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A CONTROLLED SOURCE AUDIOMAGNETOTELLURIC INVESTIGATION

OF THE

ENNIS HOT SPRINGS GEOTHERMAL AREA, ENNIS, MONTANA

by

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INTRODUCTION

During the spring, summer, and fall of 1985 personnel of the Department of Physics and Geophysical Engineering of the Montana College of Mineral Science and Technology conducted several geophysical surveys near Ennis, Montana as part of their investigation of the Ennis Hot Springs geothermal area. Ennis Hot Springs was chosen for study because it has the hottest surfact temperature (84 degrees Celsius) of all hot springs in Montana; it is located close to a small population center and thus has possibilities for local development; and it resembles other hot springs in southwest Montana that flow through fractured crystalline rock covered by valley sediments derived from late Cenozoic block faulting (Chadwick and Leonard, 1979).

The audiomagnetotelluric (AMT) technique has been shown to be a useful method of delineating electrical resistivity lows resulting from hot geothermal waters and associated altered host rock (Hoover et al., 1978; Hoover and Long, 1976). Goldstein and Strangway (1975) introduced a grounded electric dipole as a controlled artificial source of the AMT field because natural fields are unpredictable in direction and strength. Sandberg and Hohmann (1982) show that the controlled source audiomagnetotelluric (CSAMT) method can be used to map the conductivity structure of the subsurface of a geothermal region more easily than conventional resistivity methods.

The purpose of this paper, therefore, is: (1) to present the results of a CSAMT survey of the Ennis Hot Springs geothermal area; (2) to present models of the subsurface electrical conductivity

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Gunnar Robert Emilsson

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ABSTRACT

A controlled-source audiomagnetotelluric survey (CSAMT) at the Ennis Hot Springs geothermal area revealed a low resistivity anomaly (3 ohm-m to 10 ohm-m) in the vicinity of the hot springs. The hot springs issue from the base of a gravel terrace on the west side of the Madison Valley. Low apparent resistivities extend to the west under the gravel terrace as well as to the north in an elongated "plume". To the southwest the apparent resistivity increases rapidly due to an uplift in the valley basement.

One-dimensional inverse modeling in the center of the valley indicates a buried conductive layer probably due to a thick layer of clay-bearing sediments since a nearby test well does not show elevated temperatures. Near the hot springs, one-dimensional inverse modeling did not prove useful, partly because of the two and three-dimensional nature of the structure. Two-dimensional forward modeling near the hot springs provides a more quantitative delineation of the low resistivity zone and of the faulted basement uplifts to the west and south. Details of the structure beneath the conductive zone near the hot springs are difficult to resolve and most of the model control in this region is provided by well logs and seismic data.

A technique for correcting data collected in the region close to the transmitter where the plane wave assumption is not valid has been derived and has been applied to the low frequency data.

structure based upon interpretations of the field data; and (3) evaluate the applicability of the CSAMT technique to southwest Montana's geothermal systems of deep circulation through fractured crystalline rock.

Previous Work

The United States Geological Survey and the Montana Bureau of Mines and Geology in conjunction with the Montana Department of Highways drilled several test holes in the study area that provided invaluable subsurface control for computer modeling input. Previous electrical geophysical surveys in the region include scalar audiomagnetotelluric soundings by Long and Senterfit (1979), telluric profiles by Christopherson et al, (1979), and a direct current resistivity survey using a Wenner array by personnel from Montana State University. Results from these studies will be discussed with the CSAMT survey later in the report.

Interpretations of seismic refraction profiles by Mark McRae and Charles Wideman of the Montana College of Mineral Science and Technology Department of Physics and Geophysical Engineering also provided control in computer modeling of the subsurface (McRae, 1978).

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all aspects of this study. Dr. Sill, in particular, initiated the CSAMT survey and kept the equipment in working order, as well as answered my sometimes confusing questions on the subject.

Dave Semmens shared the duties as field operator. Leonard Rhinehart and Allan Payne proved to be worthy field assistants. Special thanks must go to the local landowners who allowed us to trample through their fields and lay electrical cable across their property. They include Miles Bob, William Goggins, Dan Leadbetter, Rich McMillan, William Thexton, and Glen Reinhardt.

The Department of Geology and Geophysics of the University of Utah loaned us their Geotronics EMT-5000 transmitter. A final thanks goes to Phil Wannamaker of the Earth Science Laboratory of the University of Utah Research Institute who provided us with computer programs used in modeling of the data.

GEOLOGY

The purpose of this section is to: (1) discuss the geologic features in the Madison valley that might influence the circulation and movement of thermal waters; and (2) describe the geologic units in the vicinity of the hot springs and their postulated electrical properties to be used in modeling the Ennis Hot Springs CSAMT data.

Regional

Southwest Montana is located in a region of complex geological structure characterized by basement-cored uplifts active since Precambrian time over which Paleozoic and Mesozoic sediments have been deposited (Schmidt and Garihan, 1983). Laramide thrust faulting and late Cenozoic block faulting in the region have been controlled to some extent by these pre-existing fracture zones in the crystalline basement.

Chadwick and Leonard (1979) report twenty-five warm springs in southwestern Montana having a surface temperature of equal to or greater than 38 degrees Celsius. The majority of these springs issue water which has circulated through deeply fractured crystalline rocks. Some of these fractures are associated with late Cenozoic valley front faults. Ennis Hot Springs is representative of this latter type of springs.

Local

Ennis Hot Springs issue from the base of a terrace cut through

Quaternary alluvium on the western side of the lower Madison River valley about three kilometers north of the town of Ennis, Montana, in Madison County (see Figure 1) and approximately 400 meters east of Montana Highway 287 (see Figure 2). The valley is bounded on the east by the seismically active Madison Range normal fault. This fault has a cumulative displacement of over several thousand meters, and separates the valley floor from the Madison and Gallatin mountain ranges. Pardee (1950) reports a recent scarp extending southward from Jack Creek (about 14 kilometers east of the hot springs) along the fault with a displacement in some sections of more than 10 meters. Rocks exposed in the Madison Range immediately adjacent to the valley near Ennis include Precambrian quartzo-feldspathic gneisses and schists and Paleozoic sediments thrust eastward against gently-dipping Mesozoic rock units (Swanson, 1950). Schmidt and Garihan (1983) suggest that this Laramide thrust may have partially influenced the development of the Madison Range fault.

The western edge of the valley is characterized by foothills of the Tobacco Root Mountains comprised predominantly of Precambrian gneisses and schists. Gravel terraces resulting from the downcutting of the Madison River due to recurrent movement along the Madison Range Fault onlap onto these foothills. These terraces have been classified into three distinct units on the east side of the valley (Paul and Lyons, 1960). No definite scarp exists between the valley sediments and the metamorphic rocks immediately adjacent in the Tobacco Root Mountain foothills. However, regional gravity and seismic data suggest the basement of the valley be downthrown to the east with several faults of considerably smaller displacement than

Figure 1. Index map of western Montana with an enlargement of Madison County showing the survey area of Figure 2.

Figure 2. Map showing Ennis Hot Springs and the CSAMT survey area in relation to the towns of Ennis and Jeffers, Montana. Transmitters tx 1, 2, and 3 are shown as thick, hatchured lines. Test well TX-10 and the Valley Garden Fishing Access (VG) are located west of the Madison River.

the Madison Range fault to the east (Burfiend, 1967; Schmidt and Garihan, 1983).

The North Meadow Creek fault, part of the Bismark-Spanish Peaks-Gardiner fault system, lies north to northeast of the hot springs. This northwest-trending high angle fault system is believed to be a major structural feature controlling volcanic and tectonic activity in southwest Montana (Garihan et al, 1983). Cenozoic movement along the fault is evidenced by a truncated plug of early Eocene rhyodacite near the town of McAllister, which is about 9 kilometers north of the hot springs (Chadwick, 1978).

In summary, the structural geology of the lower Madison River valley indicates probable recent movement along northeast- and northwest-trending fault segments that penetrate crystalline basement.

Figure 3 is a sketch map showing these features. These fault systems could provide the necessary conduits for the deep circulation of the thermal water.

The valley fill near the hot springs, as depicted by the USGS and Montana Bureau of Mines and Geology well logs, consists mainly of poorly consolidated clay, sand, and siltstone with discontinuous lenses of coarse sand and gravel (Leonard, written communication). These sediments are probably of Tertiary age. The high electrical conductivity of some clays might provide a poor contrast between these strata and strata containing thermal waters.

