BIPOLE-DIPOLE SURVEY AT ROOSEVELT HOT SPRINGS
THERMAL AREA, BEAVER COUNTY, UTAH

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MASTER

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EARTH SCIENCE LABORATORY

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Salt Lake City, Utah

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September, 1980

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ABSTRACT

A bipole-dipole electrical resistivity survey at Roosevelt Hot Springs thermal area, Beaver County, Utah was undertaken to evaluate the technique in a well-studied Basin and Range geothermal prospect. The major electrical characteristics of the area are clearly revealed but are not particularly descriptive of the geothermal system. More subtle variations of electrical resistivity accompanying the geothermal activity are detectable, although the influence of near-surface lateral resistivity variations imposes upon the survey design the necessity of a high station density. A useful practical step is to conduct a survey using transmitter locations and orientations which minimize the response of known features such as the resistivity boundary due to a range front fault.

Survey results illustrate the effects of transmitter orientation and placement, and of subtle lateral resistivity variations. A known near-surface conductive zone is detected while no evidence is found for a deep conductive region.

INTRODUCTION

This report presents the results of a bipole-dipole survey conducted at Roosevelt Hot Springs thermal area during June 1979. The survey was undertaken to evaluate the utility of the technique for geothermal prospecting. Survey planning incorporated information regarding the resistivity structure derived from dipole-dipole surveys reported by Ward and Sill (1976), and magnetotelluric investigations interpreted by Wannamaker (1978) and Wannamaker et al. (1980). Also important in the survey design are the hypotheses presented by Doicin (1976, 1977) and the numerical modeling results due to Dey and Morrison (1977) and to Hohmann and Jiracek (1979).

Roosevelt Hot Springs thermal area is located on the west flank of the Mineral Mountains about eight miles NNE of the town of Milford, Utah in Beaver County (Figure 1). The area has been studied intensively by investigators from the Department of Geology and Geophysics of the University of Utah and the Earth Science Laboratory of the University of Utah Research Institute. Several geologic maps have been produced covering all or portions of the Mineral Mountains; particular reference is made here to that of Nielson et al. (1978). Studies of wall rock alteration and hydrothermal effects by Parry et al. (1978) are of central importance to development of the hypothetical electrical target.

The principal geothermal target for electrical prospecting techniques is generally held to be a large conductive region

Figure 1
Location of
Roosevelt Hot Springs
Thermal Area

associated with the geothermal reservoir. Factors plausibly contributing to increased conductivity include an increase of water conductivity due to higher temperature and salinity, increased porosity due to fracturing and mineral dissolution, and increased surface conduction due to clay alteration. Furthermore, a cooling pluton consisting of a silicate melt or partial melt can be expected to have a very high conductivity (see laboratory and theoretical evidence summarized by Wannamaker et al., 1980). On the other hand, mitigating factors include a sharp decrease of water conductivity at very high temperatures due to ion association (Quist and Marshall, 1969), the possibility of vapor-dominated regions within the system (White et al., 1971), decreased permeability due to reprecipitation of silica at high temperatures (Fournier, 1978), and uncertainty about the role of porosity in a geothermal reservoir.

Empirical evaluation of the hypothesis of the existence of a conductive reservoir target has yielded mixed results. The Broadlands geothermal field, on New Zealand's North Island, is a distinctly conductive target of about four kilometers diameter (Bibby and Risk, 1973), readily defined by its electrical properties. In the United States, the Yellowstone geothermal system has been shown to have a large conductive zone associated with the Mud Volcano reservoir area (Zhody et al., 1973). This latter zone is reportedly due to hot water and alteration minerals overlying a vapor-dominated region. On the other hand, the Beowawe, Nevada KGRA has only a narrow conductive zone (Smith, 1979) as an electrical expression. Another example of a

geothermal system with little conductive material is the Cove Fort-Sulphurdale KGRA in Utah (Ross, 1979). At the Roosevelt Hot Springs thermal area, magnetotelluric, controlled-source audiomagnetotelluric, and dipole-dipole resistivity data reveal no significant deep-seated conductive region but they have identified a shallow conductive zone which clearly correlates with the region of anomalously high heat flow.

GEOPHYSICS

General

The general geometry of the bipole-dipole array is indicated in plan view as Figure 2. The array is designed to map the electric field at the surface of the earth which is caused by a pair of current electrodes, shown as A and B in Figure 2. Potential difference is observed along two orthogonal pairs of voltage electrodes in order to define the gradient of the potential, or the electric field, at the observation site. In practice a common point was used between the receiving dipoles; as shown in Figure 2, the voltage electrodes are the points L, M, and N.

The same general geometry has been employed under different names in the past, the distinctions usually referring to the assumptions involved in processing the results. Historically our nomenclature has been neither precise nor consistent in this regard. Such diverse appellations as roving dipole, dipole-dipole, bipole-quadripole, dipole mapping, and electric-field mapping have been applied to surveys conducted in this manner. Some authors prefer to reserve the term "dipole" for configurations where either or both transmitting and receiving electrode separations are of negligible length compared to the distance between the transmitter and receiver, (c.f., Keller's introduction in Al'pin et al., 1966). Others require that the four receiving electrodes be recognized in the name and/or mathematics and use the term "quadripole." Semantics aside, we settle upon the term "bipole-dipole array" for historic and intuitive reasons.

Figure 2: Generalized Geometry of the Bipole-Dipole Array, Plan View; Position & Orientation of Receiver are Arbitrary

Maps of electric fields are not very useful by themselves, so a method of presenting results which assists geologic inference is advisable. The concept of apparent resistivity has gained wide acceptance because of its simplicity, versatility, and implicit physical significance. Qualitatively, apparent resistivity is the resistivity of a homogeneous conductive medium which would yield the same electrical terminal constraints as those observed. It allows for geometric variations between transmitter and receiver and of the medium itself (i.e., whole space, half space, etc.), and for experimental parameters (e.g., source current, waveform employed, etc.). As applied here, the apparent resistivity is assumed to be purely real and due to conduction only. Furthermore, the apparent resistivity is calculated herein from the difference in potential between discrete points due to current injected at distinct points, rather than from an approximated electric field due to an approximated infinitesimal electric dipole; the method used retains accuracy at small transmitter-receiver separations where the field-and-dipole approximation breaks down.

Geometric factors may be calculated to relate observed receiver voltages to apparent resistivities, given all the electrode locations and the transmitter current. These factors may be contoured conveniently on a map overlay to facilitate direct data reduction in the field whenever standardized receiver and transmitter lengths are employed. An example of such an overlay for receiver and transmitter lengths of 100 meters and 2380 meters, respectively, is shown as

Figure 3. Only one quarter of the figure is reproduced since the geometric factors have two-fold symmetry.

