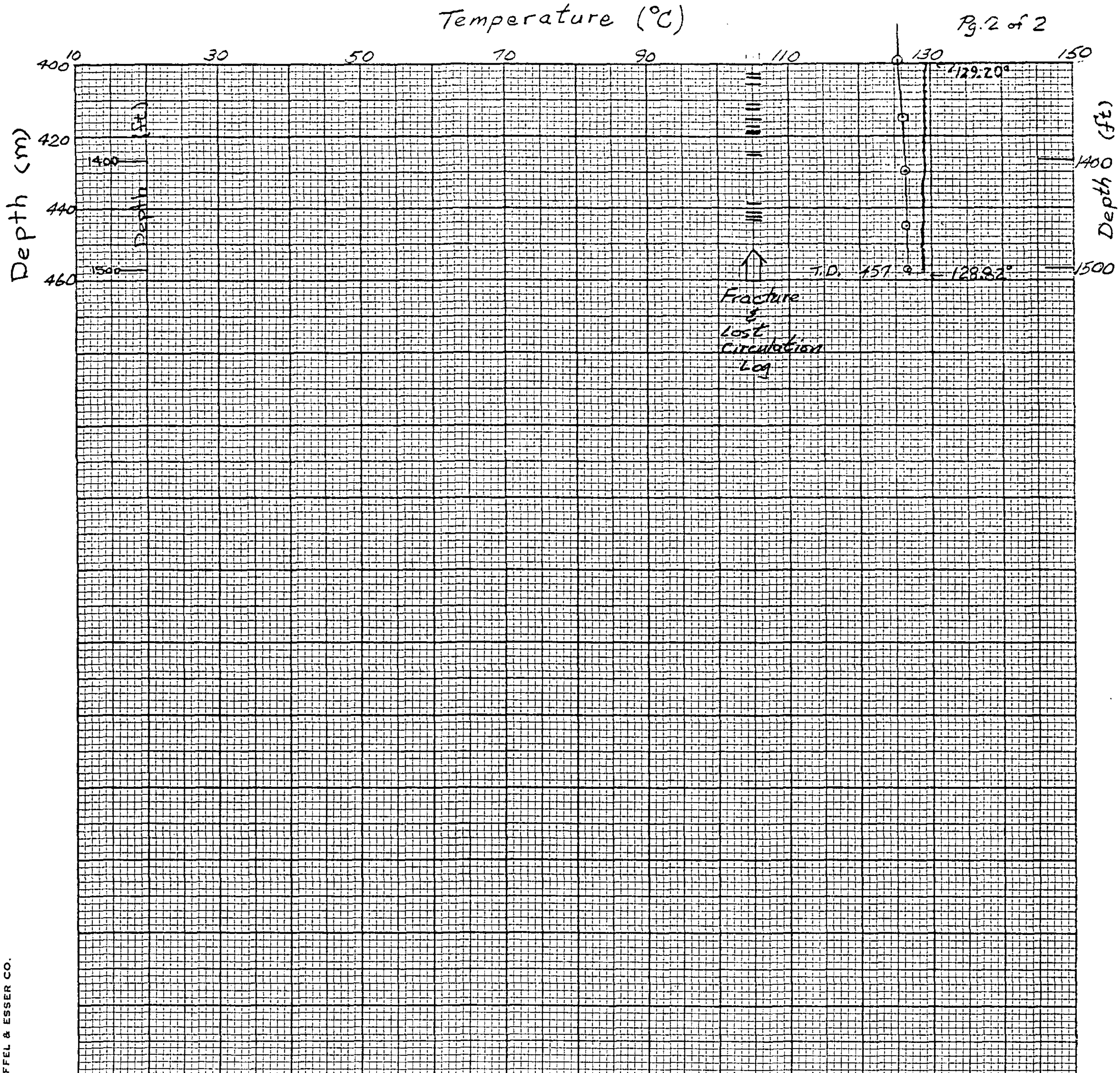


Figure 13. Temperature logs and maximum thermometer readings, CAR-8.



TEMPERATURE LOG SUMMARY

CAR-8 Geothermal Drillhole
Mineral County, Nevada

Completed for

ASARCO, Inc.

by

University of Utah Research Institute
August 1994

Figure 13 (continued). Temperature logs and maximum thermometer readings, CAR-8.

Table 1. Maximum Thermometer Readings, CAR-8 (by ASARCO during drilling).

Depth		Temperature		Time#
meters	feet	°C	°F	minutes
30.5	100	26.7	80	10
59.1	194	33.3	92	5
94.5	310	35.6	96	10*
121.9	400	72.8	163	10
153.0	502	62.2	144	10*
161.5	530	97.8	208	30
182.9	600	84.4	184	10
213.4	700	98.3	209	10*
243.8	800	103.9	219	10*
274.3	900	114.4	238	10
290.0	950	127.8	262	30
304.8	1000	129.4	265	10*
320.0	1050	125.6	258	10*
338.3	1110	125.6	258	10*
350.5	1150	124.4	256	10*
365.8	1200	122.8	253	10*
368.8	1210	122.8	253	10*
377.3	1238	128.3	263	10*
384.1	1260	125.6	258	10*
399.3	1310	125.6	258	10*
414.5	1360	126.1	259	10*
429.8	1410	126.1	259	10*
445.0	1460	126.7	260	10*
457.2	1500	126.7	260	10*

#Time of Taylor Maximum thermometer at bottom of hole.
*assumed to be 10 minutes

summarizes all temperature measurements. A temperature reversal at 40 m probably indicates formation cooling in permeable units due to drilling fluids. A sharp temperature increase from 84.5°C (80 m) to 121.3°C at 85 m probably indicates a hot water entry near this area. The Drilling Monitor Log indicates a 1 foot void, lost circulation, and a watercourse at 314 feet, and no cuttings recovery from 320-330 feet. The temperature observed at 100 m (328 ft), at 127.2°C, is the highest temperature in the upper part of the hole.

Drillers changed to NC core at 330 feet, and few watercourses were noted until 495 ft. Temperatures decline to 117°C at 210 m (689 ft) then increase sharply as fractures increase to 129 °C, near the current bottom-of-hole (920 ft). Much of the borehole shows depressed temperatures due to formation cooling by drilling fluids. Temperatures are less disturbed near the base of the hole, about 3.5 hours after circulation. Temperatures over 128°C in this zone of many watercourses may indicate a major fluid entry which contributes to fluid circulation in the borehole, as noted in the August 18 temperature log.

A second temperature log was completed on August 18, 1994, some 49 days after completion of the hole on June 30. Borehole temperatures should have equilibrated such that a final temperature log, and accurate temperature gradients, could be established for CAR-8. Since the hole had been shut it, there was some possibility of pressure buildup and the accumulation of steam and noncondensible gases. A 4 foot long (1.5 in diameter) diverter pipe was affixed to the wellhead and the valve slowly opened. A minor amount of steam that quickly dissipated in the hot, dry air, was accompanied by hissing and visible condensation at the diverter pipe. A personal H_2S monitor indicated the presence of this gas, requiring some caution in bleeding off the gases and in conducting the logging. The occurrence of H_2S is discussed in more detail later. The hole was logged by H. Ross and D. Langton, using the UURI N.P. Instruments equipment described earlier. Steam rising from the top of the water table began condensing on the electrode making it impossible to get an exact water level measurement. Based on the behavior of the water level indicator and the rate of stabilization of the temperature probe, we estimate the water level to be between 35-40 m (115-131 ft).

A detailed temperature log is included in Appendix 2. A summary log is presented in Figure 13 with other temperature data. Measurements were made at 5 m intervals above the water level, then at 2 m (6.6 ft) intervals to the bottom of the hole. The hole is much warmer (up to 65°C) from 30 to 80 m (115-131 ft) than observed on June 22, verifying that this zone had been substantially cooled by drilling fluids in June. An estimated boiling point-v.s. depth curve computed by J. Moore, and shown on Figure 13, shows that boiling is probably occurring at the water surface. Temperatures drop below the boiling point at about 45 m (148 ft) depth, and remain below the boiling point to depth. A maximum temperature of 130.13°C occurs at 96 m (315 ft) corresponding to the 1 ft void and watercourse noted in the geologic log, and identified as a hot water entry (HWE) in the June 22 log. Temperatures are almost isothermal below this point, reaching a low of 128.98°C at 174 m (571 ft), then generally increasing to 130.11°C at 270 m (886 ft) before declining again to 128.82°C at total depth. The total variation from depths of 84 m to total depth at 457 m is about 1.3°C, strongly suggesting fluid movement within the borehole and/or within the casing. Looking at small temperature differences, one can identify possible HWEs, or approaches to fractures carrying warmer fluids, from 250-286 m (820-938 ft), a zone with many watercourses, and 354-360 m (1,161-1,181 ft), perhaps corresponding to a single watercourse identified at 1,163 ft (354 m).

Possible cooler water entries (CWEs) or approaches to fractures carrying cooler fluids, may occur at 120-126 m, 174-202 m, 332-336 m, 344-346 m, and near the hole bottom at 454-457 m. Borehole diameter and rock thermal conductivity could also account for the small temperature differences observed on the log.

Discussions with Ron Fierback of Tonto Drilling indicate that the 6 inch casing was cemented in to a depth of 278 ft (84.7 m), and that H rods were hung from the surface to a depth 4 feet off the bottom of the hole. This type of completion permits fluid circulation within the well and this convection likely explains the isothermal nature of the well. If the rods had been drilled in at TD using a casing shoe the well would have been isolated from fluid circulation, thus permitting determination of a reliable thermal gradient. The temperature logs indicate a geothermal reservoir temperature greater than 130°C, but the true reservoir temperature is unknown. Perhaps the best estimate of the conductive temperature gradient is based on maximum thermometer data and the June 22 log, from the surface to 270 m (886 ft). This averaged gradient is about 100°C/270 m, or 370°C/km. The depth to 150°C, if this gradient continued, would be about 330 m (1,100 ft).

Fluid Sampling

Many lost circulation zones were encountered during drilling and a large amount of drilling fluid was pumped into the formations. UURI geologists and geochemists believed that the well would have to flow for several weeks or more to get a fluid sample that would likely give reliable geothermometers, and this was made known to ASARCO. ESRI geologists do not recommend flow testing at the present time because of the expense. Petrographic studies to determine the presence of diagnostic mineral assemblages that are temperature sensitive, and fluid inclusion studies could also indicate possible reservoir temperatures. No suitable fluid inclusions were found in the samples submitted to UURI. Temperatures from fluid inclusion studies may relate to much earlier temperatures in the present hydrothermal system, or to an earlier mineralization episode.

Hydrogen Sulfide Occurrence

Hydrogen sulfide (H_2S) is a fairly common noncondensible gas in geothermal systems. It is also quite toxic and safety precautions should be taken during geothermal drilling and other well-related activities. UURI used an ISC Model HS267 dual alarm, continuous hydrogen sulfide detector to monitor H_2S levels during the logging operation. This personal H_2S monitor features a digital readout in ppm and an audio alarm set for 10 ppm. The monitor remained at the wellhead until alarm levels were noted, and was then taken upwind from the site until background levels (0 ppm) levels of H_2S were observed. The instrument was calibrated just prior to the lease period.