Poorly sorted cobbles and gravels with a thickness up to 12 meters overlie the finer-grained valley fill. Two distinct terraces are cut into this alluvium as observed going west from the hot springs. These terraces are highly permeable, and a relatively high

Figure 3. Sketch Map showing major geologic features in the Madison River valley near Ennis Hot Springs, Madison County, Montana.

resistivity was assigned to these gravels for modeling as they are probably well-drained and relatively dry.

GEO THERMAL

Subsurface temperatures measured in wells in the Ennis Hot Springs CSAMT survey are ranged from 6.2 degrees Celsius near the water table in the valley fill to 97 degrees Celsius in fractured Precambrian gneiss at a depth of 335 meters (Sonderegger and Zaluski, 1983). Ennis Hot Springs issue at a temperature of 84 degrees Celsius.

The wells encountering thermal water show an upward leakage through the bedrock in the vicinity of the spring and lateral movement of the water through valley sediments to the northeast (Leonard, written communication).

An estimate of the total heat output from the Ennis Hot Springs region has been calculated by Semmens (1987). The minimum estimate is based on the measured spring flow rate (minimum convective output) and the conductive flux calculated from observed temperature gradients in wells. These calculations give a convective output of 384 KW and conductive output of 34 KW, for a total of 418 KW. This is a bare minimum since there is certainly additional subsurface leakage from the hot springs that is unaccounted for. Based on the "safe yield" from a test well, Semmens (1987) estimates a total heat output of about 10 MW.

Semmens (1987) reports estimates for the reservoir temperature of about 160° to 165° C based on various geothermometers. Using a

deep circulation model and normal geothermal gradients, he estimates that the waters must circulate to depths of 3.3 to 5 kilometers.

THE CONTROLLED SOURCE AUDIOMAGNETOTELLURIC METHOD

The following discussions are presented to give the reader unfamiliar with the CSAMT method a brief background to aid in the understanding of the interpretations of the Ennis Hot Springs CSAMT survey results. The first section on MT theory is not intended to be a complete mathematical derivation, rather, it discusses the advantages and limitations of the method in modeling the subsurface. The second section on CSAMT is concerned mainly with correcting CSAMT data that does not fit some of the mathematical assumptions of MT theory.

Basic Magnetotelluric Theory

The magnetotelluric (MT) method was first described by Cagniard (1953). The sources of the telluric currents for conventional MT frequencies (below 1 hertz) are fluctuations in the earth's magnetic field. In the audio frequency range (above 1 hertz) the fields are due to wave guide propagation of energy released during worldwide thunderstorm activity. To overcome the problems of small signal strength from these sources, Goldstein and Strangway (1975) introduced an artificial source to transmit at these frequencies.

Basically, the MT method measures the plane wave impedance of the subsurface by taking the ratio of the orthogonal electric and

magnetic field components. This impedance, Z , generally is a tensor quantity (Swift, 1967), but in one-dimensional (layered or homogeneous) earth it becomes a complex scalar. Assume an $e^{i\omega t}$ time dependence (that is, treating the electromagnetic wave as function of sines and cosines), and a plane, vertically propagating electromagnetic wave (such that partial derivatives of the wave with respect to x and y are zero in a cartesian coordinate system with z positive in the vertical downward direction). It can be shown by applying Maxwell's equations that the scalar apparent resistivity (ρ_a) is given by

$$\rho_a = \frac{1}{\omega\mu} \left| \frac{E}{H} \right|^2 \quad (1)$$

where μ is the magnetic permeability (usually taken to be that of free space), ω is the angular frequency in radians per second, and E and H are the orthogonal electric and magnetic fields. For a formal derivation of this formula the reader is referred to Cagniard (1953), Keller and Frishknecht (1966), and Swift (1967), as well as numerous other geophysical textbooks. In units commonly used in geophysical field work the apparent resistivity formula becomes

$$\rho_a = \frac{1}{5f} \left| \frac{E}{B} \right|^2 \quad (2)$$

where ρ_a is in ohm-meters, E is in millivolts per kilometer, and B , the magnetic induction ($B = \mu H$), is in gammas.

Another important quantity measured in MT is the phase difference between the electric and magnetic fields. In a homogeneous earth the magnetic field lags the electric field by 45 degrees. For a layered earth the phase is greater than 45 degrees for a resistive layer over a conductive layer, and less than 45 degrees for a conductive layer over a resistive layer (Keller and Frisknecht, 1966). The use of phase information will be demonstrated in the discussion of one-dimensional MT inversion.

The depth of exploration in MT theory is taken to be that of a skin depth (δ) defined as the depth at which the amplitude of the electromagnetic wave has decayed to $1/e$ or 37 percent of its value at the surface. The skin depth is given by

$$\delta = \sqrt{2/\mu\sigma\omega} \quad (3)$$

where σ is the conductivity ($\sigma = 1/\rho$). When $\mu = \mu_0$ this becomes

$$\delta = 500 \sqrt{\rho/f} \quad (4)$$

where δ is in meters, ρ is in ohm-meters, and f is in hertz. The depth of exploration in magnetotellurics, therefore, is inversely proportional to the square root of the frequency being sampled. A depth sounding in MT is accomplished by recording EM signals over a wide range of frequencies, with higher frequencies sampling shallower depths than lower frequencies.

The apparent resistivity calculated in equation (1) is the true resistivity for a homogeneous half-space. For a layered (one-dimensional) earth the impedance becomes a complex scalar, and for a two-dimensional earth it becomes a complex tensor. By considering a horizontally layered earth with layers of constant resistivity and applying the proper boundary conditions, the impedance at the earth's surface can be calculated by applying a 2 by 2 transmission matrix at the lowest resistivity interface and calculating upward (Swift, 1967).

To illustrate, first consider a simple case of one layer of conductivity σ_1 with a depth of z to an interface with a basal half space of conductivity σ_2 . The expressions for the E and H fields using the transmission matrix become

$$\begin{bmatrix} E \\ H \end{bmatrix} = \begin{bmatrix} \cos(k_1 \Delta z) & \frac{i\mu\omega}{k_1} \sin(k_1 \Delta z) \\ \frac{ik_1}{\mu\omega} \sin(k_1 \Delta z) & \cos(k_1 \Delta z) \end{bmatrix} \begin{bmatrix} E \\ H \end{bmatrix}_{\Delta z} \quad (5)$$

$$k_1 = \sqrt{i\mu\omega\sigma}$$

where k is the wave propagation number. This matrix was formulated by applying Maxwell's equations and the proper boundary conditions to an incident and reflected electromagnetic wave. Note that the k 's are not constant but are a function of the conductivity of the layer through which the wave is propagating. The ratios E to H represent the wave impedances that are used to calculate the apparent resistivity. By applying trigonometric identities, the impedance Z_0 can be expressed in terms of the impedance of the basal half-space as

$$Z_o = \left(\frac{E}{H}\right)_o = \frac{Z\Delta z + \frac{i\mu\omega}{k_1} \tan(k_1\Delta z)}{1 + \frac{ik_1}{\mu\omega} \tan(k_1\Delta z)} \quad (6)$$

where Z_z , the characteristic impedance of the basal half-space, is given as

$$Z\Delta z = \frac{\mu\omega}{k_2}, \quad k_2 = \sqrt{i\mu\omega\sigma_2} \quad (7)$$

By substituting the expression for the surface impedance into equation (1), the apparent resistivity calculated becomes

$$\rho_a = \frac{1}{\omega\mu} |Z_o|^2 \quad (8)$$

with a phase (ϕ) of

$$\phi = \tan^{-1} \left[\frac{\text{Im}(Z_o)}{\text{Re}(Z_o)} \right] \quad (9)$$

These solutions for the apparent resistivity and phase are a function of the complex scalar impedances that themselves are dependent upon the conductivity and thicknesses of the electrical layers. Figure 4, taken from Keller and Frishknecht (1966), shows apparent resistivity and impedance phases for two layer models plotted versus the reciprocal of the product of k multiplied by Δz .

This approach can be extended to any number of layers and by starting at the basal half-space and iterating upward, the apparent resistivity and phase can be calculated for each desired frequency.