The geometric factors may be calculated by assuming an x-directed transmitter of separation L (refer to Figure 4), i.e., electrodes at $(\pm L/2, 0)$. Voltage difference along an x-directed pair of receiver electrodes of separation ℓ will be

$$V_x = \frac{I \rho_{ax}}{2\pi} \left(\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{r_3} + \frac{1}{r_4} \right), \quad (1)$$

where

I is the transmitter current,

ρ_{ax} is apparent resistivity,

$$r_1 = [(x - L/2)^2 + y^2]^{1/2}, \quad (2)$$

$$r_2 = [(x + L/2)^2 + y^2]^{1/2}, \quad (3)$$

$$r_3 = [(x + \ell - L/2)^2 + y^2]^{1/2}, \quad (4)$$

and

$$r_4 = [(x + \ell + L/2)^2 + y^2]^{1/2}. \quad (5)$$

Along a similar y-directed receiving pair the voltage will be

$$V_y = \frac{I \rho_{ay}}{2\pi} \left(\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{r_5} + \frac{1}{r_6} \right), \quad (6)$$

where

I , ρ_{ay} , r_1 , and r_2 are as above,

$$r_5 = [(x - L/2)^2 + (y + \ell)^2]^{1/2}, \quad (7)$$

Figure 3: Typical Geometric Factor Overlay

Figure 4: Parameters Used for Geometry Factor Calculation

and

$$r_6 = [(x + L/2)^2 + (y+l)^2]^{1/2} . \quad (8)$$

Geometric factors appropriate to the two individual components may then be written as

$$Q_x = 2\pi \left(\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{r_3} + \frac{1}{r_4} \right)^{-1} , \quad (9)$$

and

$$Q_y = 2\pi \left(\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{r_5} - \frac{1}{r_6} \right)^{-1} . \quad (10)$$

Either of equations 1 or 6 may be used to calculate apparent resistivities if the receiving spreads are appropriately oriented. In the case of the typical non-uniform earth, the two apparent resistivities will not generally be equal. We usually wish apparent resistivity to be independent of receiver orientation and to be finite and continuous throughout space. That neither of the resistivities ρ_{ax} or ρ_{ay} satisfy the criteria is readily demonstrated. Potential electrodes placed on a half space equipotential line yield an infinite apparent resistivity, since the radius terms in Equations 1 and 6 sum to zero. In a field survey, the electric field will be distorted from that predicted for a homogeneous half space by the inhomogeneities present. When the potential electrodes are placed on an equipotential line in this distorted field, such that the observed voltage is zero, an apparent resistivity of zero results. Similar considerations can be developed for other coordinate systems (c.f., the treatment of radial and azimuthal components of the electric field by Keller et

al., 1975).

Combining the two expressions above under the assumption of a locally unidirectional field gets around these problems. This assumption is satisfied when the receiving dipoles are short with respect to the distance from the nearest transmitter electrode. Then we apply the approximation:

$$V = [V_x^2 + V_y^2]^{1/2} = [(\frac{\rho_{ax}I}{Q_x})^2 + (\frac{\rho_{ay}I}{Q_y})^2]^{1/2} \quad (11)$$

In so doing we find an expression for apparent resistivity based upon the potential difference due to the total field

$$\rho_a = \frac{V}{I} [\frac{1}{Q_x^2} + \frac{1}{Q_y^2}]^{-1/2} = \frac{V}{I} Q' , \quad (12)$$

where ρ_a is the bipole-dipole apparent resistivity and Q' is the geometric factor.

The development of the geometric factor presented here differs from the ones commonly employed in the literature (viz., Al'pin et al., 1966; Keller et al., 1975) in that neither transmitter nor receiver length is presumed negligible, nor is transmitter-receiver separation presumed large. When the latter separation is large, the present solution converges to the familiar one. For receiver positions near a transmitter electrode, the present assumptions can be satisfied by the practical step of shortening receiver separations, while for other close positions (e.g., receiver dipole pairs near the center of the transmitting bipole), the present form is correct

without modification.

For convenience, any necessary conversion factors and constants are often included in the geometric factor. Among these are the corrections for waveforms occasioned by the particular instruments in use. Herein we will include within the geometric factor the corrections necessary to apply field units of meters, amperes, and millivolts as recorded by the various instruments involved, calling the corrected geometric factor Q . Thus we obtain

$$\rho_a = \frac{V}{I} Q. \quad (13)$$

The lateral asymmetry of the geometric factors of Figure 2 portrays an important characteristic of the bipole-dipole array: responses due to electrical inhomogeneities are functions of transmitter orientation. This aspect has been noted and treated for a number of simple geometries (e.g., Al'pin et al., 1966; Doicin, 1976; Bibby and Risk, 1973; and Keller et al., 1975). More complicated inhomogeneities have been treated by Dey and Morrison (1977) and by Hohmann and Jiracek (1979). An important and general conclusion of all this inquiry is that transmitter orientation effects are a significant consideration for the interpretation of bipole-dipole survey results. Several schemes for dealing with transmitter orientation effects have been presented; early efforts by Breusse and Astier (1961) lead to a vector cross product technique proposed by Stefanescu and Tanasescu (1965) and advocated by Doicin (1976) and Doicin et al., (1965).

The so-called quadripole-quadripole method involves observing the orthogonal electric field or components due to two orthogonal transmitter bipoles and calculating an apparent resistivity from the vector cross product of the two resultant fields. Doicin (1976) derives the appropriate data reduction formula which is

$$\rho_{qq} = \frac{2}{QIK} [|\vec{E}_1 \times \vec{E}_2|]^{\frac{1}{2}}. \quad (14)$$

where

E_1 is the electric field due to one transmitter pair,

E_2 is the electric field due to the orthogonal transmitter pair,

K is the square root of the magnitude of the vector cross product of the fields expected at the survey point in a homogeneous earth,

and, Q is the geometric factor of equation 13.

He also presents results of numerical model studies employing alpha-centers (Stefanescu and Stefanescu, 1974) and vertical contacts which demonstrate the superior lateral resolution of quadripole-quadripole data with respect to simple bipole-dipole results. This aspect is of particular importance in determining the lateral extent of anomalous bodies since, as Hohmann and Jiracek (1979) point out, boundaries perpendicular to current flow are well resolved while those parallel to current flow are poorly resolved. The vector cross product method takes advantage of this fact, incorporating the effect of the perpendicular current flow in all data points.