H_2S was not reported by the driller or site geologist during drilling, perhaps due to the large amount of drilling fluid pumped downhole in order to maintain circulation. UURI first observed H_2S at 9:26 am, about 8 minutes after the valve was partially opened. H_2S quickly increased to 23 ppm, as observed some distance upwind during retreat from the wellhead, immediately after the valve was closed. A higher level of 237 ppm was observed more than 100 ft upwind from the wellhead shortly after the valve was reopened. Potentially lethal concentrations may have been present at the wellhead. When the monitor indicated that H_2S had dissipated, the valve was partially opened and the site vacated for several minutes. Figure 14 shows that H_2S levels remained at <1 ppm throughout most of the time that the valve was open, suggesting that small pockets (bubbles?) of H_2S migrated to the borehole in response to pressure gradients. The H_2S is probably not a major safety concern, but we recommend that all future drilling and testing operations include standard H_2S safety measures, such as the presence of wind flags, gas monitors, and (perhaps) emergency breathing apparatus on site.

The presence of H_2S at these levels may contribute to corrosion at the wellhead. Many wellfield operators leave wells on bleed to permit the gradual release of the H_2S. The life of the wellhead may be of the order of 7 to 15 years without some remedial action.

DISCUSSION

The SP anomalies located near the warm temperatures observed in the CAR-1,-2,-3,-5,-7, and -8, well within the low resistivity zone, probably arise from the upflow of thermal fluids. The electrical resistivity survey recorded low apparent resistivities throughout much of the CAR lease area. Numerical modeling of the data has resolved the low resistivity zone and shows an extensive, tabular 3-5 ohm-m body that may extend beyond the AEM 900Hz resistivity low. Much of this low-resistivity zone appears to be an outflow plume of thermal waters. The models also show 1- and 3-ohm-m bodies within the low, and to the southeast and southwest at depths of 500-1000 feet. Low resistivity bodies that show vertical extent and appear to go to depth (as opposed to subhorizontal tabular bodies) are likely the best indicators of thermal fluid upflow zones and reservoir areas. These considerations led to the recommendations for siting CAR-8 and CAR-9.

Archie's Law relates bulk (intrinsic) electrical resistivity to the resistivity of pore fluids, and porosity of the rock volume:

$$\rho_B = \alpha \rho_w \varphi^{-m} \quad \text{, or to a first approximation,} \quad \rho_B \simeq (1) \rho_w \varphi^{-2}$$

where ρ_B = bulk resistivity, ρ_w = resistivity of pore fluids, φ = porosity, and α and m are constants relating to the type of porosity, grain sorting, and cementation. In a first approximation, α=1, and m =2. Archie's Law often applies for relatively "clean" sandstones and silts, when electrical conduction by clay and metallic minerals is not a major factor. The ASARCO geologic log for CAR-8 indicates the presence of considerable montmorillonite, probably other clay minerals, and pyrite. Table 2 illustrates Archie's Law estimations of ρ_w determined from the observed bulk resistivities and for several assumed porosities. From the ρ_w, one can use empirical charts (i.e.

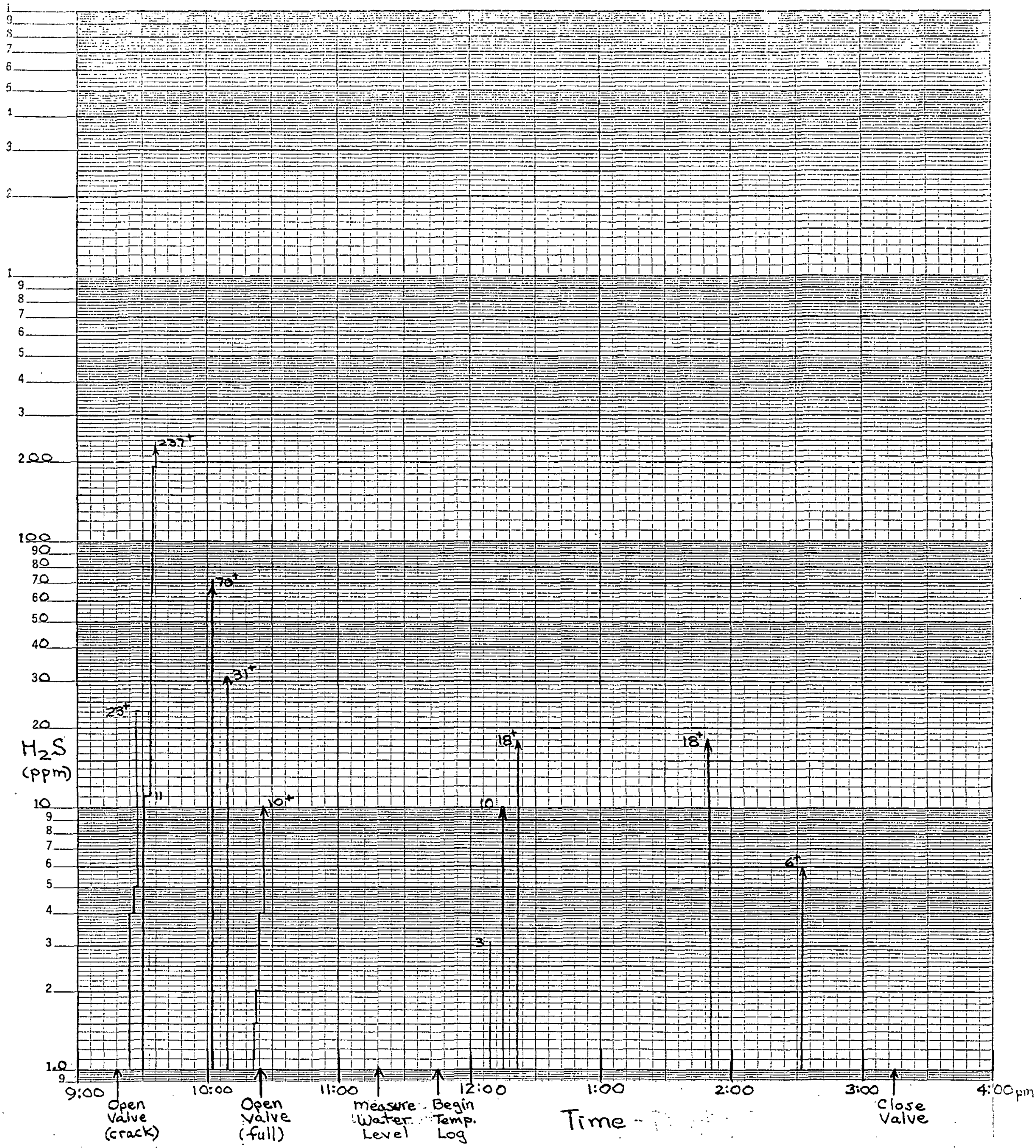


Figure 14. H2S readings at CAR-8, August 18, 1994. Values above 10 ppm were recorded while retreating upwind from the drill hole; higher values would have been observed at the wellhead.

Models	ϱ_B (Ω-m)	φ(%)	φ^2	$\varrho_W = \varrho_B \varphi^2$ (Ω-m)	Tds (ppm)	Temperature °F	Temperature °C	More Likely Bodies
Background (Qal, Qfg)	15	10% = 0.10	0.01	0.15	20,000	175	79	
					10,000	280	138	*
		20% = 0.2	0.04	0.60	10,000	70	21	*
					5,000	140	60	*
		40% = 0.4	0.16	2.40	1,000	155	68	
					2,000	80	27	
Outflow Plume zone	5	20% = 0.2	0.04	0.20	5,000	450	232	*
					10,000	210	99	*
					20,000	115	46	
		30% = 0.3	0.09	0.45	2,000	450	232	*
					5,000	185	85	*
					10,000	95	35	
		40% = 0.4	0.16	0.80	1,250	400	204	
					2,000	250	121	
					5,000	75	24	
Outflow & Upflow zone	3	30% = 0.3	0.09	0.27	5,000	310	154	*
					10,000	155	68	
		40% = 0.4	0.16	0.48	2,500	270	132	
					5,000	185	85	
					7,000	130	54	
Upflow & Reservoir	1	30% = 0.3	0.09	0.09	13,500	400	204	*
					20,000	260	127	*
		40% = 0.4	0.16	0.16	7,000	400	204	
					10,000	260	127	
					14,000	200	93	
					22,500	130	54	

Table 2. Fluid salinity and temperature estimates from Archie's Law

Schlumberger, 1985) to estimate fluid salinities and temperature, which determine the fluid resistivity, ρ_w . Even for generous (high, 30-40%) porosities, low fluid resistivities would be required to give rise to the modeled bulk resistivities. The low fluid resistivities require high salinity (tds) fluids and/or high fluid temperatures. Garside (1994) reports relatively low (776 ppm tds) fluid salinity at Rawhide Hot Springs to the northeast, but no fluid analyses are available for the CAR well fluids. If conduction by clay and sulfide minerals is not a dominant factor and fluids are not high salinity (not >5,000 tds), then fluid temperatures of 150 -200°C may be required to account for the 1 and 3 ohm-m bodies. The modeled low-resistivity (1- and 3-ohm-m) bodies are lower than 4- and 5-ohm-m bodies modeled for thermal areas at Newcastle, Cove Fort, and Roosevelt Hot Springs in Utah. Because of the several unknowns in this analysis, we use it only to indicate the possibility of high-temperature fluids at depth on the CAR leases.

Electrical resistivity results and geologic observations from CAR-8 indicate the presence of a porous and permeable, shallow (250-300 ft deep) geothermal reservoir. Temperature logs indicate fluid temperatures of 130°C for this reservoir. Self-potential anomalies and near-vertical fractures noted in the drill core, and structures interpreted from magnetic data, suggest proximity to a fluid upflow zone. This upper reservoir is fed by fluids from a deeper, presumably higher-temperature, reservoir. The deeper reservoir could be present beneath CAR-8 or nearby.

The temperature distribution at depth within the geothermal reservoir is not known because fluid circulation in the CAR-8 well bore precludes a meaningful temperature log. Studies of active thermal systems have shown that mineralogic data can provide a good first approximation of temperatures that could be expected. At temperatures of less than about 180°C, the common minerals include montmorillonite, chalcedony, and calcite. Between 180 and 220°C, quartz, potassium feldspar, interlayered illite-smectite and chlorite-smectite are common. At still higher temperatures, illite and chlorite replace the interlayered clays, and epidote and wairakite form. The clay minerals are particularly significant because of their tendency to re-equilibrate with increasing temperature.

Lithologic logs of the cuttings and core were prepared by ASARCO and a number of samples were studied by X-ray diffraction methods. The data indicate that CAR-8 encountered a secondary mineral assemblage consisting of quartz, calcite, montmorillonite, and pyrite. Feldspar and muscovite were also identified in the X-ray patterns, but based on the other minerals present, these are probably detrital in origin. The secondary mineral assemblage was found to be similar throughout the well. No epidote or other minerals typical of high-temperature conditions were reported. Together, these observations suggest that temperatures have never been higher than about 180°C at depths of 1500 feet.

There is potential for reservoir temperatures of 150 to 200°C, but this must be proved by additional drilling, or fluid geochemistry if clean fluids can be produced from CAR-8 or future drill holes.