Two-dimensional magnetotelluric theory considers bodies of contrasting conductivities infinite in strike along a specified

Figure 4. Master curves of the resistivity of a basal half-space over the resistivity of an overlying layer of thickness Δz , and the phase as a function of the inverse of the product of the wave number and the layer thickness (adapted from Keller and Frischknecht, 1966).

direction. Retaining our cartesian coordinate system with the z-direction positive downward and the y-direction along strike such that partial derivatives with respect to y are zero, Maxwell's equations for plane electromagnetic waves of frequencies less than 10 Mhz become

$$\nabla \times \mathbf{E} = -i\mu\omega \mathbf{H} \quad (10)$$

$$-i\mu\omega H_x = -\frac{\partial E_y}{\partial z} \quad (11)$$

$$-i\mu\omega H_y = \frac{\partial E_x}{\partial z} - \frac{\partial E_z}{\partial x} \quad (12)$$

$$-i\mu\omega H_z = \frac{\partial E_y}{\partial x} \quad (13)$$

$$\nabla \times \mathbf{H} = \sigma \mathbf{E} \quad (14)$$

$$\sigma E_x = -\frac{\partial H_y}{\partial z} \quad (15)$$

$$\sigma E_y = \frac{\partial H_x}{\partial z} - \frac{\partial H_z}{\partial x} \quad (16)$$

$$\sigma E_z = \frac{\partial H_y}{\partial x} \quad (17)$$

so that equations (11), (13), and (16) represent one set of uncoupled equations for an electric field parallel to strike (no E_z or E_x components), and equations (12), (15), and (17) represent another set of uncoupled equations for an electric field perpendicular to strike.

Equations (12), (15), and (17) containing E_x , E_z , and H_y

components represent the transverse magnetic (TM) mode of wave propagation, since the magnetic field is transverse to the z-direction. Likewise, equations (11), (13), and (16) containing the H_x , H_z , and E_y components represent the transverse electric (TE) mode of wave propagation. The TM mode, therefore, involves the E-field component perpendicular to strike, while the TE mode involves the E-field parallel to strike. The boundary conditions at a vertical contact are $E_{\parallel}$, $H_{\parallel}$, $H_{\perp}$, and $J_{\perp}$ components are continuous (J is the current density). Since $J = \sigma E$, the E component is discontinuous, so the apparent resistivity calculated over a vertical boundary likewise will be discontinuous. This is illustrated in Figure 5, taken from page 41 of Swift (1967).

Complete information on the impedance in two-dimensional earths requires measurements of both the TE and TM orthogonal electromagnetic field components, so the impedance becomes a two by two complex tensor.

To best illustrate the differences between the TE and TM modes, a simple model of possible electrical resistivities of the stratigraphic units in the Ennis Hot Springs region is presented in Figure 6(a). A basement with a resistivity of 100 ohm-m is faulted with a displacement of 240 m. A layer of coarse sediments with a resistivity of 30 ohm-m and a thickness of 10 to 25 m overlies finer, saturated sediments containing clay with a resistivity of 10 ohm-m. Near the fault a zone of sediments containing thermal water was assigned a resistivity of 3 ohm-m. A finite element forward modeling program was used with this model to generate apparent resistivities at the earth's surface for various frequencies (Wannamaker, et al., 1985). Since the skin depth, one measure of the depth of exploration

Figure 5. Electromagnetic fields over a vertical contact, with resultant apparent resistivities for the TE (E-parallel) and the TM (E-perpendicular) modes of wave propagation (adapted from Swift, 1967).

Figure 6. Simplified electrical resistivity model of Ennis Hot Springs (Figure 6(a)), with apparent resistivity pseudosections calculated from the model for the TM mode (Figure 6(b)), and the TE mode (Figure 6(c)). All resistivities and apparent resistivities are in ohm-m.

in MT, is inversely proportional to the square root of the frequency, these apparent resistivities can be plotted versus frequency at each measurement station to form a pseudosection. The highest frequency data corresponding to the smallest depths are plotted at the top and successively lower frequency data are plotted in logarithmic intervals below. Apparent resistivity pseudosections are different from true resistivity sections because (1) they are a function of the resistivities of the overlying electrical layers as well as the resistivity of the material at the skin depth which might be taken as the depth of exploration; and (2) they are plotted with a vertical axis of frequency, not depth. Apparent resistivity pseudosections can be plotted with respect to an apparent skin depth, but this might lead to the erroneous interpretation of that the pseudosection is a true depth section.

Again referring to Figure 6, the boundary charges on the interface between the 100 ohm-m and 10 ohm-m material give a contrast of apparent resistivities in the TM mode (Figure 6(b)) greater than the apparent resistivities calculated from the continuous electromagnetic fields of the TE mode (as seen in Figure 6(c)). Note the overshoot in the apparent resistivity for the TM mode on the resistive side of the fault as also seen in the plot of the apparent resistivity over the vertical contact in Figure 5.

Figure 7(a) shows an electrical model similar to that shown in Figure 6(a) except for a fault with a displacement of 150 m placed below the right edge of the 3 ohm-m block. The apparent resistivities calculated from this model in the TM model (Figure 7(b)) show only a slight change from those presented in Figure 6(b), while the

Figure 7. Same as Figure 6, except a fault has been added to the electrical resistivity model in (a).

apparent resistivities in Figure (7c) for the TE mode are unchanged. This model illustrates the problem of detecting structures in the basement beneath a conductive zone.

To summarize, the concepts in this section as applied to later one- and two-dimensional modeling of the Ennis Hot Springs CSAMT data are: (1) electromagnetic waves do not propagate freely in the earth, instead they decay exponentially in depth as a function of the frequency and the conductivity of the earth (the skin effect). The dependence on conductivity means the method has difficulty detecting electrically resistive layers beneath more conductive layers. (2) The accumulation of boundary charges in the TM mode can make apparent resistivities higher or lower than the true resistivities of the electrical units on either side of vertical contacts. The TM mode, therefore, is a better detector of vertical contacts than the TE mode. On the other hand, overshoots and undershoots of the apparent resistivities using this mode of wave excitement make one-dimensional inversions of data near these contacts non-valid. Additionally, in a three-dimensional earth the electrical conductivity units are no longer infinite in strike so boundary charges from contacts that are not accounted for in two-dimensional modeling introduce unknown errors into the modeling process.

Controlled Source Audiomagnetotelluric Theory

A grounded electric dipole was introduced as a source by Goldstein and Strangway (1975). The advantages to having a controlled source include a strong signal and the ability to control the

polarization of the electric field. Measurements of the electric field parallel to the dipole are made either in the broadside (receiver along the center line of the transmitter) or the end-fire (receiver along the axis line of the transmitter) configuration. A null region at 45 degrees to the transmitter where E-parallel field components are small represents a region to be avoided.

One of the problems of CSAMT is the question of whether the plane wave assumption is valid. Goldstein and Strangway (1975) and Sandberg and Hohmann (1982) have shown that the assumption is valid for receivers located more than 3 skin depths away from the transmitter in the broadside configuration, and more than 5 skin depths away in the end-fire configuration for a homogeneous earth. A problem arises in that the signal strength often is too weak for a transmitter located at such a distance for the lower frequencies and in resistive terrain, and the length and location of the transmitter are sometimes constrained by local land usage.

Yamashita and Hallof (1985) discuss a near-field data correction to CSAMT data. Bartel and Jacobsen (1987) also describe a graphical technique to correct near-field data. By applying the image theory expressions of Bannister (1979) for an infinitesimal horizontal electrical dipole, equations for the near-field apparent resistivity in the broadside and end-fire configurations are derived in this paper. These derivations are included as Appendix A. The expressions are of the form

$$\rho_a = k_n r \left| \frac{E}{H} \right| \quad (18)$$

where r is the distance from the transmitter to the receiver, and k_n is the near-field correction factor (to use the terminology of Yamashita and Hallof (1985)). This factor is a function of r/δ , and is presented as Figure 8. The phase difference between the electric and magnetic fields for a homogeneous half-space from the image theory expressions is given for the end-fire configuration in Figure 9. Note the phase achieves the plane wave approximation value of 45 degrees as r becomes much greater than the skin depth.

To test the validity of the expression the correction was applied to the analytical results of Figure 1 of Sandberg and Hohmann (1982). (Because nearly all of the CSAMT survey at Ennis Hot Springs was carried out in the end-fire configuration, only that correction factor will be considered here.) Figure 10 compares the near-field corrected data to Sandberg and Hohmann's (1982) analytical results. The model was a homogeneous half-space having an apparent resistivity of 100 ohm-m. A transmitter length of 610 meters was used. The frequency is 32 hertz, so five skin depths is at 4400 meters. The greatest error in the corrected data occurs at stations closest to the transmitter. This is because the station is not far enough away from the transmitter in order for the dipole length to be considered much smaller than the receiver separation. A maximum error of about 20 percent is observed for the remaining stations. This gives a fair approximation to the "true" apparent resistivities, considering the correction is (1) derived for an infinitesimal dipole and applied to a dipole of finite length; and (2) is derived from an approximation to the complex integral expressions presented in Goldstein and Strangway (1975).