Survey Procedure

The present survey employed a Zonge Engineering and Research Organization GDP-12 receiver and a Geotronics Corporation FT-20 transmitter. The receiving lines were consistently 100 meters long and oriented within ± 3 degrees of orthogonality. The transmitter lines varied according to available space, being generally about 2 kilometers long. A pair of stable quartz-oscillator clocks served as a phase reference between transmitter and receiver. Typical time error between the clocks after a ten-hour work day was about 100 microseconds, or 0.04 milliradians at 0.0625 Hz, effectively negligible when compared to uncertainties of phase estimates due to electrical noise. Typical transmitter currents of 10 to 15 amps and receiver sensitivities to 20 to 30 microvolts, depending on natural noise, permitted reliable observations out to transmitter-receiver separations of 9 kilometers. All stations were read at transmitter frequencies of 1 Hz, 0.25 Hz, and 0.0625 Hz.

The Geotronics transmitter accurately maintains a square wave of current, the recorded magnitude of which is the peak amplitude of the square wave. The Zonge receiver records the peak amplitude of the fundamental component of the square wave from a fast Fourier transform performed on a stacked waveform. A correction factor of $\pi/4$ is included in the geometric factors to compensate for the difference in recorded voltage and current wave forms.

All stations were located by reference to recognizable features on a 1:24,000 scale topographic base map whenever possible (Figure 5). Occasionally, remote stations were triangulated from known points

Figure 5

Topographic Base Map, Roosevelt Hot Springs KGRA,
Beaver County, Utah. Six section corners are marked
on this figure and on Figures 6 through 14 to fac-
ilitate correlation. A, B, and C, indicate transmit-
ter locations.

FIGURE 5
TOPOGRAPHIC BASE MAP,
ROOSEVELT HOT SPRINGS KGRA
BEAVER COUNTY, UTAH

using a Brunton compass; locational uncertainty estimated by multiple replicate sightings in such cases is generally less than 100 meters. Transmitter electrodes, when not positioned by reference to recognized features, were located by calibrated vehicle odometer. A similar locational uncertainty of 100 meters is estimated for the transmitting electrodes.

Three transmitter sites were occupied, each one consisting of two bipoles oriented as nearly orthogonal to one another as possible (Figure 5). The three were positioned for a representative sampling of the electrical environments known to be present. Transmitter A (Figure 5) is positioned at the margin of the geothermal zone and at the boundary between the conductive valley fill and resistive bedrock of the Mineral Mountain. The east-west bipole straddles the boundary, having one electrode well within the conductive zone previously described (Ward and Sill, 1976) and the other well out of it. This positioning should yield good resolution of the shallow conductive body (viz., Bibby and Risk, 1973 and Hohmann and Jiracek, 1979). Should a deep conductive body underlie this region, it should be well resolved. An unusually dense receiver station density is employed in the immediate vicinity of Transmitter A in an effort to define the shallow conductive zone. Sites A-1 through A-32 (shown in Figures 6 and 7) were originally occupied as a typical bipole-dipole survey. Without the addition of fifteen sites (A-33 through A-47) the target zone is virtually unrecognizable in the results. Transmitter B (Figure 5) is located entirely within the resistive mountain range in an unlikely and impractical position for reconnaissance surveying, but

one instructive for the location of a known reservoir. Transmitter C (Figure 5) lies within the conductive valley fill material, approximately opposite the conductive zone from transmitter B. Shallow Pleistocene lake beds in this region have very conductive material in the immediate vicinity of the transmitter. Hohmann and Jiracek (1979) modeled similar situations, showing that all apparent resistivities are decreased by the presence of a conductive body underlying both transmitting electrodes.

Results

Bipole-dipole apparent resistivities calculated from observed voltages at 0.0625 Hz according to equation 13 are presented for each individual transmitter bipole as Figures 6 through 11. These plan views show apparent resistivity in ohm-meters plotted at the receiver sites from which they are taken; they overlie the topographic base map, Figure 5, and are correlated spatially by the section corners shown on each figure. The vector cross product apparent resistivities, ρ_{qq} , for each of the transmitter sites A, B, and C are shown in Figures 12, 13, and 14, respectively. Averages of observed voltage and phase for all stations are presented in the appendix.

An evaluation of errors in these data indicates that the uncertainty of location dominates at small receiver-transmitter separations and the uncertainty of the voltage magnitude estimates dominate at long separations. Most probable error for these data is estimated to be less than $\pm 10\%$ for all but the most widely separated stations, where $\pm 20\%$ is typical because of low ratios of signal to noise.

Discussion

The principal electrical inhomogeneity within the surveyed area is the contrast between the resistive, competent rock of the Mineral Mountain Range and the conductive material filling the valley. The range is largely composed of late Tertiary granitic plutonic rock and well indurated Precambrian gneisses (Nielson et al., 1978).

FIGURE 6
BIPOLE-DIPOLE APPARENT RESISTIVITY,
TRANSMITTER A, EAST-WEST BIPOLE

LEGEND

- └A-3 Receiver site
- 67.1 Apparent resistivity (ohm-m)
- Transmitter electrodes; arrow points to positive electrode
- └3 Section corners to be correlated with those shown on FIGURE 5

FIGURE 7
BIPOLE DIPOLE APPARENT RESISTIVITY,
TRANSMITTER A, NORTH-SOUTH BIPOLE

LEGEND

- └ A-3 Receiver site
- 67.1 Apparent resistivity (ohm-m)
- Transmitter electrodes; arrow points to positive electrode
- └ 3 Section corners to be correlated with those shown on FIGURE 5

FIGURE 8
BIPOLE-DIPOLE APPARENT RESISTIVITY,
TRANSMITTER B, EAST-WEST BIPOLE

LEGEND

- LA-3 Receiver site
- 37.9 Apparent resistivity (ohm-m)
- ⊕ Transmitter electrodes; arrow points to positive electrode
- 3 Section corners to be correlated with those shown on FIGURE 5

FIGURE 9
BIPOLE-DIPOLE APPARENT RESISTIVITY,
TRANSMITTER B, NORTH-SOUTH BIPOLE

LEGEND

- LB-3 Receiver site
- 67.1 Apparent resistivity (ohm-m)
- Transmitter electrodes; arrows point to positive electrode
- NR No reading
- 3 Section corners to be correlated with those shown on FIGURE 5

FIGURE 10
BIPOLE-DIPOLE APPARENT RESISTIVITY,
TRANSMITTER C, EAST-WEST BIPOLE

LEGEND

- LC-6 Receiver site
- 67.1 Apparent resistivity (ohm-m)
- Transmitter electrodes; arrow points to positive electrode
- 3 Section corners to be correlated with those shown on FIGURE 5

FIGURE 11
 BIPOLE-DIPOLE APPARENT RESISTIVITY,
 TRANSMITTER C, NORTH-SOUTH BIPOLE

LEGEND

- LC-4 Receiver site
- 67.1 Apparent resistivity (ohm-m)
- Transmitter electrodes; arrow points to positive electrode
- 3 Section corners to be correlated with those shown on FIGURE 5