Economic Considerations

Electric power is being generated at fluid temperatures as low as 107°C (Wabuska, NV; Garside, 1994) but the efficiency is low and the economics for a remotely sited area would be marginal at best. Low power-generation costs for natural gas have displaced the market for new geothermal power production in much of Nevada, and power sales contracts are difficult to obtain at the present time. Direct-heat utilization, such as greenhouse heating and aquaculture, is a possible use at the CAR leases, but the site is remote from transportation corridors and any communities, and the resource value would be much reduced.

The CAR lease area hosts a significant geothermal system, with potential for resource temperatures of 150-200°C at greater depths. We recommend that ASARCO maintain the geothermal leases for future value as the power market improves, and continue to explore for the presence of the deeper reservoir as funding for this project may permit. Options for the next stage of exploration include the following:

Drilling: Deepen CAR-8 (500 ft) to obtain a deeper temperature log without circulation in the wellbore. Drill CAR-9 to 1500-2000 feet as another temperature gradient test. Plan for short-term flow tests to obtain clean fluid samples for geothermometry and chemical analyses only after satisfactory conductive temperature gradients are determined, and temperatures of 150°C or higher are indicated.

Geophysics: Given more encouragement for higher reservoir temperatures, it may be cost-effective to complete 3 or 4 additional electrical resistivity lines to refine the geometry of the geothermal system, and to guide future drilling and lease control. Four additional lines of 1000 ft dipoles and numerical modeling could be completed for about $13,000.

REFERENCES

Black, J.E., Mancusco, T.K., and Gant, J.L., 1991, Geology and mineralization at the Rawhide Au-Ag deposit, Mineral County, Nevada: Geological Society of Nevada symposium: The Geology and Ore Deposits of the Great Basin, v.2, pp.1123-1141.

Ekren, E.B., and Byers, F.M., Jr., 1986a, Geologic map of the Murphys Well, Pilot Cone, Copper Mountain, and Poinsettia Spring Quadrangles, Mineral County, Nevada: U.S. Geological Survey Miscellaneous Investigation Series, Map I-1576, scale 1:48,000.

Ekren, E.B., and Byers, F.M., Jr., 1986b, Geologic map of the Mount Annie NE, Mount Annie, Ramsey Spring, and Mount Annie SE Quadrangles, Mineral and Nye Counties, Nevada: U.S. Geological Survey Miscellaneous Investigation Series, Map I-1579, scale 1:48,000.

Garside, L.J., 1994, Nevada low-temperature geothermal resource assessment: 1994: Nevada Bureau of Mines and Geology, Final report to Oregon Institute of Technology, 58 p.

Garside, L.J., and Hess, R.H., 1994, Nevada geothermal resource use - 1993 update: Geothermal Resources Council Bulletin, v. 23, pp. 47-54.

Hardyman, R.F., and Oldow, J.S., 1991, Tertiary tectonic framework and Cenozoic history of the Central Walker Lane, Nevada: Geological Society of Nevada symposium: The Geology and Ore Deposits of the Great Basin, v.1, pp. 279-301.

Koutz, F.R., 1990, Drilling results - Summary report: CAR Claims (190), Paradise 1990 AEM Project, Mineral County, Nevada: ASARCO - Great Basin Exploration Division internal report, 23p.

Ross, H.P., Blackett, R.E., Shubat, M.A., and Mackelprang, C.E., 1990, Delineation of fluid upflow and outflow plume with electrical resistivity and self-potential data, Newcastle geothermal area, Utah: Geothermal Resources Council Transactions, v. 14, pp. 1531-1526.

Ross, H.P., Blackett, R.E., and Shubat, M.A., 1991, Exploring for concealed hydrothermal resources using the self-potential method, Escalante Desert, Utah: Geothermal Resources Council Transactions, v.15, pp.279-287.

Ross, H.P., Blackett, R.E., and Witcher, J.C., 1995, The self-potential method: cost-effective exploration for moderate-temperature geothermal resources: Proceedings, World Geothermal Congress, 1995, Florence, Italy: v.2, pp. 875-879.

Schlumberger Well Services, 1985, Log interpretation chart book, Houston, TX, 74 p.

Trexler, D.T., Flynn, T., Koenig, B.A., and Ghusn, G. Jr., 1983, Geothermal Resources of Nevada, 1983; map produced by National Geophysical Data Center, NOAA for DOE, scale: 1;500,000.

Wright, P.M., Ward, S.H., Ross, H.P., and West, R.C., 1985, State of the art - Geophysical exploration for geothermal resources: Geophysics, v.50, p. 2666-2696.

Corwin, R.F., and Hoover, D.B., 1979, The self-potential method in geothermal exploration: Geophysics, v.44, pp. 226-245.

FIGURE CAPTIONS

Figure 1. Location of the CAR geothermal leases within the Walker Lane structural zone (modified from Hardyman and Oldow, 1991).

Figure 2. Nevada geothermal resources occurrences and resource potential (modified from Garside, 1994; Garside and Hess, 1994).

Figure 3. Location of the CAR geothermal leases and exploration drill holes CAR 1-7. Scale 1:48,000.

TABLES

APPENDICES

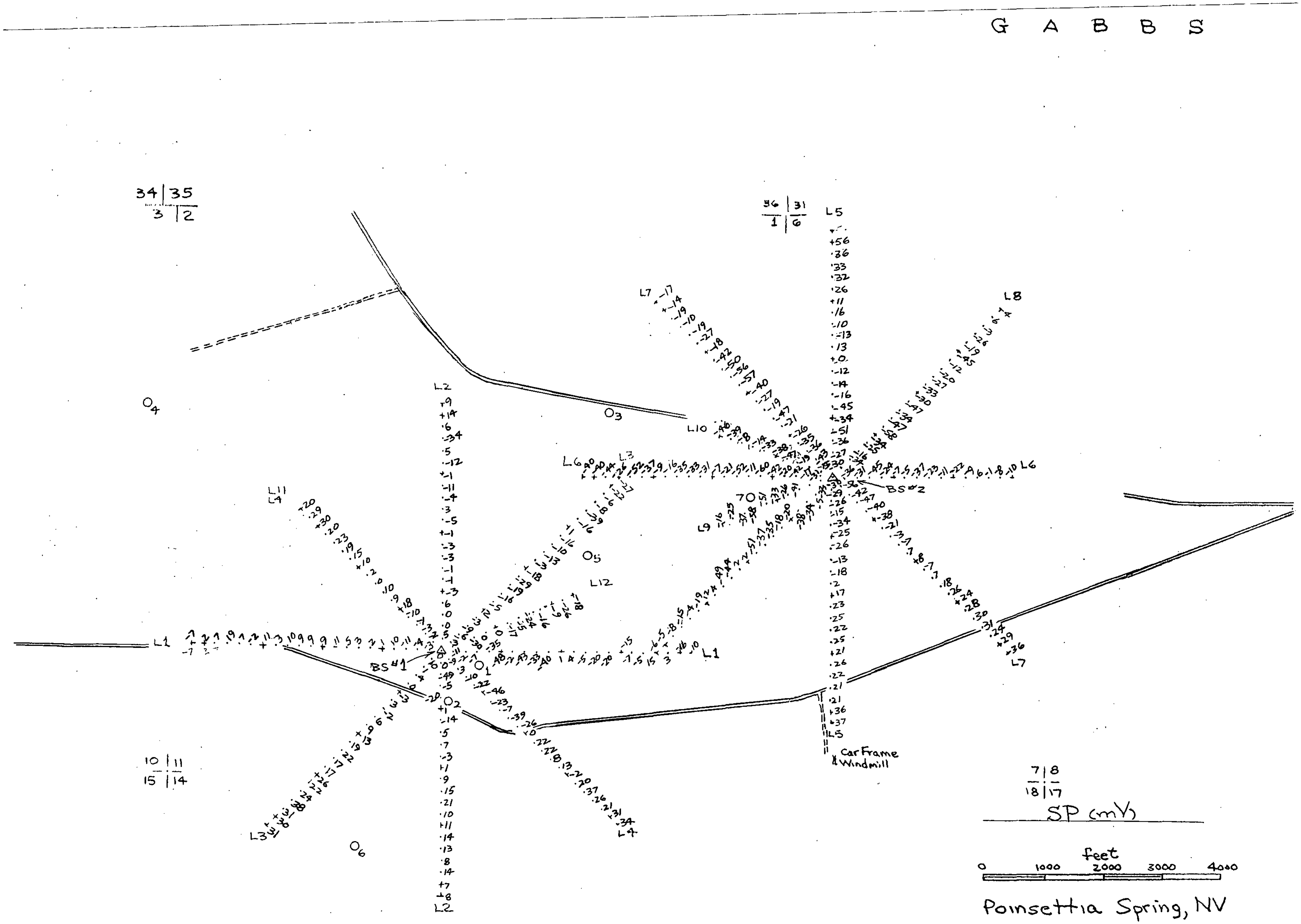
APPENDIX 3. Temperature Logs of CAR-8 drill hole, June 22, 1994 and August 22, 1994.