IMAGE THEORY NEAR-FIELD CORRECTION FACTORS

Figure 8. Plot of near-field correction factors derived from the image theory expressions of Bannister (1979). The broadside factor is the same as the correction factor presented in Figure 4(d) of Yamashita and Hallof (1985).

Figure 9. Phase difference between the electric and magnetic fields derived from the image theory expressions for the end-fire configuration.

IMAGE THEORY CORRECTION ON ANALYTICAL RESULTS

Figure 10. End-fire near-field correction factor applied to Figure 1 of Sandberg and Hohmann. The transmitter is located at the origin.

Figure 11, a plot of the ratio of the near-field apparent resistivity to the far-field apparent resistivity versus r/δ , illustrates the near-field, transition-field, and far-field regions. The near-field is demonstrated in the region where the ratio has a slope of one. The far-field, where the plane wave assumption is valid, is that region where the ratio is equal to unity. The transition-field is defined as the curved region where both near-field and far-field terms are present. This, unfortunately, is the region where the image theory approximation differs the most from the analytical results (Bannister, 1979).

A computer program correcting Cagniard apparent resistivities to the near-field values was applied to the field data collected at Ennis Hot Springs. The output of this program is given in Appendix B. By looking at r/δ in the output and comparing it with Figure 11, it can be determined in which region the measurement was made. If the measurement was made in the transition-field, the value can be found by interpolating between the far-field and near-field apparent resistivities.

CSAMT FIELD PROCEDURES

Most of the CSAMT equipment used in the Ennis Hot Springs survey was designed and manufactured by the Zonge Engineering and Research Organization (ZERO). The transmitting dipole consisted of a wire grounded to 4 or more metal stakes each driven into ground that had been saturated with salt water to lower the earth-electrode impedance. These stakes were then wired together in parallel at the

Figure 11. Apparent resistivity calculated from near-field correction expression over the Cagniard resistivity as a function of the distance from the transmitter over the skin depth.

surface, and a single wire from each pole was connected to the transmitter. The transmitter was powered by a 120 volt, 400 hertz motor-generator.

The first two transmitting dipoles, the east-west oriented T 1 and the north-south oriented T 2, were initially connected to a Geotronics FT-20A transmitter. This transmitter does not operate at frequencies above 256 hertz, however, and was later replaced by the Geotronics EMT-5000 transmitter. Use of this transmitter allowed us to obtain data at frequencies up to 2048 hertz.

The receiver set-up consisted of three lead/lead chloride electrodes with a dipole spacing of 100 meters to measure the electric field and a highly sensitive ferrite coil to measure the orthogonal magnetic field. These were connected to a ZERO GDP-12 microprocessor, which, after taking a reading, would display the magnitude of the electric field and its phase, followed by the magnitude of the magnetic field and its phase. The GDP-12 would then calculate the Cagniard resistivity and the phase difference between the two fields. Each morning the GDP-12 would be synchronized to the transmitter controller to improve the signal-to-noise ratio.

Data was collected at 1, 2, 4, 8, 16, 32, 64, 128, 256, 512, 1024 and 2048 hertz. Stacking of the data ranged from around 30 cycles at 1 hz to 2048 cycles averaged at 2048 hertz. Two or more stacks were taken at each setting to check the repeatability of the data.

Figure 12 (ZERO CSAMT field procedures manual, 1979) illustrates the transmitter and receiver set-up for the broadside configuration. Our survey used the same set-ups, but mostly in the end-fire configuration.

Controlled Source CSAMT Geometry

Figure 12. Schematic diagram showing the CSAMT field equipment for the broadside configuration that was used in the Ennis Hot Springs survey (adapted from the ZERO CSAMT field procedures manual).

ENNIS CSAMT SURVEY

The Ennis Hot Springs CSAMT survey was conducted using 100 meter station intervals in a grid 2500 meters by 2500 meters. Three transmitters (T) were used throughout the survey. T 1 and 2 were located about 1600 meters west of the reference base of the survey grid, while T 3 was about 2200 meters from the reference base. Originally T 3 had a dipole length of 305 m, but later was increased to 460 m to increase signal strength. The reference base (0 N, 0 E station) is located in the northwest corner of the junction between U.S. 287 and the private road leading to the hot springs (see Figure 2).

We ran several east-west lines and measured the east-west electric field component and its coupled north-south magnetic field component. At a few suspected fault crossings and in the null regions we utilized the north-south transmitter (T 2). Figure 13 is a posting of the stations occupied with the location of test wells and key private wells. The area of the map is outlined in Figure 2.

Figures 14 through 19 show plan contour maps of the apparent resistivity calculated at the sites at 1024, 256, 64, 16, 4, and 1 hertz. A near-field correction, discussed in Appendix A, was applied to the lower frequency data. A complete listing of all the data collected during the survey is included as Appendix B, including the output of the near-field correction program. Since the depth of exploration is considered to be that of a skin depth, these maps show successively deeper structure. The contour levels are at 1, 3, 5, 10, 30, 50, 100, 300, 500, and 1000 ohm-meters for all plots presented in

Ennis CSAMT stations

Figure 13. Posting of Ennis CSAMT survey stations within the survey grid. Distances are in meters. The survey grid border is outlined in Figure 2. Three test wells and one domestic well discussed in the text are shown.

apparent resistivity [ohm-m]

Figure 14. Plan map of apparent resistivities at 1024 hertz. Contours are at 1, 3, 5, 10, 30, 50, 100, 300, and 500 ohm-m.

Figure 15. Plan map of apparent resistivities at 256 hertz.
Contours are at 1, 3, 5, 10, 30, 50, 100, 300, and 500 ohm-m.

Figure 16. Plan map of apparent resistivities at 64 hertz.
Contours are at 1, 3, 5, 10, 30, 50, 100, 300, and 500 ohm-m.

Figure 17. Plan map of apparent resistivities at 16 hertz.
Contours are at 1, 3, 5, 10, 30, 50, 100, 300, and 500 ohm-m.

Figure 18. Plan map of apparent resistivities at 4 hertz.
Contours are at 1, 3, 5, 10, 30, 50, 100, 300, and 500 ohm-m.

Figure 19. Plan map of apparent resistivities at 1 hertz.
Contours are at 1, 3, 5, 10, 30, 50, 100, 300, and 500 ohm-m.

this report.

One of the obvious features of these maps at the higher frequencies is large resistivities west of 500 W and south of 500 N, near where McRae (1978) has postulated a fault uplifted to the west. Unaltered Precambrian metamorphic rocks would be expected to provide a large resistivity contrast compared to the conductive valley sediments. The CSAMT data suggest the fault to be north-south-trending, however, the 500 N survey line failed to detect higher resistivities in this region, perhaps indicating an intersecting fault trending roughly east-west.

Resistivity lows extending northward from the hot springs agree with the results of the scalar AMT soundings of Long and Senterfit (1979). Figure 20 is an apparent resistivity contour map of their survey for a north-south electric field and Figure 21 is the same for an east-west electric field. These apparent resistivities are calculated for an apparent skin depth of 300 m by interpolating between the two frequency bands at 7.5 and 27 Hz which were used in their survey. This survey with its much greater areal coverage and coarser station spacing provides a regional background for the results of the CSAMT study. Relatively high resistivities (over 100 ohm-m) found in the d.c. resistivity survey near the hot springs (Leonard, written communication) were not seen in the CSAMT data.

The greatest distribution of conductive material (less than 10 ohm-m) would appear to be in the 64 Hz map Figure 16. For 10 ohm-m earth this would be at a skin depth around 200 m, well below the top of the fractured gneiss penetrated at a depth of 160 m in test well Tx-11. The 64 Hz band was beset with 60 Hz noise from a local power

Figure 20. Apparent resistivity contour map for an apparent skindepth of 300 m from the scalar AMT data of Long and Senterfit (1979). The electric field was measured with north-south orientated dipole.

Figure 21. Apparent resistivity contour map for an apparent skin depth of 300 m from the scalar AMT data of Long and Senterfit (1979). The electric field was measured with east-west- orientated dipole.

substation located in the northwestern corner of the map region, and a powerline running along U.S. 287, but the 128 hz and the 32 hz maps show nearly the same anomalous region.

Higher frequency maps show a greater than 30 ohm-m zone on the eastern edge of the map that is absent in the lower frequency maps. Stations east of the survey area show apparent resistivities on the order of 30 to 100 ohm-m. An interpretation of this is that cold groundwater flow associated with either the Madison River or aquifers coming from the Madison Range front are mixing with the hot, more conductive water extending laterally eastward from the spring.

Apparent resistivity maps at selected frequencies show, with the exception of the southwest edge of the survey, a highly conductive (<30 ohm-m) earth at all frequencies, perhaps indicating a broad region of hot water, altered host rock, or clay-bearing sediments.