FIGURE 12
QUADRIPOLE-QUADRIPOLE
APPARENT RESISTIVITY TRANSMITTER A

LEGEND

- ⊞ B-3 Receiver site
- 67.1 Apparent resistivity (ohm-m)
- Transmitter electrodes; arrows point to positive electrodes
- ⊞ Section corners to be correlated with those shown on FIGURE 5

FIGURE 13
QUADRIPOLE-QUADRIPOLE
APPARENT RESISTIVITY TRANSMITTER B

LEGEND

- B-3 Receiver site
- 67.1 Apparent resistivity (ohm-m)
- Transmitter electrodes; arrows point to positive electrodes
- Section corners to be correlated with those shown on FIGURE 5

FIGURE 14
QUADRIPOLE-QUADRIPOLE
APPARENT RESISTIVITY TRANSMITTER C

LEGEND

- └C-6 Receiver site
- 67.1 Apparent resistivity (ohm-m)
- ⊙ Transmitter electrodes; arrows point to positive electrodes
- └3 Section corners to be correlated with those shown on FIGURE 5

The valley consists of unconsolidated Tertiary and Quaternary alluvium and Pleistocene beds of Lake Bonneville (ibid). Intrinsic resistivities deduced from the dipole-dipole results of Ward and Sill (1976) characterize the range as 300 to 500 ohm-meters and the valley fill as 10 to 20 ohm-meters. Wannamaker (1978) infers an even wider range of intrinsic resistivities in his "trial-and-error best-fit model", showing significant volumes of 2000 ohm-meter and 1.2 ohm-meter material at depths of less than 1 kilometer. This contrast has led to interpretation difficulties in most of the electrical surveys at the Roosevelt Hot Springs thermal area. For example, the first separation dipole-dipole ($a = 300$ meters) results reported by Ward and Sill (1976) show a pronounced shallow resistivity low coincident with the region of high heat flow and roughly corresponding to the area of "productive" geothermal wells. Data from larger separations generally exhibit higher resistivities, owing at least in part to the influence of the adjacent unaltered pluton.

The resistivity contrast attributed to the range front boundary is clearly the dominant feature of all the bipole-dipole and quadripole-quadripole results. All data plotted in Figures 6 through 14 display generally lower apparent resistivities to the west than to the east. Actual magnitudes of apparent resistivity vary widely with transmitter position and orientation. In general, the east-west transmitters (Figures 6, 8, 10) provide the best definition of the range front boundary since they constrain current flow to be normal to the boundary. Transmitters roughly paralleling the boundary yield very little information about its location. The two sets of

bipole-dipole results from transmitter site A, Figures 6 and 7, particularly illustrate this point. Both sets of data reveal low apparent resistivities corresponding to the nearby shallow conductive zone, but only the east-west bipole (Figure 6) clearly shows the valley to range front boundary. Interestingly, the north-south bipole, being relatively insensitive to the boundary, yields a low resistivity contour closure over the shallow conductive zone.

The east-west bipole of transmitter site B (Figure 8) shows strongly aligned north-south-trending apparent resistivity contours accompanying the range-to-valley transition and negligible expression of the conductive zone. The north-south bipole at B yields (Figure 9) only minimal evidence of the range front. The picture is more complicated at transmitter C where shallow layering at the transmitter site appears to dominate the response from the east-west bipole. Comparison between the generally high apparent resistivities of transmitter B (Figures 8 and 9) and the generally low ones at the same receiver positions when the transmitter is at C (Figures 10 and 11) further illustrates the importance of transmitter position as well as orientation.

Shallow conductive region

The bipole-dipole resistivity data indicate a region of transition between conductive valley fill and resistive bedrock rather than a single sharp boundary (c.f., Figures 6 and 7). In some cases the conductive-resistive boundary appears to be to the west of the Opal Mound and in other cases it appears at the foothills, about two

kilometers further east. This inconsistency can be significantly misleading in the absence of extraordinary station density, redundant electrical data as we have here, or other independent information about the subsurface. Crebs and Cook (1976) have interpreted gravity and magnetic data to show a buried bedrock horst in the region of the Opal Mound (e.g., see their Figures 6, 7 and 16). Nielson et al. (1978) also indicate such a feature (see their cross section B-B', Plate II). The shallow electrical resistivity data (Ward and Sill, 1976) indicate a north-trending resistive salient at the Opal Mound. The open station spacing employed in typical reconnaissance mode bipole-dipole surveying can easily miss this important aspect of the geology.

The numerous receiver sites concentrated near Transmitter A show the apparent resistivity to be variable and complicated on a local scale. A station straddling the Opal Mound, A-4, B-5, and C-12 (Figs. 6, 7, 8, 9, 10, 11), yields high apparent resistivities for all transmitter sites and orientations, possibly due to locally decreased porosity caused by the opal deposit or to the resistive unaltered horst. Bibby and Risk (1973) present numerical modelling results for outcropping hemi-ellipsoidal bodies relevant in the evaluation of near-surface inhomogeneities. Their Figure 5 suggests that such inhomogeneities will always be a problem in bipole-dipole surveys. Stations adjacent to those just mentioned may be more representative of the general resistivity structure; one to the northwest shown as A-5, B-2, and C-11 and another to the southeast shown as A-7, B-15, and C-13 seem to reflect the near-surface conductive zone. A

reconnaissance survey which included only the first of these three stations would be highly misleading. Without the additional fifteen stations taken at Transmitter A (A-33 through A-47), the one resistive station obscures the broader conductive zone, making the A-series results similar to the B- and C-series results.

Another interpretation problem is illustrated by station A-44 which appears as a high apparent resistivity from the east-west bipole and a low apparent resistivity from the north-south bipole (Figures 6 and 7). The explanation appears to be due to a very thin near-surface resistive zone sensed by the small transmitter-receiver separation with respect to the east-west transmitter and not by the longer separation of the north-south transmitter. With the multiple transmitter positions and a minimum of geologic inference, the bipole-dipole survey feebly detects but certainly does not define the target.

Heat Source

Locating a deep heat source is important in geothermal exploration, as such would permit evaluation of the significance of easily defined surficial features and the implementation of an integrated exploration and development program. Many factors induce local variations in near-surface electrical properties, causing difficulty in achieving the primary goal, the detection of an exploitable heat source. Several plausible lines of reasoning suggest that deep-seated, anomalously hot regions may be attractive electrical targets. As mentioned above, a young, cooling igneous mass which includes a partial melt will be conductive. Furthermore, a pluton

cooling by free convection of hydrothermal fluid, should such exist, will have a locally high fluid permeability in order to maintain flow. Brace et al. (1968) demonstrated a strong correlation between fluid permeability and electrical conductivity in laboratory studies of the effects of confining pressure on permeability. At depths of several kilometers, high-pressure pore fluids would maintain anomalously high porosity and permeability, and thus low resistivity, through the effective stress law. Thus we may reasonably expect a conductivity contrast between a deep heat source and its surroundings.