APPENDIX 1

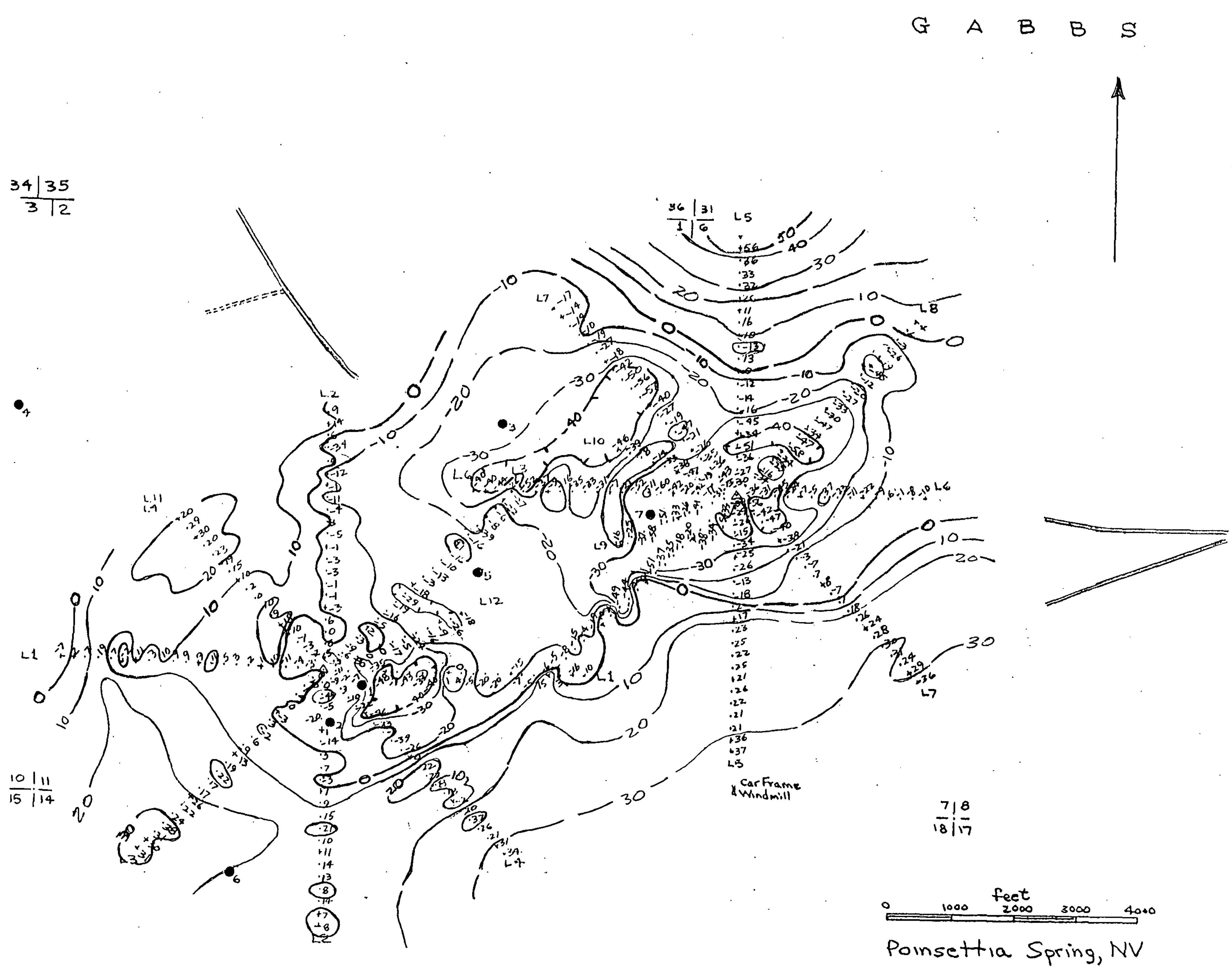
REDUCED SELF-POTENTIAL VALUES

CAR GEOTHERMAL LEASE
MINERAL COUNTY, NEVADA

Self-Potential (SP) data recorded March 28-April 1, 1994. Data reported as millivolts (mV) with respect to Base Station No. 1. Scale: 1:24,000



GABBS
34 | 35
3 | 2
36 | 31
1 | 6
L5
L8
L7
L10
L6
L3
BS#2
L9
L11
L4
O4
O3
O5
L12
L1
BS#1
O1
O2
O6
10 | 11
15 | 14
Car Frame
& Windmill
7 | 8
18 | 17
SP (mV)
feet
0
1000
2000
3000
4000
Poinsettia Spring, NV



GABBS
34 | 35
3 | 2
36 | 31
1 | 6
10 | 11
15 | 14
7 | 8
18 | 17
Car Frame & Windmill
feet
0
1000
2000
3000
4000
Poinsettia Spring, NV

APPENDIX 2

OBSERVED DIPOLE-DIPOLE ELECTRICAL RESISTIVITY DATA

CAR GEOTHERMAL LEASE
MINERAL COUNTY, NEVADA

CAR Line 1 - 500 foot dipoles

CAR Line 2 - 1000 foot dipoles

CAR Line 3 - 1000 foot dipoles

CAR Line 4 - 1000 foot dipoles

CAR Line 5 - 1000 foot dipoles

CAR Line 6 - 1000 foot dipoles

Apparent resistivity values in ohm-m.

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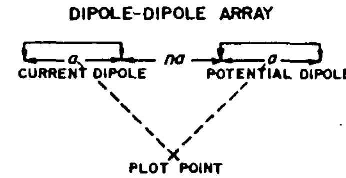
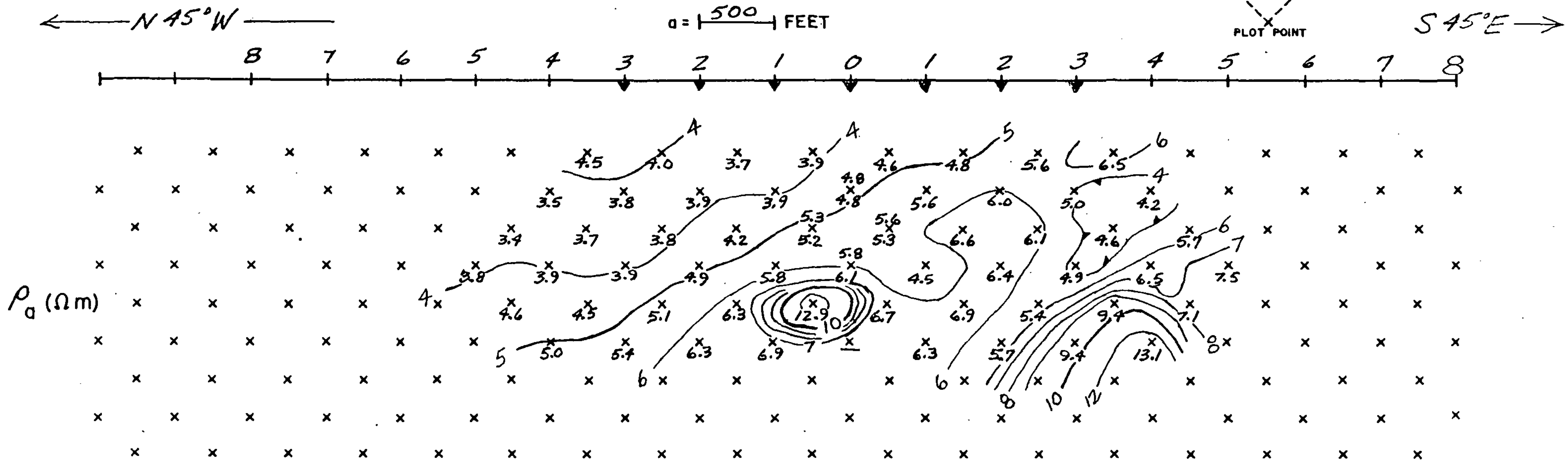
DIPOLE - DIPOLE ARRAY APPARENT RESISTIVITY





AREA CAR Lease, Mineral Co., STATE NV LINE 1 DATA BY CEM HAR DATE 4/12/94 TRANSMITTER Elliot M-15 RECEIVER Elliot Fluke

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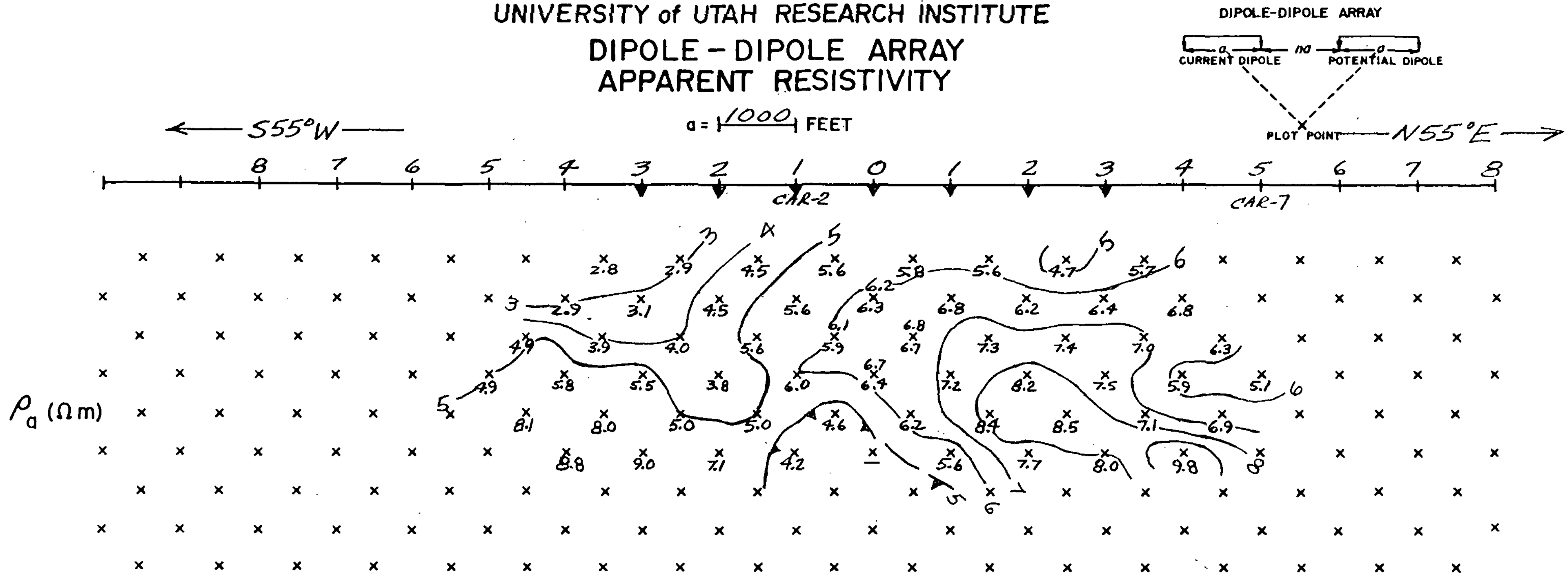
UNIVERSITY of UTAH RESEARCH INSTITUTE

DIPOLE - DIPOLE ARRAY APPARENT RESISTIVITY



AREA CAR Lease, Mineral Co., STATE NV LINE 2 DATA BY CEM / HAR DATE 4/14/94 TRANSMITTER Elliot M-15 RECEIVER Elliot Fluke

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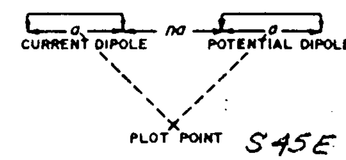
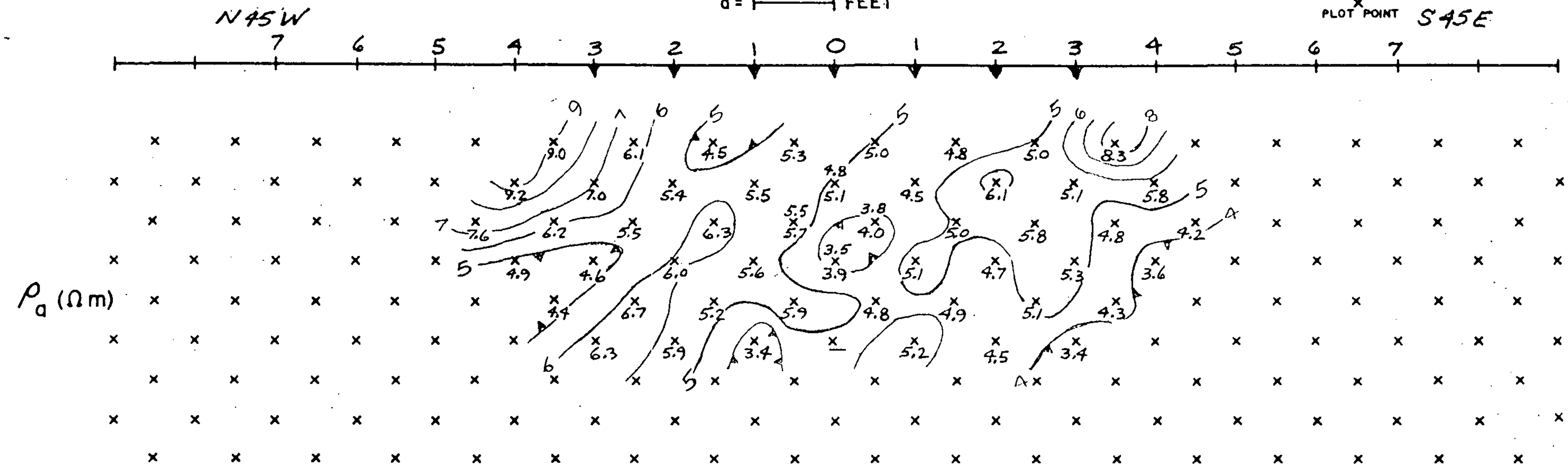
UNIVERSITY of UTAH RESEARCH INSTITUTE