MODELING

Modeling of the Ennis Hot Springs CSAMT data was accomplished using two computer programs provided by the Earth Science Laboratory of the University of Utah Research Institute (Petrick, 1984; Stodt, 1978; Wannamaker et al, 1985). A one-dimensional MT inversion program constrained by well log data, gravity, and seismic interpretations was used to obtain initial estimates of the resistivities of the earth materials for subsequent use in a two-dimensional MT finite element forward modeling program.

Inversion

Inversion of selected stations was accomplished using MT1D, a one-dimensional, nonlinear weighted least squares inversion program with ridge regression (Petrick, 1984). Sites for inversion were generally chosen for their location away from faults (two-dimensional structures), the orientation of the electric field of the receiver, and the proximity of the station to logged wells for control of the thicknesses of the electrical layers.

Sandberg and Hohmann (1982) inverted all the stations along their CSAMT lines at Roosevelt Hot Springs, Utah, and stitched them together to obtain an initial guess for two-dimensional modeling. This technique was tried for the Ennis Hot Springs CSAMT survey, but the presence of large scale two-dimensional structures (faults) affected the electric field in ways that were not considered in the one-dimensional inversion process, so most of the inversion results were not useful.

As shown in the section on MT theory, apparent resistivities calculated from data collected in the TM mode exhibit overshoots and undershoots near vertical boundaries. Since most of the data in the Ennis Hot Springs CSAMT survey grid was collected with an east-west oriented electric field dipole, and the general strike of the Madison Range fault and related faults of smaller displacement on the west side of the valley is north-south, the TM (E-perpendicular) mode is the mode of primary importance. Data collected with a north-south oriented dipole can be considered to be in the TE mode, unless east-west structures are present. Since the TE mode is less sensitive

to vertical contacts, TE mode data away from fault boundaries should provide the most significant inversions results.

Figures 22 and 23 show the results of one-dimensional inversions of two stations, occupied east of the Madison River at the Valley Garden state fishing access (labeled "VG" on Figure 2). These inversions are for a north-south receiving dipole (using transmitter T 2), and since the locations of the stations are in the center of the valley away from the bounding valley faults, the TE mode, one-dimensional assumptions should apply. Apparent resistivities and phases were weighted by the standard deviation between repeated measurements at each station. The apparent resistivities for the 1 and 2 hz data have been corrected for the near-field, but their corresponding phases were not and consequently were not used in the inversion. Both inversions show a well resolved (estimated standard deviation percentage less than 12 percent) layer of 40 ohm-m material 220 to 280 m thick over a conductive zone of 3 ohm-m material 220 to 240 m thick that was not nearly as well resolved (see Table 1 for estimated parameter percentage standard deviations). A basal resistive layer is also given, but its resistivity value was poorly resolved since it underlies a thick, highly conductive zone.

The estimated parameter standard deviations (Table 1) for the two Valley Garden stations increase for the deeper layers, so the inversion results are probably best for the shallower layers. No reasonable estimate of the basement resistivity was obtained from inversion attempts on the stations occupied east of 500 W (where the fault postulated in the previous section exists in Figures 14 through 19). West of the suspected fault on the upthrown side, the large skin

1-D INVERSION OF VALLEY GARDEN ACCESS

Figure 22. Observed apparent resistivities and phases compared to model-generated data from 1-D inversion of Valley Garden fishing access south station. The estimated percentage data fit is 10.3 % for the apparent resistivities, and 5.1% for the phases. Estimated percentage parameter standard deviations are given in Table 1.

1-D INVERSION OF VALLEY GARDEN ACCESS

Figure 23. Observed apparent resistivities and phases compared to model-generated data from 1-D inversion of Valley Garden fishing access north station. The estimated percentage data fit is 6.8 % for the apparent resistivities, and 5.3% for the phases. Estimated percentage parameter standard deviations are given in Table 1.

1-D INVERSION OF 325 S, 300 W (TX-9 DATA)

Figure 24. Observed apparent resistivities and phases compared to model-generated data from 1-D inversion of station 325 S, 300 W. The estimated percentage data fit is 30.5% for the apparent resistivities, and 12.1% for the phases. Estimated percentage parameter standard deviations are given in Table 1.

TABLE 1.

Estimated percentage standard deviations (EPSD) parameters from one-dimensional inversions for the Valley Garden fishing access stations (south and north), and station 325S., 300 W. Note that the Valley Garden station's parameters were unconstrained, while the thicknesses of the layers of station 325 S., 300 W. were held constant because of information from the lithology and resistivity logs of earth.

VALLEY GARDEN FISHING ACCESS (SOUTH)

<u>Resistivity (OHM-M)</u>	<u>EPSD</u>	<u>Thickness (M)</u>	<u>EPSD</u>
40.0	7.2	220.	11.8
3.3	40.9	224.	47.
1.0E+05	3790.	-	-

VALLEY GARDEN FISHING ACCESS (NORTH)

<u>Resistivity (ohm-m)</u>	<u>EPSD</u>	<u>Thickness (m)</u>	<u>EPSD</u>
40.0	6.2	277.	11.6
3.5	46.3	240.	61.
140.	193.	-	-

325 SOUTH, 300 WEST

<u>Resistivity (ohm-m)</u>	<u>EPSD</u>	<u>Thickness (m)</u>	<u>EPSD</u>
2.2	27.9	5.	-
9.5	21.8	100.	-
25.	26.9	-	-

depths due to the resistive terrain and the proximity of the stations to the fault introduce boundary effects that violate the 1-D inversion assumptions. Initial estimates of the basement resistivity for forward 2-D modeling were obtained by modeling the structure of the basement based on the data and interpretations of McRae (1978) and Leonard (written communication), and iterating a few models with different basement resistivities until one was determined that fit the data best (and within an acceptable range of resistivities for crystalline rocks.)

Resistivities of the electrical layers in the valley fill determined by the inversion, on the other hand, were used in the initial 2-D forward modeling. The upper layer of 40 ohm-m material is consistent with resistivities of saturated fluvial and lacustrine deposits, but the thick layer of underlying 3 ohm-m material is less resistive than might be expected for valley fill. Test hole Tx-10, located 2 km northwest of the Valley Garden stations (Figure 2), penetrated, at 220m, a less permeable, denser valley fill than the overlying sediments. This suggests a conductive zone of sediments containing clay, as opposed to conductive thermal waters since the maximum temperature in Tx-10 was 28.7 degrees Celsius at 267 m. Clay zones are also observed in the well logs of Tx-9, Tx-11, and Tx-12 (Figure 13).

Although the Valley Garden stations would seem to satisfy the one-dimensional criteria the best, any faults or lateral inhomogeneities with an east-west component a few skin depths from the site would introduce the TM mode effects that might invalidate the one-dimensional inversion process. Resistivity estimates from inversion results thus were applied to two-dimensional forward modeling with

some degree of flexibility. Estimates of the resistivities of the lithologic units logged in test wells in the Ennis area were attempted using 1-D inversion by holding thicknesses of the units constant. Inversion of station 325 S, 300 W used strata thicknesses from nearby test hole Tx-9. The uppermost unit is a 5 m layer of well-drained cobbles and gravels that should be fairly resistive compared to the 100 m layer of finer, clay-bearing sediments lying below. The metamorphic basement at a depth of 107 m should be highly resistant, although alteration of its feldspar minerals to clay by the circulating thermal water could lower the bulk resistivity of the basement in the Ennis geothermal area.

Inversion results from this station are presented in Table 1, and a comparison between the observed apparent resistivities and phases and apparent resistivities and phases calculated from the estimates of the resistivities determined by the inversion are shown in Figure 24. The results in Table 1 would appear to show that the model fit the data well, with estimated parameter standard deviations ranging from 20 to 30 percent, but a resistivity of 2 ohm-m for dry cobbles and gravels and 25 ohm-m for basement crystalline rocks a few hundred meters from the postulated fracture zone is highly unlikely. More likely this is just an example of misapplication of inverse modeling, since a thin resistive layer near the surface would not appreciably affect the sounding curve. For example, the skin depth at 2 KHz in 50 ohm-m material is about 80 m compared to first layer thickness of 5 m. In this case, the inversion is attempting to set the first layer resistivity to a low value since that is all the data will support. Given the restrictions imposed by the fixed layer thicknesses, it is

not surprising that the inversion does not provide much useful information about the layer resistivities. Similar attempts at combining well log data from Tx-11 and Tx-12 with nearby soundings also provided little useful information.