Detectability of a deep conductive zone is still a matter of uncertainty. Ward and Sill (1976) concluded that their dipole-dipole surveys, using spacings of 100 meters, 300 meters, and 1000 meters, were essentially insensitive to changes below about 500 meters, but felt that very large conductive bodies would be detectable to depths of 1 or 2 kilometers. The present survey is of a larger scale, as well as of different geometry, and should be sensitive to deeper inhomogeneities of sufficient size. Hohmann and Jiracek (1979) modeled a large conductive body buried in a homogeneous medium. Figure 15, taken from their work, shows a 4 km by 4 km body or a 2 km by 8 km body to be detectable at depths of 2 km. Similar bodies at depths of 3 km produce less than a 10% change of apparent resistivity and are considered undetectable. The 25% variations of apparent resistivity of Figure 15 are insignificant when compared to the order of magnitude variations commonly observed in the survey data (Figures 6 through 11). The models considered are optimistically large, shallow, and free of geologic noise, and perhaps overly conductive.

4 x 4 kilometer Body

2 x 8 kilometer Body

**CHARACTERISTICS COMMON
TO BOTH MODELS**

Transmitter length = 2 km.

Body depth = 2 km.

Body thickness = 1 km.

Body resistivity = $10 \Omega\text{-m}$

Background resistivity = $100 \Omega\text{-m}$

Figure 15: Numerical Model Results

(After Hohmann & Jiracek, 1979)

Even so, they do not yield anomalies recognizable in a typical geologic environment under tightly controlled survey conditions.

Quadripole-quadripole results

The vector cross product apparent resistivities for transmitter sites A, B, and C are presented as Figures 12, 13, and 14, respectively. The patterns observed are generally somewhat different from those seen in the bipole-dipole data, lending empirical credence to the hypothesis that ρ_{qq} is less sensitive to transmitter orientation than is the bipole-dipole method. At present, this mode of data reduction is of largely empirical significance. Accordingly, the data are reproduced here without further interpretative comment.

SUMMARY

The bipole-dipole survey results detect the known near-surface conductive zone only under circumstances of unreasonably high station density. The prospecting problem is severely complicated at the Roosevelt Hot Springs thermal area by extraneous resistivity variations unrelated to the geothermal system and by the sensitivity of the bipole-dipole array to local resistivity variations. No evidence is presented of a deep conductive region, though geologic noise makes recognition of such unlikely. The best prospecting information results from transmitter orientations which minimize the response from known geologic noise.

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APPENDIX

The following tables present the observed voltage and phase spectra for the survey. Note that the transmitter current varies between receiver stations but is constant at any one station. Both voltage and phase are corrected for instrument response which was determined by making a calibration reading across a known resistor in series with the transmitter output. Both dipole and bipole polarities were maintained during the survey. The north or east bipole electrode was positive (refer to Figure 4) and the common point between the receiving lines was the reference. To illustrate this convention, consider that the electric field at station A-6 is due to the north-south bipole. The field direction is about 6° west of north, hence negative voltages are reported for the south-and east-bearing receiver dipoles. Negative phases correspond to a phase lag while positive ones imply a phase lead.

TRANSMITTER A ; EAST-WEST BIPOLE

VOLTAGES IN MILLIVOLTS, PHASES IN MILLIRADIANS

PC #	AZIM, DEGREES	VOLTAGE AT 1 HZ	PHASE AT 1 HZ	VOLTAGE AT 0.25 HZ	PHASE AT 0.25 HZ	VOLTAGE AT 0.0625 HZ	PHASE AT 0.0625 HZ
1	0	-12.690	-33.	-13.039	-16.	-13.455	-10.
1	270	-255.024	5.	-25.908	5.	-268.173	8.
2	180	35.526	6.	35.913	0.	36.465	1.
2	270	-9.881	120.	-9.756	37.	-9.919	9.
3	180	.097	34.	-.029	-55.	-.010	-743.
3	90	-11.967	65.	-11.566	31.	-11.718	19.
4	180	-5.818	-44.	-5.973	-16.	-6.103	-3.
4	270	-40.738	-81.	-41.409	-25.	-42.003	-6.
5	100	.881	-327.	.953	-110.	.985	-38.
5	280	-6.569	-100.	-6.667	-26.	-6.742	-2.
6	180	1.451	1064.	1.203	170.	1.200	40.
6	90	-17.465	55.	-17.062	24.	-17.092	13.
7	180	-12.419	24.	-12.536	3.	-12.753	0.
7	270	-1.766	-159.	-1.908	-57.	-1.942	-10.
8	0	1.486	86.	1.839	24.	1.460	8.
8	270	-2.815	73.	-2.959	-58.	-2.983	-11.
9	0	.649	64.	.728	-90.	.758	-18.
9	270	-.866	73.	-.999	-111.	-1.026	-31.
10	0	-.219	-4.	-.172	118.	-.166	56.
10	270	-.967	73.	-1.095	-108.	-1.116	-23.
11	0	1.179	-547.	1.214	-158.	1.252	-40.
11	90	-12.343	69.	-11.859	29.	-11.922	13.
12	0	-1.212	5830.	-.663	408.	-.565	125.
12	90	-.751	2.	-7.035	17.	-7.001	11.
13	180	.167	-138.	.120	326.	.074	257.
13	90	.035	-493.	.048	-238.	.043	-146.
14	180	.679	19.	.550	118.	.516	56.
14	90	.329	-527.	.427	-185.	.450	-49.
15	0	-1.965	155.	-1.700	82.	-1.671	24.
15	270	.816	430.	.511	296.	.454	122.
16	0	-.044	-475.	-.046	-22.	-.052	40.
16	90	.178	-509.	.245	-208.	.260	-58.
17	0	-.141	-296.	-.140	3.	-.139	20.
17	270	-.137	-584.	-.205	-263.	-.220	-32.
18	180	.149	-276.	.134	94.	.116	89.
18	90	.032	-1052.	.077	-536.	.079	-169.
19	180	.380	44.	.278	208.	.228	103.
19	90	-.082	471.	-.036	1056.	-.016	755.
20	180	2.013	97.	1.832	55.	1.816	18.
20	270	-1.123	-287.	-1.239	-93.	-1.272	-36.
21	320	-.789	-542.	-.916	-169.	-9.584	-57.
21	230	7.463	157.	6.721	66.	6.624	28.
22	0	.308	-42.	.256	110.	.330	43.
22	270	.367	-450.	.459	-155.	.477	-51.
23	180	-.551	164.	-.397	205.	-.361	75.
23	270	.745	-405.	.878	-139.	.910	-34.
24	180	.049	251.	.035	178.	.026	141.