DIPOLE - DIPOLE ARRAY
APPARENT RESISTIVITY



a = 1000 FEET



AREA CAR Lease, Mineral Co. STATE NV LINE 3 DATA BY CEM HRR DATE 4/16/94 TRANSMITTER Elliot RECEIVER Elliot Fluke

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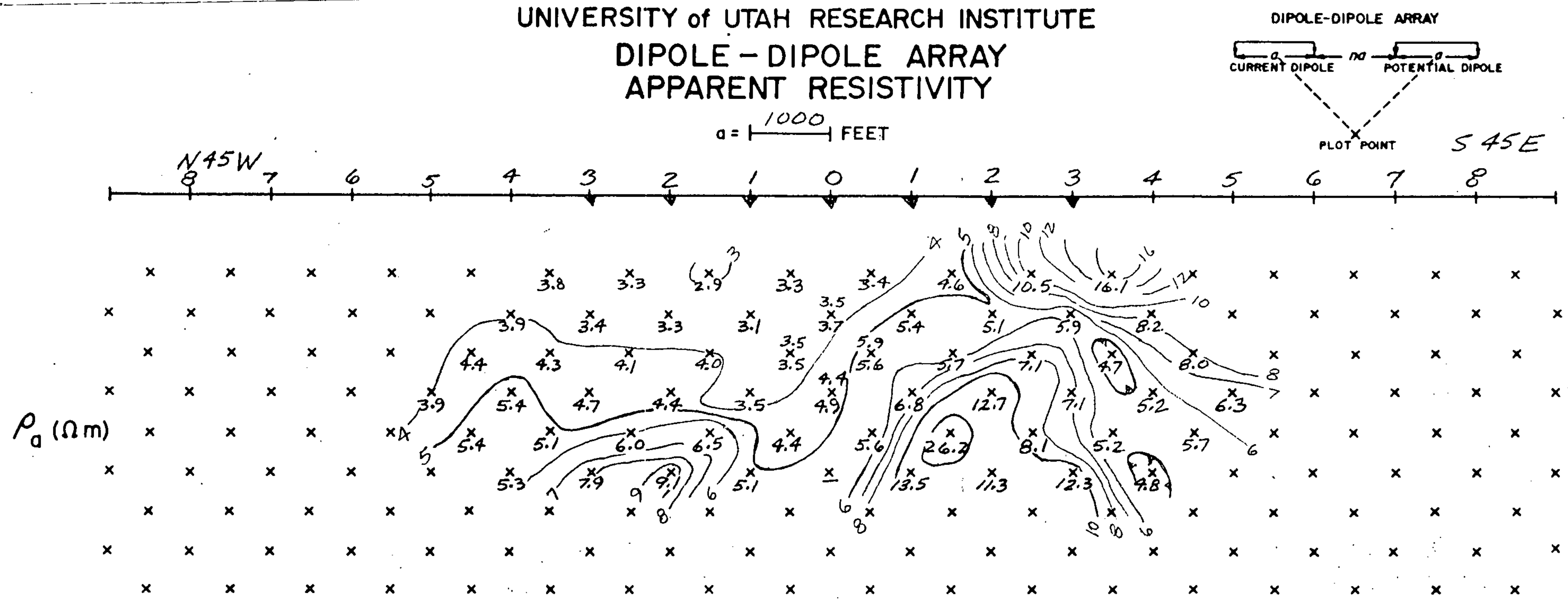
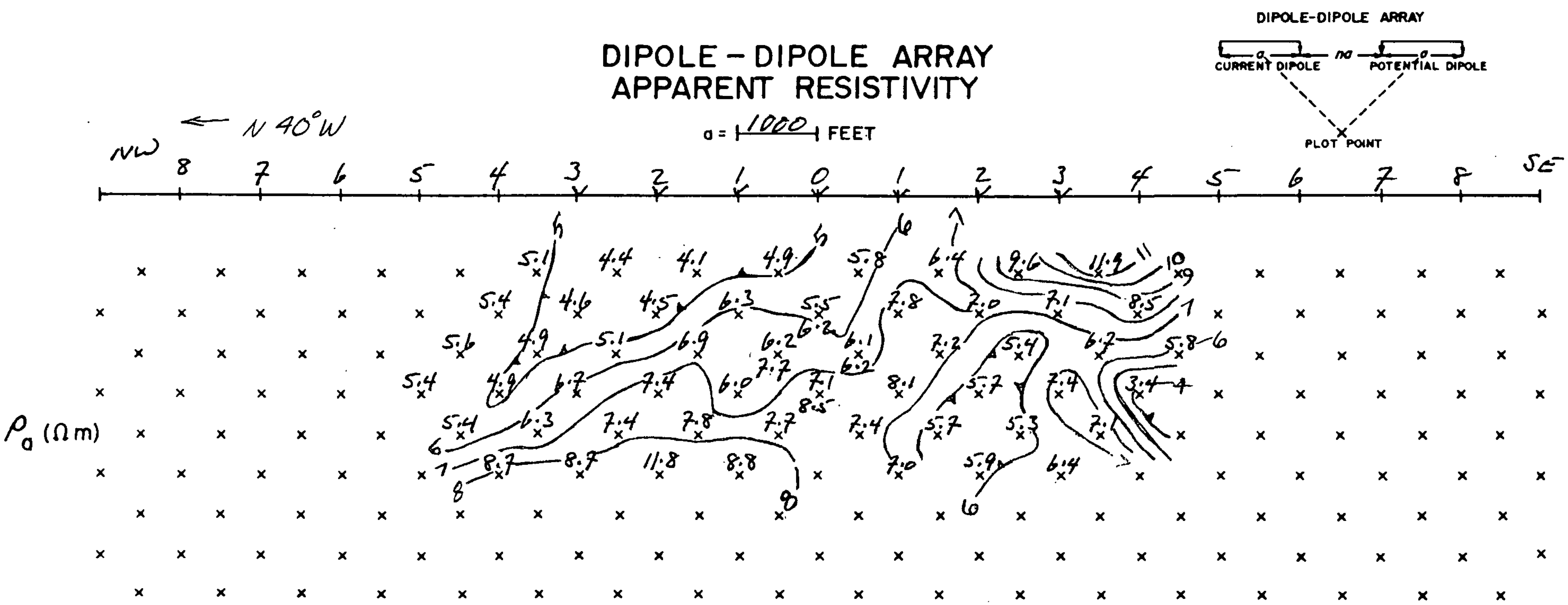
UNIVERSITY of UTAH RESEARCH INSTITUTE
DIPOLE - DIPOLE ARRAY
APPARENT RESISTIVITY



AREA CAR Lease, Mineral Co. STATE NV LINE 4 DATA BY CEM HAR DATE 4/18/94 TRANSMITTER Elliot RECEIVER Elliot Fluke

DIPOLE – DIPOLE ARRAY
APPARENT RESISTIVITY

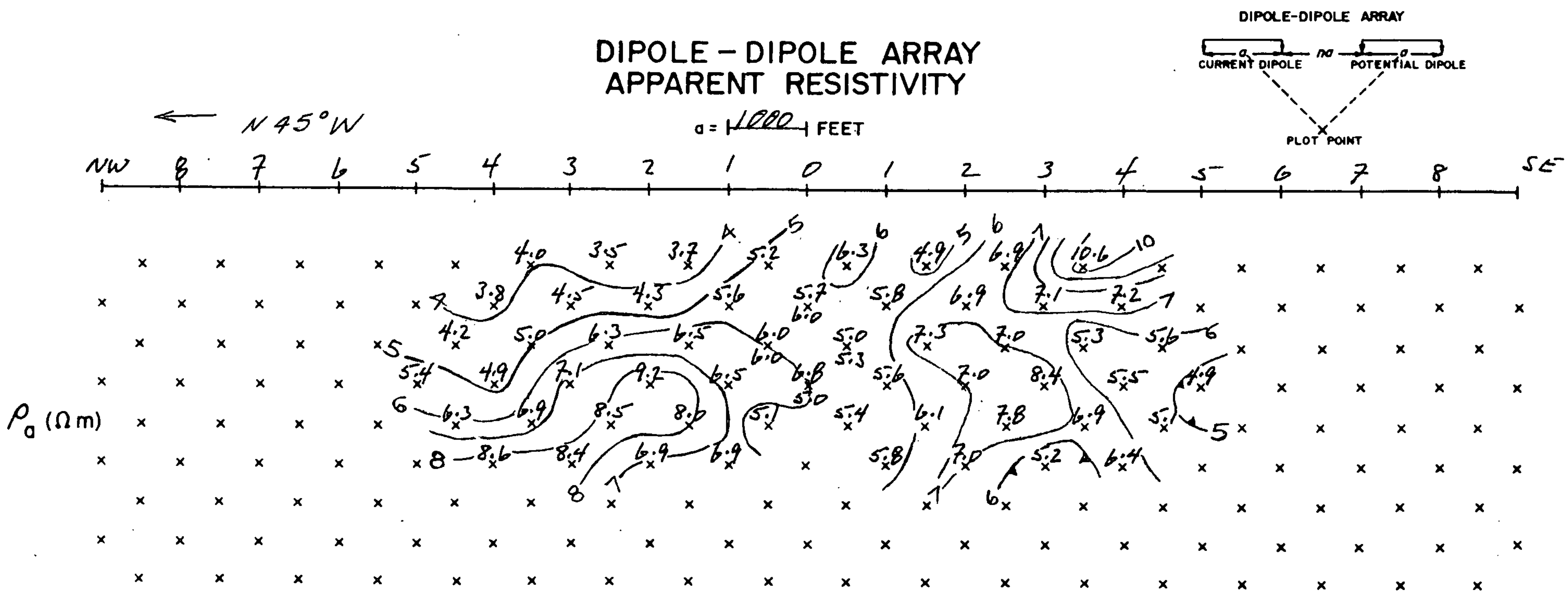
a = 1000 FEET



AREA CAR CLAIMS STATE NV LINE 5 DATA BY C.S. DATE 4/18/94 TRANSMITTER ______ RECEIVER Fluke 27

DIPOLE – DIPOLE ARRAY
APPARENT RESISTIVITY

a = 1000 FEET



AREA CAR CLAIMS STATE NV LINE 6 DATA BY C S. DATE 4/19/94 TRANSMITTER ______ RECEIVER Fluke 27

APPENDIX 3

TEMPERATURE LOGS OF CAR-8

CAR GEOTHERMAL LEASE
MINERAL COUNTY, NEVADA

Temperature log of June 22, 1994

Temperature log of August 18, 1994.