Two-dimensional Forward Modeling

A finite element program (PW2D) for the solution of responses of two-dimensional earth resistivity structures to plane electromagnetic waves (Wannamaker et al, 1985) was used to test models of the electrical conductivity of the subsurface.

Several east-west lines of data were collected with an east-west electric field receiving dipole utilizing transmitters T 1 and T 3 except for line 1500 N which used transmitter T 2 because it was in the null region for east-west electric fields from T 1. Because of the similarity of pseudosections of the apparent resistivities of these lines, only models of the 0 N and 500 N lines will be presented.

Figure 25 is the observed apparent resistivity pseudosection for the 0 N line, and Figure 26 shows its respective observed phase. Stations taken along this and other lines are indicated by the station number in hundreds of meters on the top of the section. The "T" shaped character with the station numbers represent a powerline where readings could not be taken due to 60 hz interference. The hot springs occur at about 350 E on this line, where the strongest resistivity low is seen.

Figure 27 shows the electrical resistivity model of the subsurface along the 0 N line profile that was arrived at after many

Figure 25. Pseudosection of observed apparent resistivity, 0 N line, Ennis CSAMT. The numbers across the top of the diagram represent stations where the CSAMT data was collected. The T-shaped character represents a powerline. The distances given in the bottom of the diagram are in meters.

Figure 26. Pseudosection of observed phase, 0 N line, Ennis CSAMT.

Figure 27. Electrical Conductivity model of 0 N line, Ennis CSAMT.

Apparent resistivity [ohm-m]

Figure 28. Pseudosection of model apparent resistivity, TM mode, 0 N line, Ennis CSAMT. Compare to the observed apparent resistivity presented in Figure 25.

Figure 29. Pseudosection of model phase, TM mode, 0 N line, Ennis CSAMT. Compare to the observed phase presented in Figure 26.

time consuming adjustments to fit the observed pseudosection shown in Figure 25. As discussed in the inversion section, this east-west electric field data is considered to be TM mode, so forward modeling was done in this mode. Figures 28 and 29 are the pseudosections of apparent resistivities and phases (respectively) generated by the program for the model of Figure 27.

The observed apparent resistivity and phase pseudosections show a large contrast near 700 W, approximately where Leonard (written communication) has interpreted a fault based upon seismic, gravity, and drilling data. Using his interpretations of the depth to basement, a fault having a displacement of 150 m was modeled at 700 w. a resistivity of 150 ohm-m was assigned to the basement because it gave the TM mode boundary effects to the model-generated apparent resistivities approximately to the same degree as seen in the observed data on both sides of the fault. A resistivity of 10 ohm-m was assigned to the valley sediments at depth during the initial stages of modeling, because these two resistivities gave a rough approximation to the large 10 ohm-m apparent resistivity contour extending from the postulated fault to 1000 E.

The gravel terrace above the hot springs was modeled (using a topographic option in the computer program) with a resistivity of 50 ohm-m in the west decreasing to 25 ohm-m near the springs. Successive layers of mixing of cold groundwater with underlying thermal water (evidenced in Tx-9) were modeled as 25, 10, and 5 ohm-m blocks. Model results with these layers compare favorably with the observed pseudosection from 0 to 500 W.

Because the propagation of electromagnetic waves in the earth is

a diffusion phenomena (the skin effect), forward modeling solutions are much more sensitive to conductivity contrasts in the upper layers than at depth. Most of the modeling of the Ennis CSAMT data was accomplished by changing the resistivities of these upper layers. Changes in conductivity resulting from groundwater of one electrical conductivity mixing with groundwater of another probably occur as a continuous function, rather than in the discrete blocks the geophysicist uses in the modeling process. The lack of closure of the 10 ohm-m contour at 300 W at the bottom of Figure 28 is probably the result of boundary effects between the 10 and 25, and the 10 and 3 ohm-m blocks, where such a zone of mixing is likely to occur.

A region of thermal water below the hot springs was modeled by 3 ohm-m material. The apparent resistivity pseudosection generated from the model shows a 3 ohm-m contour in good agreement with the observed apparent resistivity low, although slightly smaller in magnitude. Another zone of thermal water mixing with cooler water was modeled with layers of 5, 10, and 16 ohm-m material, producing the "bulge" in the contours of less than 10 ohm-m material in the apparent resistivities in the 16 Hz range (Figure 25). Cold water from the Madison River (near 1500 E) and Moores Creek (near 550 E) percolating through the sediments was modeled with resistivities of 25 and 50 ohm-m.

A zone of 30 ohm-m apparent resistivities in the lower frequencies generated by the model on the eastern end of the line was not seen in the near-field corrected observed data. Another fault may be present at depth, but its position and displacement cannot be determined with the CSAMT data with any degree of confidence. The

location and displacement of the fault at 450 E was based on the seismic interpretations and drill hole data. Experience from modeling showed that adjusting the locations, thicknesses, and resistivities of the overlying sediments changed the resultant pseudosection as much as changing the location and amount of displacement of the basement fault modeled at 450 E, so the fault was not adjusted significantly in the modeling process.

The observed and model phase pseudosections (Figures 26 and 29) both have a closed low of 30 degrees near 500 E at a frequency of 16 hz, indicating a highly conductive zone above resistive units. Phase data is not as strongly affected by vertical boundaries as TM mode-calculated apparent resistivities. The 50 to 55 degree phase areas above the 30 degree low support the surficial resistive zones of the model in Figure 25. These areas extend eastward and do not agree with 45 to 35 degree horizontal phase layering seen in the model pseudosection. Possible explanations for this are that the resistivity of the thermal water plume is lower than the 3 ohm-m modeled; the surficial resistive layer in the east extends to a greater depth than was modeled; or a combination of the two.

The observed apparent resistivity and phase pseudosections of the 500 N line are shown in Figures 30 and 31. The conductive zone centered at the base of the terrace has a somewhat larger extent than the zone in the 0 N line and the strong resistivity increase to the west is absent in the 500 N line. The shift of the resistive zone to the west is also apparent in the plan maps such as Figure 20 and Figure 16. The abrupt shift in the contours in Figure 16 at about 500 N and 800 W may incindate a south-east fault structure. This structure

Figure 30. Pseudosection of observed apparent resistivity, 500 N line, Ennis CSAMT. The numbers across the top of the diagram represent stations where the CSAMT data was collected. The T-shaped character represents a powerline. The distances given in the bottom of the diagram are in meters.

Figure 31. Pseudosection of observed phase, 500 N line, Ennis CSAMT.

Electrical Conductivity Model of 500 N Line, Ennis CSAMT

Figure 32. Electrical Conductivity model of 500 N line, Ennis CSAMT.

Apparent resistivity [ohm-m]

Figure 33. Pseudosection of model apparent resistivity, TM mode, 500 N line, Ennis CSAMT. Compare to the observed apparent resistivity presented in Figure 30.

Figure 34. Pseudosection of model phase, TM mode, 500 N line, Ennis CSAMT. Compare to the observed phase presented in Figure 31.

is also apparent in the gravity and seismic data (Semmens, 1987) and Leonard (written communication) has also postulated a fracture zone in this region.

With the model of the 0 N line as a guide, a model for the 500 N line was developed. After several iterations the model in Figure 32 resulted and Figures 33 and 34 show the TM model apparent resistivity and phase pseudosections.

The foothills of the Tobacco Root Mountains begin a few hundred meters west of the survey region. A fault or an unconformity must exist between the valley sediments and the Precambrian Gneisses and schists of the foothills. This is close enough to the survey region to add boundary effects to the apparent resistivity data. This interface was modeled at 1400 W, off the survey grid. By extending the 3 ohm-m layer of the 0 N line model to the top of the basement and adding this contact, a good fit to the 500 N line model was achieved, leaving the 2-D assumption reasonably intact (considering the highly three-dimensional nature of the subsurface in the Ennis area.)

Phase data (Figure 31) supported the placement of this western-bounding interface in the model. The observed and model phase (Figures 31 and 34) show about the same degree of fit as the 0 N line model. It should be noted that the observed phase in Figures 26 and 31 have not been corrected for the near-field, and that phase information for frequencies less than 32 hz have been omitted from the pseudosections.

By compiling stations along the 7 east-west lines measuring the east-west electric field, a north-south pseudosection was made for the 400 E stations, which would pass over the hot springs at 0 E (Figure

35). Along this N-S line we see that the most conductive zone is centered about 300 m north of the hot spring and a considerable zone of high conductivity extends as far as 1400 m north.

Figure 35. Pseudosection of observed apparent resistivity, 400 E line, Ennis CSAMT. The numbers across the top of the diagram represent stations where the CSAMT data was collected. The T-shaped character represents a powerline. The distances given in the bottom of the diagram are in meters.