24	270	.181	-392.	.233	-167.	.234	-54.
25	180	.118	217.	.076	299.	.056	94.
25	270	.115	-143.	.119	-47.	.116	-21.
26	180	.390	362.	.265	237.	.239	88.
26	270	.097	-193.	.119	-169.	.137	-50.
27	180	1.136	162.	1.065	46.	1.068	12.
27	270	.166	73.	.220	-293.	.227	-94.
28	180	-.021	-484.	-.029	-185.	-.029	-31.
28	270	.025	-309.	.052	-353.	.065	-134.
29	180	.040	9.	.033	338.	.022	214.
29	270	.046	-302.	.069	-169.	.080	-54.
30	180	2.372	282.	2.168	84.	2.155	27.
30	270	-18.459	66.	-17.604	30.	-17.447	16.
31	180	9.031	-13.	9.002	-1.	9.077	3.
31	270	1.530	-690.	1.691	-218.	1.751	-65.
32	0	-2.081	-96.	-2.159	-30.	-2.194	-6.
32	270	1.153	-778.	1.324	-237.	1.361	-58.

ONLY VOLTAGE AMPLITUDE AT A SINGLE FREQUENCY
(USUALLY 0.0625 HZ) WAS READ AT THE
FOLLOWING STATIONS:

33	180	2.64
33	270	1.422
34	0	4.75
34	270	0.179
35	0	3.42
35	270	3.70
36	0	0.203
36	270	158.4
37	200	1.309
37	110	6.45
38	0	2.73
38	90	16.84
39	0	1.55
39	90	2.54
40	180	6.41
40	90	4.31
41	180	4.31
41	90	2.83
42	0	0.445
42	270	0.745
43	90	2.31
43	180	2.76
44	180	10.0
44	90	95.0
45	180	0.343
45	270	2.56
46	180	1.40
46	270	0.93
47	180	9.94
47	90	3.41

TRANSMITTER A ; NORTH-SOUTH BIPOLE

VOLTAGES IN MILLIVOLTS, PHASES IN MILLIRADIANS

PC #	AZIM, DEGREES	VOLTAGE AT 1 HZ	PHASE AT 1 HZ	VOLTAGE AT 0.25 HZ	PHASE AT 0.25 HZ	VOLTAGE AT 0.0625 HZ	PHASE AT 0.0625 HZ
1	0	-4.840	117.	-4.801	30.	-4.885	9.
1	270	-2.815	-67.	-2.623	58.	2.606	27.
2	180	-3.746	-27.	3.630	42.	3.685	12.
2	270	-10.190	96.	-10.027	34.	-10.027	16.
3	180	-21.683	-27.	-22.651	-10.	-23.108	-3.
3	90	22.080	-43.	22.656	-9.	22.832	2.
4	180	6.002	60.	5.885	19.	5.947	5.
4	270	-19.989	-124.	-19.490	-38.	-19.763	-9.
5	180	-3.010	151.	-2.798	54.	-2.808	14.
5	280	-1.419	-160.	-1.485	-48.	-1.502	-9.
6	180	-256.520	1.	-258.456	0.	-262.275	2.
6	90	-28.925	-7.	-28.618	1.	-28.756	5.
7	180	6.728	118.	6.495	43.	6.523	18.
7	270	-13.778	-61.	-13.875	-13.	-13.969	2.
8	0	1.663	94.	-1.560	38.	-1.570	6.
8	270	-4.515	73.	-4.629	-36.	-4.663	-4.
9	0	.368	63.	.458	-333.	.495	-96.
9	270	-1.115	73.	-1.272	-121.	-1.305	-32.
10	0	-.802	135.	-.641	141.	-.609	50.
10	270	-.357	72.	-.437	67.	-.454	-52.
11	0	10.996	-82.	11.326	-25.	11.534	-6.
11	90	.015	773.	.142	-108.	.213	-44.
12	0	4.201	-187.	4.501	-1155.	4.631	-18.
12	90	-3.467	-208.	-3.545	-52.	-3.554	-7.
13	210	.175	-132.	.133	298.	.092	217.
13	110	-.104	-578.	-.152	-322.	-.160	-56.
14	180	.677	187.	.443	297.	.370	119.
14	90	-.508	-111.	-.485	11.	-.474	16.
15	0	-.850	668.	-.365	711.	-.221	352.
15	270	3.588	-61.	3.501	-7.	3.500	3.
16	0	-.177	-86.	-.149	185.	-.128	90.
16	90	.061	-976.	.141	-360.	.155	-106.
17	0	-.204	-179.	-.169	200.	-.140	129.
17	270	.031	1214.	-.039	-728.	-.048	-202.
18	180	.174	-163.	.136	304.	.095	215.
18	90	-.083	-194.	-.079	163.	-.071	198.
19	180	.232	433.	.108	1194.	-.037	-1253.
19	90	-.357	-227.	-.371	-33.	-.373	1.
20	180	1.921	232.	1.558	127.	1.513	39.
20	270	1.573	-22.	1.524	8.	1.526	7.
21	320	10.106	-76.	10.300	-20.	10.462	-4.
21	230	12.056	33.	11.577	23.	11.524	14.
22	0	-.532	82.	-.388	214.	-.335	97.
22	270	.063	833.	-.040	-1104.	-.043	-324.
23	180	1.027	175.	.769	183.	.696	64.
23	270	.467	104.	.364	145.	.337	68.
24	180	.146	104.	.103	310.	.061	165.

24	270	-.135	-646.	-.201	-257.	-.258	-55.
25	180	.054	174.	.038	395.	.019	241.
25	270	-.148	-415.	-.198	-197.	-.224	-45.
26	180	.043	323.	.022	1163.	-.014	-543.
26	270	-.874	-289.	-.870	-99.	-.990	-23.
27	180	-.866	-294.	-.975	-110.	-1.016	-34.
27	270	-2.892	-185.	-3.024	-57.	-3.069	-10.
28	180	.046	-241.	.059	13.	.048	114.
28	270	-.011	-652.	-.030	-548.	-.044	-184.
29	180	.031	145.	.032	124.	.024	191.
29	270	-.045	-364.	-.079	-279.	-.092	-91.
30	180	-6.887	-29.	-7.029	-10.	-7.137	0.
30	270	-8.407	-183.	-8.585	-47.	-9.650	-4.
31	180	.675	768.	.395	352.	.356	106.
31	270	-2.451	35.	-2.482	8.	-2.509	14.
32	0	.269	-531.	.290	-145.	.303	-11.
32	270	-1.414	20.	-1.419	12.	-1.404	9.