SUBSURFACE TEMPERATURE SURVEY

EARTH SCIENCE LABORATORY
UNIVERSITY OF UTAH RESEARCH INSTITUTE
420 CHIPETA WAY, SUITE 120
SALT LAKE CITY, UTAH 84108

WELL CAR-8 DATE June 22, 1994
AREA CAR GEOTHERMAL LEASE
OWNER ASARCO
LOCATION Mineral County, NV

(ATTACH SKETCH MAP)

T.D. HOLE 920 ft; Top tube = 907' = 276.46m
T.D. LOGGED 908.8 ft = 277.0 m
CASING Driller: Ron Fierbach
WATER DEPTH 134 ft = 40.85 m
AIR TEMP.
INSTRUMENT Natural Precision Inst, Probe #124
OPERATOR H. Ross & P. ViKre & D. Willis

GRADIENT
MAX. TEMP.
THERMAL COND.
HEAT FLOW
Drilling ceased @ 9:00am; T-D survey began 10:15am

DEPTH	KΩ	TEMP.	COMMENTS
0.0m		85F; 29C est.	In air; 200 scale
1.0	79.85	25.85	In air; projected R
10.0	55.95	35.30	In air; " "
20.0	34.36	48.22	In air; " "
30.0	23.72	58.27	In air; " "
40.0	27.30	54.43	In air; just above w.l.
45	29.50	52.325	
50	27.38	54.35	
55	25.42	56.37	
60	24.22	57.70	
65	22.26	60.02	
70	18.21	65.65	
75	15.04	71.115	
80	9.49	84.85	
85	3.24	121.32	
90	3.40	119.51	
95	2.80	126.91	
100	2.78	127.20	
105	3.041	123.73	20 scale (0.00x)
110	3.065	123.42	
115	3.078	123.27	
120	3.395	119.56	
125	3.239	121.33	
130	3.206	121.71	
135	3.292	120.72	
140	3.311	120.50	
145	3.323	120.36	
150	3.391	119.61	
155	3.444	119.03	
160	3.432	119.16	
165	3.363	119.92	
170	3.464	118.81	
175	3.421	119.28	
180	3.357	119.98	
185.0	3.401	119.50	

TEMPERATURE

DEPTH

SUBSURFACE TEMPERATURE SURVEY

EARTH SCIENCE LABORATORY
UNIVERSITY OF UTAH RESEARCH INSTITUTE
420 CHIPETA WAY, SUITE 120
SALT LAKE CITY, UTAH 84108

WELL CAR-8 DATE June 22, 1994
AREA CAR GEOTHERMAL LEASE
OWNER ASARCO
LOCATION Mineral County, NV

(ATTACH SKETCH MAP)

T.D. HOLE 920 ft; Top tube = 907' = 276.46m
T.D. LOGGED 908.8 ft. = 277.0 m
CASING Driller: Ron Fierbach
WATER DEPTH 134 ft. = 40.85m
AIR TEMP.
INSTRUMENT Natural Precision Inst, Probe #124
OPERATOR H. Ross & P. Vikre & D. Willis

Surface Elev, est 4255 ft (748m)
GRADIENT
MAX. TEMP.
THERMAL COND.
HEAT FLOW
Drilling ceased @ 9:00 am; T-D survey began @ 10:15 am
Mud weight = 8.4 (lbs/ft³)?

DEPTH	Ω	TEMP.	COMMENTS
190.0	3.460	118.86	
195	3.498	118.45	
200	3.568	117.72	
205	3.587	117.52	12:07 P.M.
210	3.640	116.98	
215	3.586	117.53	
220	3.630	117.08	
225	3.498	118.45	
230	3.259	121.10	
235	3.358	119.97	
240	3.337	120.21	
245	3.370	119.84	
250	2.928	125.19	
255	2.667	128.84	
260	2.662	128.91	
265	2.675	128.71	
INT. CHANGE → 270	2.656	128.99	
271	2.665	128.87	
272	2.671	128.77	
273	2.674	128.73	
274	2.693	128.45	
275	2.695	128.42	
276	2.695	128.42	
277.0	2.697	128.39	
			Read comming out
120	3.290	120.74	12:41 P.M. T still incr.
115	3.117	122.78	"
110	3.050	123.61	"
105	3.057	123.53	"
100	2.874	125.90	"
95	2.858	126.12	T decr "
90	3.677	116.61	1:00 est. "

TEMPERATURE

DEPTH

SUBSURFACE TEMPERATURE SURVEY

EARTH SCIENCE LABORATORY
UNIVERSITY OF UTAH RESEARCH INSTITUTE
420 CHIPETA WAY, SUITE 120
SALT LAKE CITY, UTAH 84108

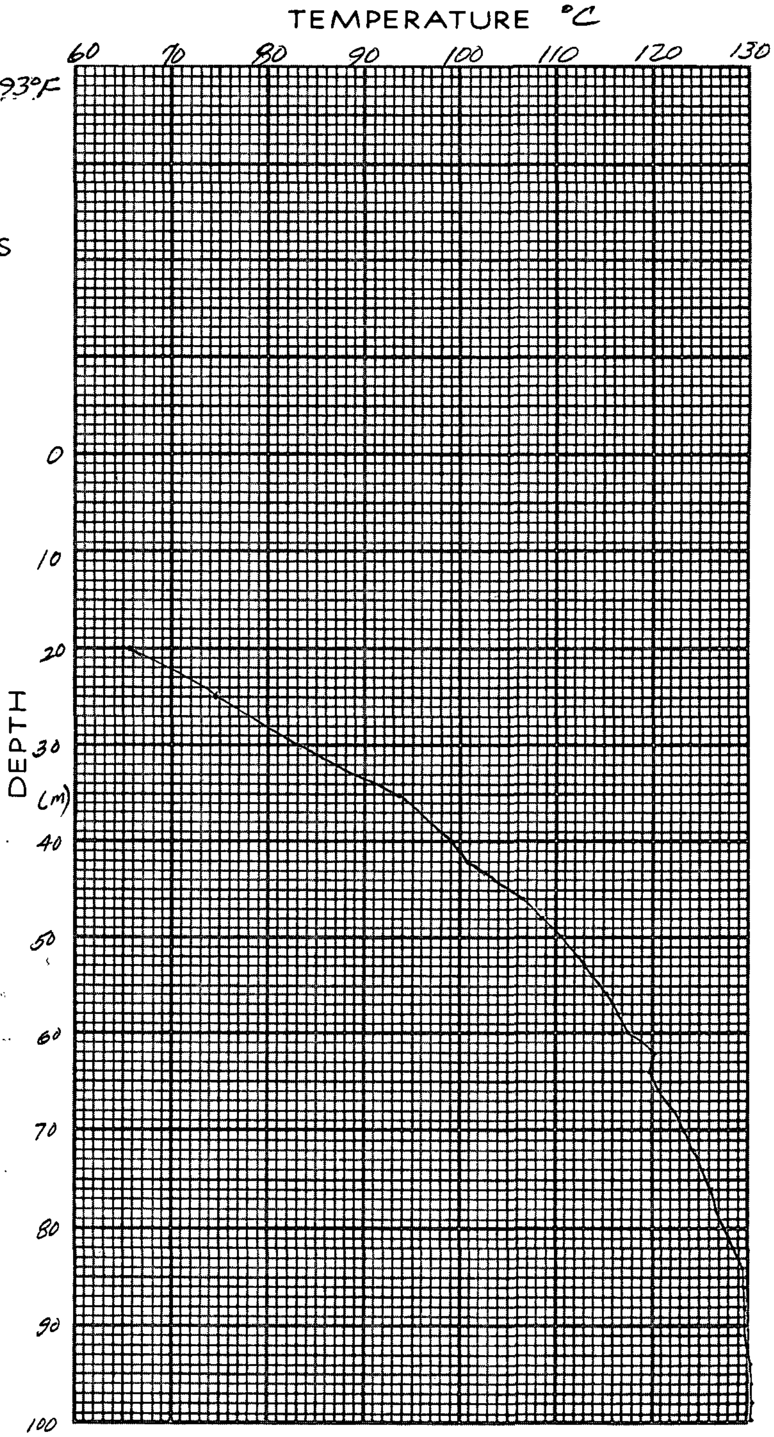
WELL CAR-8 DATE Aug. 18, 1994
AREA CAR Geothermal Lease
OWNER ASARCO
LOCATION Mineral County, NV

(ATTACH SKETCH MAP)

T.D. HOLE 1500 ft = 457.2 m
T.D. LOGGED
CASING
WATER DEPTH 35-40m (115-131 Ft.); H_2O vapor rising.
AIR TEMP. 34.13°C (93°F) @ 11:46am; >110°F mid pm.
INSTRUMENT Natural Precision Inst. Probe #124
OPERATOR H. Ross & D. Langdon

GRADIENT
MAX. TEMP.
THERMAL COND.
HEAT FLOW

DEPTH	KΩ	TEMP.	COMMENTS
0.0	58.48	34.13	In air @surface 93°F
1.0 m	62.49	32.37	"
10.0	36.23	46.81	"
20.0	18.120	65.66	" 3ppm H_2S
25.0	13.30	74.70	" 10;18 ppm H_2S
30.0	10.19	82.67	In H_2O (?)
35.0	7.22	93.47	"
40.0	6.09	99.03	"
42	5.780	100.77	minor convection
44	5.359	103.32	boiling?
46	4.94	106.11	12:37
48	4.658	108.15	
50	4.358	110.49	
52	4.128	112.42	
54	3.950	114.00	
56	3.817	115.25	
58	3.677	116.61	
60	3.565	117.75	
62	3.342	120.15	cycling; boiling?
64	3.358	119.97	
66	3.272	120.95	
68	3.163	122.23	
70	3.073	123.33	12:44
72	2.985	124.44	
74	2.926	125.21	
76	2.864	126.04	
78	2.812	126.75	
80	2.757	127.53	12:46
82	2.689	128.51	
84	2.637	129.29	
86	2.614	129.63	
88	2.600	129.84	
90	2.593	129.95	12:48
92	2.589	130.01	
94	2.586	130.06	