SUMMARY AND CONCLUSIONS

The Ennis Hot Springs CSAMT survey delineated a large elliptical shaped resistivity low of less than 10 ohm-m material extending from a few hundred meters south of the hot springs northward for at least 1500 m. The center of the most conductive region is north of the hot springs and this conductive zone extends westward under the terrace as well as eastward toward the valley. The modeling indicates the conductive zone extends at least several hundreds of meters to the east and west of terrace and the location of the hot springs. The modeled depth extent of the conductive zone is about 100 to 150 meters but it should be noted that much of the initial control on the depths was provided by well logs and seismic data. If this conductive zone is indicative of the presence of geothermal fluids, it is interesting to note that center of the most conductive area is north of the surface hot spring in the vicinity of the intersection of a postulated south-east trending fault and the north-south fault just to the east of the terrace. An intersecting fault structure would, of course, be a prime candidate for the localization of the circulation of geothermal fluids. Modeling (not shown here) of a thin conductive conduit extending below the near surface conductive zone showed that such a zone would probably not be detectable.

Controlled-source audiomagnetotellurics in this type of geothermal environment (thermal fluids issuing into valley fill from the fractured and faulted basement) had its best results in defining the conductive zone resulting from hot water aquifers and/or hydrothermally altered rocks. Defining the structural features which

control the circulation of the thermal waters close to the hot springs was hampered by the thick conductive zone in the area. Other structural features such as the uplifting of the basement to the west were well defined by the CSAMT survey.

A near field correction to data not meeting the plane wave criteria alleviated one of the problems of CSAMT surveys, that is, maintaining adequate signal strength while keeping the transmitter far enough from the receiver to keep the plane wave assumption valid. Further studies of correction procedures over inhomogeneous ground should be conducted before these corrections are used on a more routine basis.

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APPENDIX A

Derivation of the Near-Field Correction Factor

The scalar apparent resistivity calculated in the magnetotelluric method is given by

$$\rho_a = \frac{1}{\omega\mu} \left| \frac{E}{H} \right|^2$$

where ρ_a is the scalar apparent resistivity, μ is the magnetic permeability, ω is the angular frequency, and E and H are the orthogonal coupled electric and magnetic field components. This expression was derived by Cagniard (1953) for plane electromagnetic waves. Goldstein and Strangway (1975) and Sandberg and Hohmann (1982) have shown that this expression is valid for a controlled source if receivers are located more than three skin depths from the transmitter in the broadside and more than five skin depths in the collinear (end-fire) configurations for a homogeneous earth.

For a receiver located close to the transmitter the expressions for the electric and magnetic fields are derived from Maxwell's equations for a horizontal electric dipole, which contain complex integrals involving zero and first order Bessel functions that cannot be easily evaluated. By replacing the finitely conductive earth with a perfectly conductive earth located at the complex depth d, Bannister (1979) derived image theory expressions for the E and H field components that are simpler to evaluate. He states that for measurements distances on the order of a skin depth,

the image theory approximation varies from the analytical results by no more than 20 percent. Since most of the CSAMT measurements taken at Ennis Hot Springs were in the end-fire configuration, the expressions for the maximum E and H orthogonal field components are

$$E_r = \frac{I l}{2\pi\sigma} \frac{\cos\phi}{r^3} \left[2 - \frac{2r^2}{d^2} \left(1 - \frac{r}{\sqrt{r^2 + d^2}} \right) \right]$$

and

$$H = \frac{I l}{2\pi} \frac{\cos\phi}{r^2} \left[\frac{d/2}{\sqrt{r^2 + d^2}} \right]$$

where r is the distance from the transmitter to the receiver, $d = \delta(1-i)$, δ is the skin depth, I is the current, l is the dipole length, and σ is the conductivity (the unknown). Taking the ratio of these field components:

$$\frac{E_r}{H} = \frac{4}{\sigma r} \frac{\sqrt{r^2 + d^2}}{d} \left[1 - \frac{r^2}{d^2} \left(1 - \frac{r}{\sqrt{r^2 + d^2}} \right) \right]$$

simplifying further,

$$\frac{\sigma r}{4} \frac{E_r}{H} = \left[1 - \frac{r^2}{d^2} - \frac{r^4}{d^4} + \frac{r^6}{d^6} \right]^{1/2} + \frac{r^3}{d^3}$$

substituting $d = \delta(1 - i)$,

$$\frac{\sigma r}{4} \frac{E_r}{H} = \left[1 - \frac{r^4}{4\delta^4} \right]^{1/2} \left[1 - \frac{r^2}{2\delta^2} i \right]^{1/2} - \frac{r^3}{4\omega^3} (1 - i)$$

Taking the root of a complex number requires the following relationships:

$$z = \alpha + i\beta = |z| e^{i\phi}$$

where

$$|z| = \sqrt{\alpha^2 + \beta^2}$$

$$\phi = \tan^{-1}\left(\frac{\beta}{\alpha}\right)$$

so

$$z^{1/2} = |z|^{1/2} e^{i\phi/2}$$

so the expression becomes

$$\begin{aligned} \frac{\sigma r E_r}{4H_\phi} &= \underbrace{\left(1 + \frac{r^4}{4\delta^4}\right)^{3/4} \cos\left(\frac{\tan^{-1}\left(-\frac{r^2}{2\delta^2}\right)}{2}\right) - \frac{r^3}{4\delta^3}}_{\text{(In-phase) (Re)}} \\ &\quad + \underbrace{\left(1 + \frac{r^4}{4\delta^4}\right)^{3/4} \sin\left(\frac{\tan^{-1}\left(-\frac{r^2}{2\delta^2}\right)}{2}\right) - \frac{r^3}{4\delta^3}}_{\text{Quadrature (Im)}} \end{aligned}$$

taking the magnitude,

$$\frac{\sigma r |E_r|}{4 |H_\phi|} = [\text{Re}^2 + \text{Im}^2]^{1/2}$$

yields

$$\frac{\sigma r}{4} \frac{|E_r|}{H_\phi} = \left[\left\{ \left(1 + \frac{r^4}{4\delta^4} \right)^{3/4} \cos \left(\frac{\tan^{-1} \left(-\frac{r^2}{2\delta^2} \right)}{2} \right) - \frac{r^3}{4\delta^3} \right\}^2 + \left\{ \left(1 + \frac{r^4}{4\delta^4} \right)^{3/4} \sin \left(\frac{\tan^{-1} \left(-\frac{r^2}{2\delta^2} \right)}{2} \right) + \frac{r^3}{4\delta^3} \right\}^2 \right]^{1/2}$$

$$\frac{1}{\sigma} = \rho_a = k_n r \left| \frac{E_r}{H_\phi} \right|$$

where

$$k_n = \frac{1}{4} \left[\left\{ \left(1 + \frac{r^4}{4\delta^4} \right)^{3/4} \cos \left(\frac{\tan^{-1} \left(-\frac{r^2}{2\delta^2} \right)}{2} \right) - \frac{r^3}{4\delta^3} \right\}^2 + \left\{ \left(1 + \frac{r^4}{4\delta^4} \right)^{3/4} \sin \left(\frac{\tan^{-1} \left(-\frac{r^2}{2\delta^2} \right)}{2} \right) + \frac{r^3}{4\delta^3} \right\}^2 \right]^{1/2}$$

to use the notation of Yamashita and Hallof (1985). The near-field correction factor, k_n , therefore, is a function of the ratio of r to δ . A complication arises in that the skin depth is a function of the resistivity, the unknown for which we are solving. One solution to this problem is to iterate the near-field resistivity several times to achieve a reasonable approximation.

The expression for k_n for the broadside case is not nearly as compact, and it is as follows:

$$k_{nb} = \left[\left(\frac{2\delta^2 - r^2}{2\delta^3} \right)^2 + \left(\frac{2\delta^2 + r^2}{2\delta^2} \right)^2 \right]^{-1/2} \left[\left((r^4 + 4\delta^4)^{1/4} \cos \left(\frac{\tan^{-1} \left(\frac{-2\delta^2}{r^2} \right)}{2} \right) - \frac{r^5}{r^4 + \delta^4} \right)^2 + \left((r^4 + 4\delta^4)^{1/4} \sin \left(\frac{\tan^{-1} \left(\frac{-2\delta^2}{r^2} \right)}{2} - \frac{r^3\delta^2}{r^4 + \delta^4} \right)^2 \right)^2 \right]^{-1/2}$$

The two correction factors are plotted in figure 8 and can be compared to Figure 4(d) of Yamashita and Hallof (1985). Bannister (1967) gives the near-field components for the electric and magnetic fields for r much less than a skin depth. By forming the ratio of the coupled components, the near-field expressions for the broadside and end-fire configurations are:

$$\rho_a = \frac{r}{2} \left| \frac{E}{H} \right|$$

$$k_n = 0.5$$

(broadside)

$$\rho_a = \frac{r}{4} \left| \frac{E}{H} \right|$$

$$k_n = 0.25$$

(end-fire)

which are shown in the corresponding region in Figure 8. The broadside case correction factor compares quite favorably to Yamashita and Hallof's Figure 4(d) except for a slight "bump" in the transition field. This region, where r is approximately one skin depth, represents a region where the image theory approximation varies from the analytical expressions (see Bannister, 1979, page 1006, Figure 4).