ONLY VOLTAGE AMPLITUDE AT A SINGLE FREQUENCY
(USUALLY 0.0625 HZ) WAS READ AT THE
FOLLOWING STATIONS:

33	180	2.07
33	270	1.183
34	0	6.00
34	270	5.03
35	0	76.3
35	270	46.4
36	0	3.75
36	270	3.70
37	200	2.93
37	110	0.642
38	0	10.13
38	90	6.48
39	0	3.29
39	90	0.572
40	180	3.05
40	90	8.87
41	180	0.196
41	90	4.47
42	90	1.016
42	180	2.54
43	90	45.7
43	180	1.32
44	90	3.30
44	180	4.98
45	180	1.589
45	270	2.23
46	180	0.15
46	270	1.54
47	90	2.06
47	180	1.373

TRANSMITTER B ; EAST-WEST BIPOLE

VOLTAGES IN MILLIVOLTS, PHASES IN MILLIRADIANS

PC #	AZIM, DEGREES	VOLTAGE PHASE AT 1 HZ		VOLTAGE PHASE AT 0.25 HZ		VOLTAGE PHASE AT 0.0625 HZ	
1	180	3.804	-265.	4.279	-96.	4.446	-30.
1	10	.880	-55.	.907	-23.	.910	-5.
2	35	.837	-350.	.974	-129.	1.002	-48.
2	305	-.861	-546.	-1.049	-184.	-1.118	-48.
3	0	.097	495.	.044	886.	.023	625.
3	270	-.375	-529.	-.467	-178.	-.489	-51.
4	0	.026	-114.	.036	548.	-.052	-550.
4	90	.077	-597.	.118	-133.	.092	-244.
5	195	.514	-272.	.609	-106.	.553	7.
5	285	3.146	-503.	3.848	-180.	3.511	-41.
6	180	1.241	-4.	1.287	-13.	1.320	-4.
6	90	-3.213	-300.	-3.664	-102.	-3.770	-23.
7	0	-1.233	-78.	-1.322	-45.	-1.361	-19.
7	270	2.506	-552.	3.008	-184.	3.118	-48.
8	230	2.430	-354.	2.817	-124.	2.905	-35.
8	320	2.374	-393.	2.732	-132.	2.806	-33.
9	0	.101	-599.	.122	-221.	.139	-117.
9	270	1.338	-409.	1.563	-138.	1.642	-25.
10	135	-1.016	-324.	-1.074	-83.	-1.095	-2.
10	45	-3.776	-224.	-3.902	-81.	-4.017	-18.
11	175	49.174	18.	49.271	6.	49.822	4.
11	265	52.992	-22.	53.116	-5.	53.204	4.
12	0	-2.207	141.	-2.062	58.	-2.067	20.
12	270	2.396	-722.	2.818	-231.	2.962	-60.
13	180	1.736	191.	1.161	84.	1.177	30.
13	90	-1.224	-1111.	-1.328	-356.	-1.362	-104.
14	180	.745	-67.	.802	-42.	.836	-17.
14	90	-1.231	-519.	-1.513	-181.	-1.585	-51.
15	180	.685	166.	.603	77.	.600	13.
15	270	.778	-336.	.918	-127.	.950	-38.
16	0	-.180	773.	-.062	1150.	-.026	838.
16	270	.529	-155.	.597	-155.	.605	-47.
17	50	-.227	-271.	-.245	-79.	-.251	-18.
17	320	.129	-970.	.176	-330.	.190	-84.
18	210	-.006	824.	.022	-769.	.027	-279.
18	110	-.106	-614.	-.162	-256.	-.173	-71.
19	180	-.025	-1160.	-.030	-450.	-.025	-161.
19	90	-.740	-537.	-.425	-174.	-.453	-51.

TRANSMITTER B ; NORTH-SOUTH BIPOLE

VOLTAGES IN MILLIVOLTS, PHASES IN MILLIRADIANS

RC #	AZIM, DEGREES	VOLTAGE PHASE AT 1 HZ		VOLTAGE PHASE AT 0.25 HZ		VOLTAGE PHASE AT 0.0625 HZ	
1	100	1.446	-219.	1.635	-82.	1.698	-28.
1	10	1.255	121.	1.197	44.	1.188	21.
2	35	.286	-102.	.310	-53.	.312	-20.
2	305	.159	1587.	-.136	-559.	-.155	-159.
3	0	.127	333.	.072	412.	.055	157.
3	270	-.081	-550.	-.102	-176.	-.110	-9.
4	0	.036	-30.	.030	401.	.028	693.
4	90	.029	-517.	.034	-175.	.032	65.
6	180	1.488	140.	1.417	43.	1.440	16.
6	90	-.421	-1132.	-.459	-380.	-.481	-99.
7	0	.431	199.	-.443	37.	-.431	12.
7	270	-1.334	283.	-1.057	178.	-.929	65.
8	230	1.362	-213.	1.538	-80.	1.583	-18.
8	320	.904	-492.	1.071	-162.	1.104	-37.
9	0	-.227	512.	-.124	453.	-.097	195.
9	270	.692	-344.	.808	-113.	.791	-21.
10	135	-1.505	-71.	-1.579	-19.	-1.613	2.
10	45	-2.583	-235.	-2.818	-81.	-2.865	-20.
11	175	20.828	25.	81.215	7.	82.241	4.
11	265	17.200	-28.	17.398	-10.	17.512	-1.
12	0	-1.882	184.	-1.679	64.	-1.688	21.
12	270	-9.042	90.	-8.043	46.	-7.981	23.
13	180	.658	341.	.543	145.	.531	46.
13	90	4.659	101.	4.293	54.	4.233	24.
14	180	.189	444.	.156	120.	.154	-3.
14	90	.725	203.	.560	165.	.505	69.
15	180	.708	278.	.581	132.	.573	42.
15	270	.023	-1420.	.064	-414.	.074	-159.
16	0	-.216	386.	-.131	334.	-.111	117.
16	270	.040	-1427.	.053	-483.	.054	-149.
17	50	-.072	72.	-.067	167.	-.065	48.
17	320	-.056	698.	-.025	1328.	.011	-1134.
18	210	.037	-56.	.033	118.	.031	83.
18	110	-.060	-620.	-.089	-267.	-.099	-69.
19	180	.111	260.	.066	544.	.045	243.
19	90	-.162	-378.	-.209	-154.	-.222	-39.