35/pg × 6 = 210 readings

SUBSURFACE TEMPERATURE SURVEY

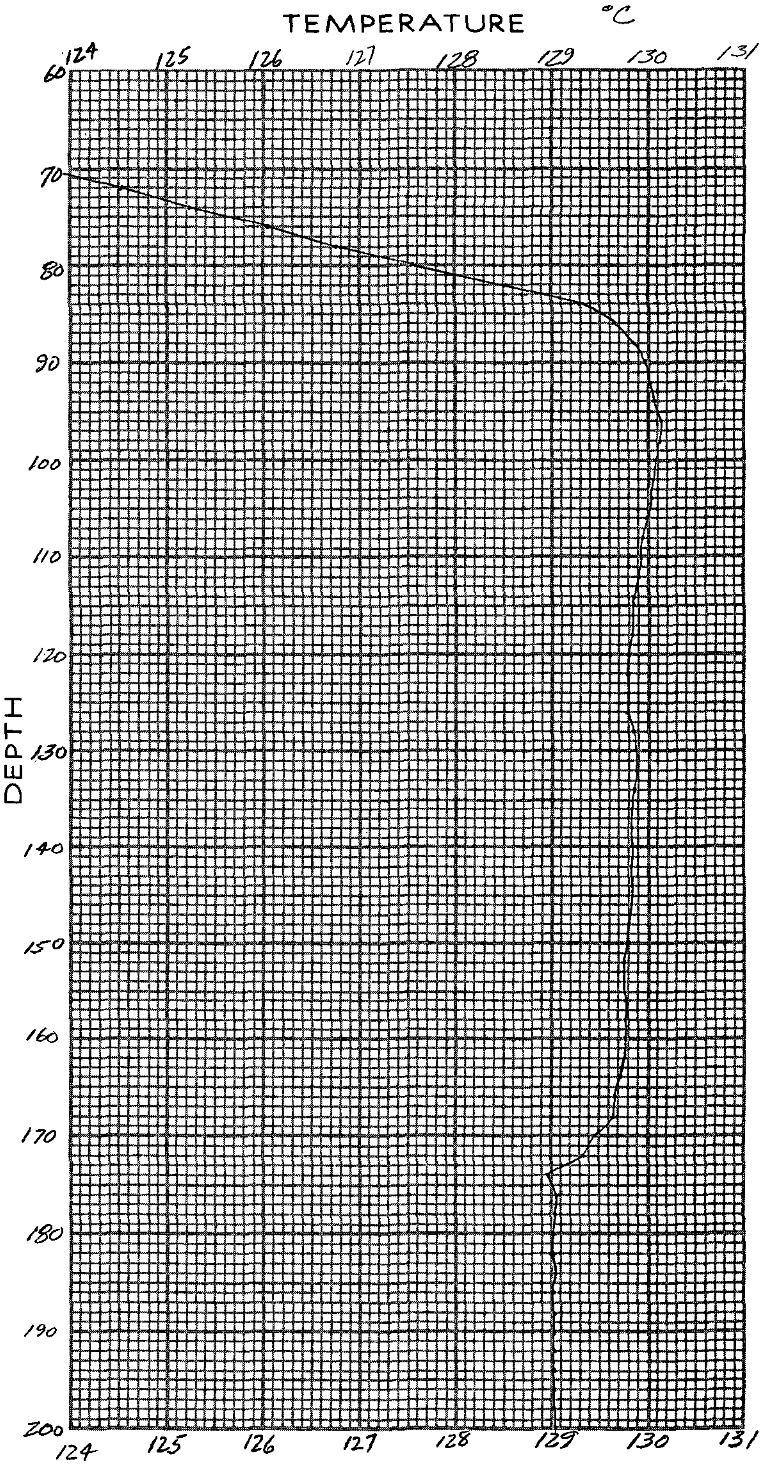
EARTH SCIENCE LABORATORY
UNIVERSITY OF UTAH RESEARCH INSTITUTE
420 CHIPETA WAY, SUITE 120
SALT LAKE CITY, UTAH 84108

WELL CAR-8 DATE Aug. 18, 1994
AREA
OWNER
LOCATION
(ATTACH SKETCH MAP)

T.D. HOLE
T.D. LOGGED
CASING
WATER DEPTH
AIR TEMP.
INSTRUMENT
OPERATOR

GRADIENT
MAX. TEMP.
THERMAL COND.
HEAT FLOW

DEPTH	Ω	TEMP.	COMMENTS
96	2.581	130.13	
98	2.582	.12	
100	2.584	.09	12:53
102	2.587	.05	
104	2.588	130.03	
106	2.591	129.99	
108	2.594	129.94	
110	2.595	.92	12:56
112	2.596	.91	
114	2.600	.85	
116	2.601	.83	
118	2.602	.82	
120	2.603	.80	12:58
122	2.603	.80	
124	2.603	.80	
126	2.603	.80	
128	2.600	.85	
130	2.598	.87	13:01
132	2.599	.86	
134	2.599	.86	
136	2.601	129.83	
138	2.601	.83	
140	2.602	.82	13:04
142	2.602	.82	
144	2.602	.82	
146	2.602	.82	
148	2.603	.80	
150	2.603	.80	13:06
152	2.604	.78	
154	2.604	.78	
156	2.604	.78	
158	2.604	.78	
160	2.604	.78	13:08
162	2.604	.78	
164	2.609	129.71	



SUBSURFACE TEMPERATURE SURVEY

EARTH SCIENCE LABORATORY
UNIVERSITY OF UTAH RESEARCH INSTITUTE
420 CHIPETA WAY, SUITE 120
SALT LAKE CITY, UTAH 84108

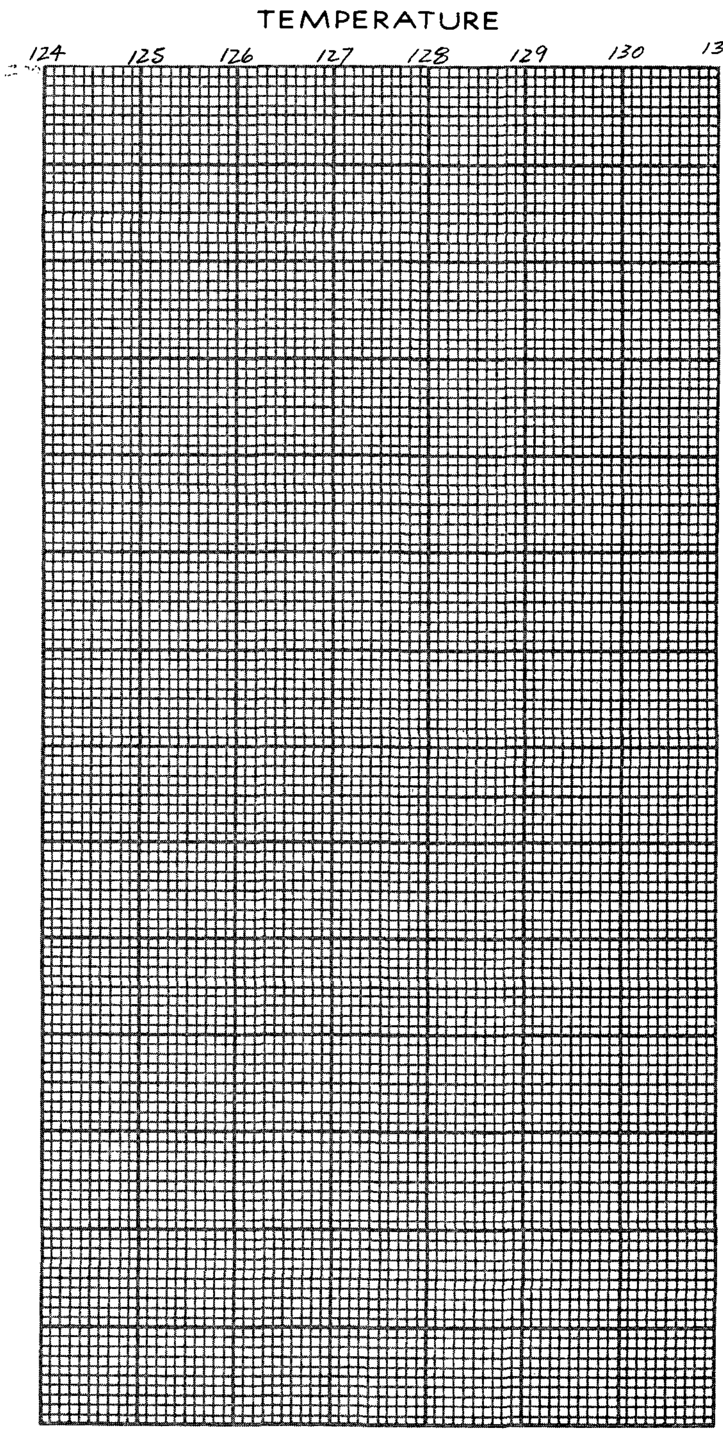
WELL CAR-8 DATE Aug. 18, 1994
AREA
OWNER
LOCATION

(ATTACH SKETCH MAP)

T.D. HOLE
T.D. LOGGED
CASING
WATER DEPTH
AIR TEMP.
INSTRUMENT
OPERATOR

GRADIENT
MAX. TEMP.
THERMAL COND.
HEAT FLOW

DEPTH	Ω	TEMP.	COMMENTS
166	2.611	129.68	Reading on 20 Scale
168	2.612	.66	
170	2.627	.44	13:09
172	2.635	.32	
174	2.657	128.98	
176	2.652	129.05	
178	2.654	.03	
180	2.655	.01	13:11 wellhead 0PPM H2S
182	2.656	129.00	
184	2.654	.02	
186	2.655	.01	
188	2.655	.01	
190	2.655	.01	13:14
192	2.655	.01	
194	2.655	.01	
196	2.655	.01	
198	2.655	.01	
200	2.654	.02	13:17
202	2.654	.03	
204	2.653	.04	
206	2.652	.05	
208	2.650	.08	
210	2.648	.11	13:18
212	2.649	.10	
214	2.649	129.10	
216	2.649	.10	
218	2.648	.12	
220	2.648	.12	13:20
222	2.646	.14	
224	2.643	.20	
226	2.641	.23	
228	2.638	.27	
230	2.635	.32	13:32
232	2.634	.33	
234	2.632	129.36	



SUBSURFACE TEMPERATURE SURVEY

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UNIVERSITY OF UTAH RESEARCH INSTITUTE
420 CHIPETA WAY, SUITE 120
SALT LAKE CITY, UTAH 84108

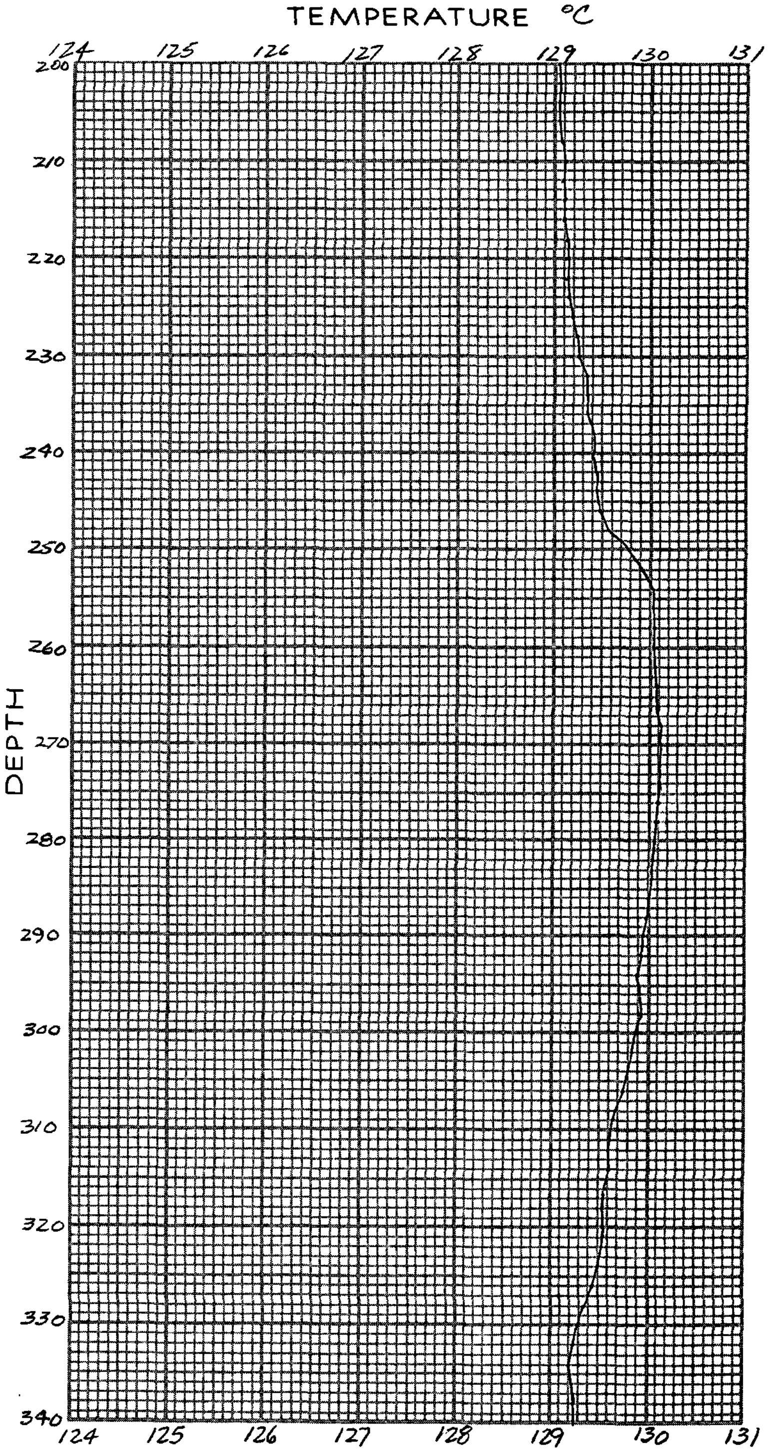
WELL CAR-8 DATE Aug 18, 1994
AREA
OWNER
LOCATION