TRANSMITTED C ; EAST-WEST BIPOLE

VOLTAGES IN MILLIVOLTS, PHASES IN MILLIRADIANS

RC #	AZIM, DEGREES	VOLTAGE PHASE AT 1 HZ		VOLTAGE PHASE AT 0.25 HZ		VOLTAGE PHASE AT 0.0625 HZ	
1	180	.065	-734.	.100	-343.	.113	-103.
1	90	-.044	-520.	-.159	-210.	-.177	-49.
2	180	-.107	179.	.162	-702.	.185	-203.
2	270	-.328	-245.	-.399	-107.	-.412	-21.
3	0	.015	-83.	.014	43.	.017	191.
3	270	.150	-563.	.210	-273.	.240	-59.
4	180	.387	67.	.400	44.	.407	14.
4	270	.389	-430.	.530	-169.	.561	-39.
5	180	.041	299.	.034	450.	.022	259.
5	270	-.065	-87.	-.091	-154.	-.097	-29.
6	180	-.024	-1455.	-.049	-537.	-.064	-132.
6	270	-.117	-263.	-.176	-146.	-.193	-20.
7	180	-.392	-97.	-.438	-35.	-.436	-6.
7	270	-.109	-1256.	-.165	-391.	-.164	-113.
8	50	.472	-398.	.576	-107.	.581	-19.
8	320	.217	-603.	.310	-203.	.303	-55.
9	0	.177	-486.	.227	-140.	.249	-19.
9	270	-.015	1662.	.037	-538.	.052	-63.
10	0	.475	-351.	.569	-90.	.564	-16.
10	270	.202	-577.	.291	-200.	.298	-122.
11	20	.002	1572.	-.037	-727.	-.051	-215.
11	290	.100	-492.	.271	-243.	.289	-62.
12	180	-.026	-26.	-.023	421.	-.010	183.
12	270	.616	-559.	.919	-229.	1.006	-77.
13	180	-.180	-381.	-.211	-83.	-.219	-2.
13	270	-.020	1133.	.026	-973.	.027	-519.
14	0	.091	-286.	.106	-12.	.097	77.
14	90	-.039	-987.	-.062	-523.	-.075	16.
15	0	.011	1446.	-.019	-775.	-.024	-246.
15	270	.170	-561.	.240	-228.	.255	-63.
16	180	-.024	-181.	-.028	55.	-.032	20.
16	90	-.095	-637.	-.139	-268.	-.162	-68.
17	0	.180	-906.	.262	-272.	.273	-62.
17	90	1.377	138.	1.275	70.	1.240	26.
18	0	1.483	-56.	1.476	3.	1.462	11.
18	270	30.250	-9.	30.135	4.	30.156	10.
19	180	.285	-199.	.351	-145.	.384	-50.
19	270	1.069	-263.	1.236	-94.	1.263	-18.
20	180	.880	-173.	1.013	-88.	-1.062	-28.
20	90	-.721	-427.	-.883	-150.	-.927	-36.
21	180	.310	-451.	.404	-197.	.432	-54.
21	270	.128	-474.	.181	-109.	.199	-23.
22	320	.346	-542.	.473	-225.	.505	-60.
22	230	.152	-530.	.204	-156.	.199	-45.
23	0	-.109	-651.	-.176	-292.	-.193	-93.
23	90	-.049	-429.	-.064	-176.	-.059	-100.
24	0	.014	-402.	-.057	-266.	-.060	-19.

24	270	-.017	-592.	.105	-224.	.184	-19.
25	0	-.012	-684.	-.099	-288.	-.107	-105.
25	90	-.015	-605.	-.194	-229.	-.199	-62.
26	180	.404	-488.	.583	-217.	.634	-61.
26	90	.192	142.	.159	148.	.135	81.

TRANSMITTER C ; NORTH-SOUTH BIPOLE

VOLTAGES IN MILLIVOLTS, PHASES IN MILLIRADIANS

RC #	AZIM, DEGREES	VOLTAGE PHASE AT 1 HZ		VOLTAGE PHASE AT 0.25 HZ		VOLTAGE PHASE AT 0.0625 HZ	
1	180	-.288	-204.	-.233	210.	-.182	153.
1	90	.006	-687.	.039	-204.	.043	-39.
2	180	.355	-315.	.482	-223.	.549	-85.
2	270	.208	638.	-.121	-84.	-.092	-486.
3	0	.079	-61.	.059	365.	.033	252.
3	270	-.162	-271.	-.158	47.	-.159	75.
4	180	-.392	224.	-.337	239.	-.283	142.
4	270	.340	-32.	.428	-117.	.464	-40.
5	180	.010	-1.	.038	-745.	.059	-278.
5	270	.056	-472.	.144	-442.	.178	-147.
6	180	.047	-404.	.100	-439.	.130	-168.
6	270	.045	-1307.	.113	-570.	.134	-166.
7	180	.118	-1055.	.235	-446.	.275	-126.
7	270	.329	-367.	.514	-249.	.582	-251.
8	50	.338	126.	.186	645.	.091	551.
8	320	-.178	-415.	-.241	-248.	-.271	-80.
9	0	.093	-216.	.076	235.	.077	153.
9	270	-.114	-148.	-.090	331.	-.047	319.
10	0	.466	7.	.336	331.	.232	193.
10	270	-.448	-116.	-.415	74.	-.387	49.
11	20	.188	-195.	.287	183.	.235	119.
11	290	-.059	-356.	-.140	3.	-.126	48.
12	180	-.213	-185.	-.169	219.	-.134	146.
12	270	-.842	-302.	-.772	60.	-.675	74.
13	180	-.269	-112.	-.197	358.	-.133	260.
13	270	-.250	-197.	-.204	193.	-.162	141.
14	0	.218	-95.	.160	409.	.102	246.
14	90	.275	-186.	.224	187.	.195	129.
15	0	.174	-159.	.141	237.	.110	155.
15	270	-.231	-303.	-.212	87.	-.187	200.
16	180	-.068	-5.	-.051	402.	-.033	320.
16	90	.152	-189.	.119	129.	.106	65.
17	0	-12.429	-34.	-12.913	-19.	-13.182	-3.
17	90	.200	1119.	-.156	-874.	-.165	-241.
18	0	1.524	189.	1.229	186.	1.108	76.
18	270	-.329	-20.	-.369	30.	-.355	32.
19	180	-.953	-15.	-.791	172.	-.686	89.
19	270	-.282	-103.	-.251	117.	-.241	-14.
20	180	-1.031	23.	-.836	193.	-.726	98.
20	90	-.044	326.	-.080	-357.	-.113	-147.
21	180	-.592	-164.	-.491	180.	-.406	112.
21	270	.141	-46.	.119	132.	.109	56.
22	320	-.315	-290.	-.274	148.	-.218	110.
22	230	.288	-67.	.151	268.	.110	187.
23	0	.106	-789.	.100	108.	.085	89.
23	90	-.104	-204.	-.083	276.	-.067	186.
24	0	.024	-142.	.036	175.	.029	107.

24	270	.001	730.	-.016	-836.	-.041	-843.
25	0	.207	-213.	.173	196.	.131	123.
25	90	.047	-356.	.081	51.	.110	401.
26	180	-.291	189.	-.184	785.	-.066	1006.
26	90	-.368	66.	-.309	125.	-.302	25.