(ATTACH SKETCH MAP)

T.D. HOLE
T.D. LOGGED
CASING
WATER DEPTH
AIR TEMP.
INSTRUMENT
OPERATOR

GRADIENT
MAX. TEMP.
THERMAL COND.
HEAT FLOW

DEPTH	Ω	TEMP.	COMMENTS
236	2.632	129.36	
238	2.629	.41	
240	2.629	.41	13:23
242	2.627	.44	
244	2.626	.45	
246	2.623	.49	
248	2.617	.58	
250	2.605	.77	13:24
252	2.596	.91	
254	2.589	130.01	
256	2.589	.02	
258	2.588	.03	
260	2.587	.05	13:26
262	2.587	.05	
264	2.585	.07	
266	2.585	.07	
268	2.583	.11	
270	2.583	.11	13:27
272	2.583	.11	
274	2.583	.11	
276	2.584	.10	
278	2.585	.08	
280	2.587	.05	13:28
282	2.588	.03	
284	2.589	130.02	
286	2.590	130.00	
288	2.591	129.99	
290	2.594	129.94	13:30
292	2.596	.91	
294	2.597	.89	
296	2.596	.91	
298	2.596	.91	
300	2.597	.89	13:31
302	2.600	.85	
304	2.603	129.80	



SUBSURFACE TEMPERATURE SURVEY

EARTH SCIENCE LABORATORY
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420 CHIPETA WAY, SUITE 120
SALT LAKE CITY, UTAH 84108

WELL CAR-8 DATE Aug. 18, 1994
AREA
OWNER
LOCATION

(ATTACH SKETCH MAP)

T.D. HOLE
T.D. LOGGED
CASING
WATER DEPTH
AIR TEMP.
INSTRUMENT
OPERATOR

GRADIENT
MAX. TEMP.
THERMAL COND.
HEAT FLOW

DEPTH	Ω	TEMP.	COMMENTS
306	2.606	129.75	
308	2.610	.69	
310	2.615	.61	13:34
312	2.616	.60	
314	2.616	.60	
316	2.617	.58	
318	2.619	.55	
320	2.619	.55	13:35
322	2.620	.54	
324	2.623	.50	
326	2.627	.44	
328	2.632	.36	
330	2.637	.29	13:38
332	2.641	.22	
334	2.643	.20	
336	2.641	.22	
338	2.639	129.25	
340	2.639	.25	13:40
342	2.644	.18	
344	2.649	.10	
346	2.649	.10	
348	2.645	.17	
350	2.638	.27	13:41
352	2.635	.31	
354	2.634	.33	
356	2.634	.33	
358	2.634	.33	
360	2.634	.33	13:43
362	2.635	.32	
364	2.635	.32	
366	2.636	.30	
368	2.636	.30	
370	2.636	.30	13:47
372	2.637	.28	
374	2.637	129.28	

TEMPERATURE

DEPTH

SUBSURFACE TEMPERATURE SURVEY

EARTH SCIENCE LABORATORY
UNIVERSITY OF UTAH RESEARCH INSTITUTE
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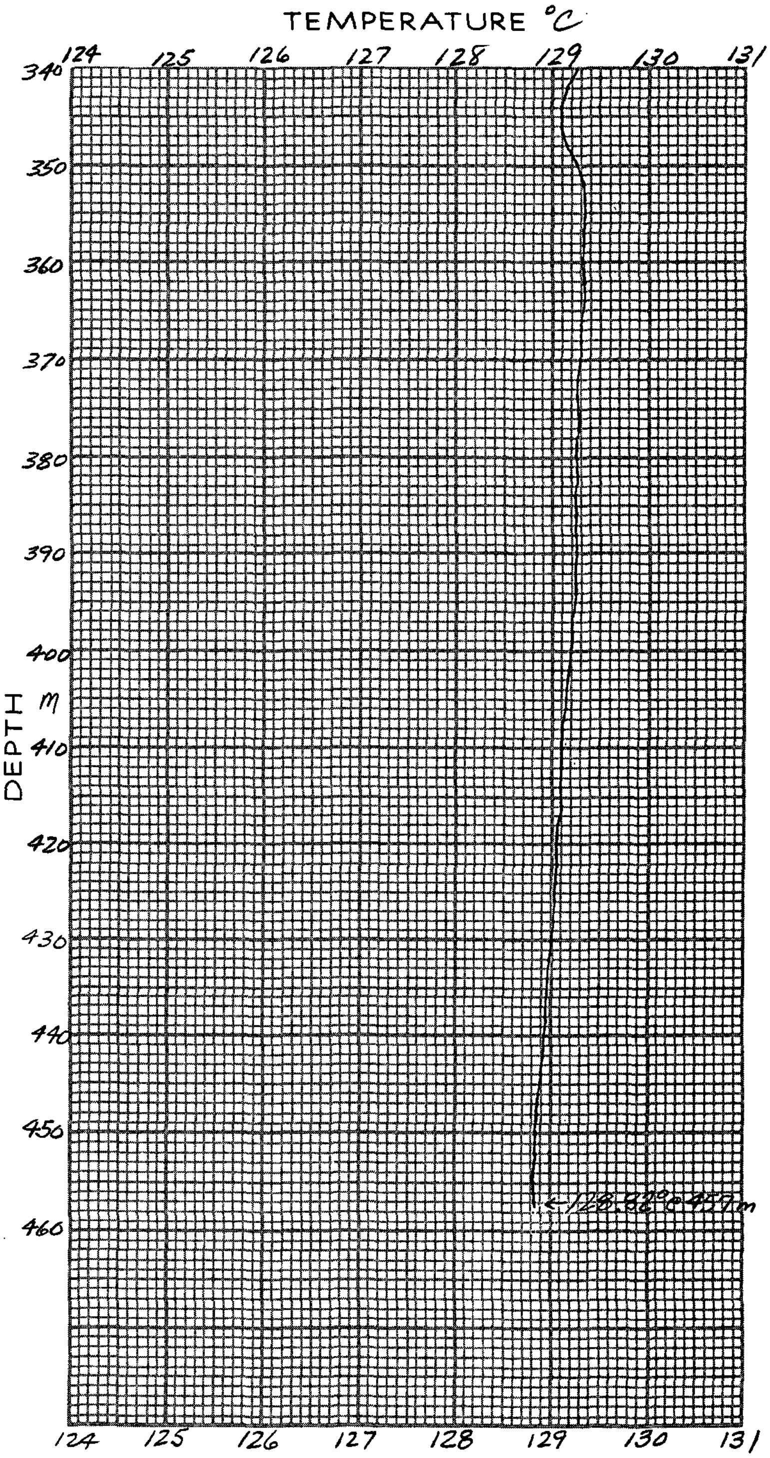
WELL CAR-8 DATE Aug. 18, 1994
AREA
OWNER
LOCATION

(ATTACH SKETCH MAP)

T.D. HOLE
T.D. LOGGED
CASING
WATER DEPTH
AIR TEMP.
INSTRUMENT
OPERATOR

GRADIENT
MAX. TEMP.
THERMAL COND.
HEAT FLOW

DEPTH	Ω	TEMP.	COMMENTS
376	2.637	129.29	
378	2.638	.27	
380	2.638	.27	13:49
382	2.638	.27	
384	2.639	.25	
386	2.639	.25	
388	2.640	.24	
390	2.640	.24	13:50
392	2.641	.22	
394	2.641	.22	
396	2.642	.21	
398	2.642	.21	
400	2.643	129.20	13:52
402	2.644	.18	
404	2.645	.16	
406	2.646	.15	New Battery
408	2.648	.11	
410	2.649	.10	14:03
412	2.649	.10	
414	2.649	.10	
416	2.649	.10	
418	2.650	.08	
420	2.651	.07	14:04
422	2.652	.05	
424	2.653	.04	
426	2.654	.02	
428	2.655	.01	
430	2.656	129.00	14:06
432	2.657	128.98	
434	2.658	.97	
436	2.659	.96	
438	2.660	.94	
440	2.661	.93	
442	2.662	.91	
444	2.663	128.90	



SUBSURFACE TEMPERATURE SURVEY

EARTH SCIENCE LABORATORY
UNIVERSITY OF UTAH RESEARCH INSTITUTE
420 CHIPETA WAY, SUITE 120
SALT LAKE CITY, UTAH 84108

WELL CAR-8 DATE Aug. 18, 1994
AREA
OWNER
LOCATION

(ATTACH SKETCH MAP)

T.D. HOLE
T.D. LOGGED
CASING
WATER DEPTH
AIR TEMP.
INSTRUMENT
OPERATOR

GRADIENT
MAX. TEMP.
THERMAL COND.
HEAT FLOW

DEPTH	Ω	TEMP.	COMMENTS
446	2.664	128.88	
448	2.665	.87	
450	2.666	.85	14:12
452	2.667	.84	
454	2.668	.82	
455	2.668	.82	
456	2.668	.82	14:14 6+ ppm H_2S
457	2.668	128.82	14:15 T.D. = 1499.3 ft.
400 *	2.643	129.19	14:24 : to 10+ ppm H_2S
350 *	2.638	129.27	14:29 : .018 ppm H_2S 000 ppm
300 *	2.606	129.84	14:33
250 *	2.601	129.83	14:45
200 *	2.655	129.01	14:51
150 *	2.605	129.78	14:56
100 *	2.589	130.01	14:59
50 *	4.251	111.37	3:08
0	28.–	53.74	3:14 128°F (?)

Comming up hole *

TEMPERATURE

DEPTH