APPENDIX B

ENNIS HOT SPRINGS CSAMT DATA

Following is a computer program output of the Ennis Hot Springs CSAMT data that has been corrected for near-field effects. The first two columns list the x- and y- coordinates (in m) in reference to the survey grid. The third column is the apparent resistivity (ohm-m) calculated in the field by the GDP-12 for Cagniard's equation. The fourth column contains the apparent resistivity (ohm-m) calculated using the expression for the end-fire apparent resistivity given in Appendix A. If the r , the distance from the transmitter to the receiver, is greater than 4.5 times the skin depth, the near-field apparent resistivity is flagged with a 9999. This 4.5 value represents the end of the transition field as seen in Figure 11. Columns 5, 6, and 7 list the frequency (Hz), transmitter, and receiver dipole orientation, respectively. Column 8 is the ratio of r over the "apparent" skin depth. This skin depth value was arrived at after iterating the near-field apparent resistivity three times and using that value in the skin depth formula.

X	Y	RESISTIVITY	NEAR	FREQUENCY	TRANSMITTER	RECEIVER	R/S
-650.	500.	10.	9999.	16.	3.	E	.73E+01
-650.	500.	10.	9999.	8.	3.	E	.52E+01
-650.	500.	15.	14.	4.	3.	E	.31E+01
-650.	500.	20.	14.	2.	3.	E	.21E+01
-500.	500.	8.	9999.	2048.	3.	E	.87E+02
-500.	500.	11.	9999.	1024.	3.	E	.53E+02
-500.	500.	9.	9999.	512.	3.	E	.41E+02
-500.	500.	6.	9999.	256.	3.	E	.36E+02
-500.	500.	7.	9999.	128.	3.	E	.23E+02
-500.	500.	8.	9999.	64.	3.	E	.15E+02
-500.	500.	11.	9999.	32.	3.	E	.93E+01
-500.	500.	9.	9999.	16.	3.	E	.73E+01
-500.	500.	9.	9999.	8.	3.	E	.52E+01
-500.	500.	21.	17.	4.	3.	E	.26E+01
-500.	500.	50.	23.	2.	3.	E	.16E+01
-500.	500.	81.	20.	1.	3.	E	.12E+01
-400.	500.	12.	9999.	2048.	3.	E	.69E+02
-400.	500.	11.	9999.	1024.	3.	E	.51E+02
-400.	500.	10.	9999.	512.	3.	E	.38E+02
-400.	500.	9.	9999.	256.	3.	E	.28E+02
-400.	500.	9.	9999.	128.	3.	E	.20E+02
-400.	500.	12.	9999.	64.	3.	E	.12E+02
-400.	500.	16.	9999.	32.	3.	E	.74E+01
-400.	500.	16.	9999.	16.	3.	E	.53E+01
-400.	500.	14.	13.	8.	3.	E	.40E+01
-400.	500.	20.	17.	4.	3.	E	.26E+01
-400.	500.	74.	26.	2.	3.	E	.14E+01
-400.	500.	229.	31.	1.	3.	E	.94E+00
-300.	500.	12.	9999.	2048.	3.	E	.66E+02
-300.	500.	12.	9999.	1024.	3.	E	.47E+02
-300.	500.	10.	9999.	512.	3.	E	.36E+02
-300.	500.	9.	9999.	256.	3.	E	.27E+02
-300.	500.	10.	9999.	128.	3.	E	.18E+02
-300.	500.	13.	9999.	64.	3.	E	.11E+02
-300.	500.	16.	9999.	32.	3.	E	.72E+01
-300.	500.	16.	9999.	16.	3.	E	.51E+01
-300.	500.	16.	15.	8.	3.	E	.37E+01
-300.	500.	28.	20.	4.	3.	E	.22E+01
-300.	500.	77.	26.	2.	3.	E	.14E+01
-300.	500.	120.	22.	1.	3.	E	.11E+01
-200.	500.	15.	9999.	2048.	3.	E	.57E+02
-200.	500.	15.	9999.	1024.	3.	E	.40E+02
-200.	500.	13.	9999.	512.	3.	E	.31E+02
-200.	500.	9.	9999.	256.	3.	E	.26E+02
-200.	500.	9.	9999.	128.	3.	E	.18E+02
-200.	500.	10.	9999.	64.	3.	E	.12E+02
-200.	500.	11.	9999.	32.	3.	E	.83E+01
-200.	500.	10.	9999.	16.	3.	E	.62E+01
-200.	500.	10.	10.	8.	3.	E	.44E+01
-200.	500.	15.	13.	4.	3.	E	.27E+01
-200.	500.	33.	16.	2.	3.	E	.17E+01
-200.	500.	104.	20.	1.	3.	E	.11E+01
-100.	500.	13.	9999.	2048.	3.	E	.59E+02
-100.	500.	12.	9999.	1024.	3.	E	.43E+02

X	Y	RESISTIVITY	NEAR	FREQUENCY	TRANSMITTER	RECEIVER	R/Z
200.	1500.	22.	9999.	512.	2.	E	.22E+02
200.	1500.	23.	9999.	1024.	2.	E	.30E+02
200.	1500.	8.	9999.	2048.	2.	E	.71E+02
350.	1500.	160.	23.	1.	2.	E	.97E+00
350.	1500.	85.	25.	2.	2.	E	.13E+01
350.	1500.	46.	24.	4.	2.	E	.18E+01
350.	1500.	24.	23.	8.	2.	E	.28E+01
350.	1500.	15.	9999.	16.	2.	E	.49E+01
350.	1500.	10.	9999.	32.	2.	E	.84E+01
350.	1500.	7.	9999.	64.	2.	E	.14E+02
350.	1500.	12.	9999.	128.	2.	E	.15E+02
350.	1500.	16.	9999.	256.	2.	E	.19E+02
350.	1500.	19.	9999.	512.	2.	E	.24E+02
350.	1500.	22.	9999.	1024.	2.	E	.32E+02
350.	1500.	39.	9999.	2048.	2.	E	.34E+02
550.	1500.	88.	19.	1.	2.	E	.12E+01
550.	1500.	47.	20.	2.	2.	E	.16E+01
550.	1500.	25.	19.	4.	2.	E	.23E+01
550.	1500.	14.	13.	8.	2.	E	.39E+01
550.	1500.	9.	9999.	16.	2.	E	.67E+01
550.	1500.	6.	9999.	32.	2.	E	.12E+02
550.	1500.	8.	9999.	64.	2.	E	.14E+02
550.	1500.	14.	9999.	128.	2.	E	.15E+02
550.	1500.	16.	9999.	256.	2.	E	.20E+02
550.	1500.	17.	9999.	512.	2.	E	.28E+02
550.	1500.	16.	9999.	1024.	2.	E	.40E+02
550.	1500.	16.	9999.	2048.	2.	E	.57E+02
750.	1500.	86.	20.	1.	2.	E	.12E+01
750.	1500.	25.	20.	4.	2.	E	.24E+01
750.	1500.	9.	9999.	16.	2.	E	.72E+01
750.	1500.	7.	9999.	32.	2.	E	.12E+02
750.	1500.	12.	9999.	64.	2.	E	.12E+02
750.	1500.	18.	9999.	128.	2.	E	.14E+02
750.	1500.	20.	9999.	256.	2.	E	.19E+02
750.	1500.	19.	9999.	512.	2.	E	.28E+02
750.	1500.	19.	9999.	1024.	2.	E	.40E+02
750.	1500.	15.	9999.	2048.	2.	E	.63E+02
200.	500.	61.	11.	1.	1.	E	.11E+01
200.	500.	31.	12.	2.	1.	E	.15E+01
200.	500.	16.	11.	4.	1.	E	.22E+01
200.	500.	8.	8.	8.	1.	E	.37E+01
200.	500.	4.	9999.	16.	1.	E	.73E+01
200.	500.	2.	9999.	32.	1.	E	.15E+02
200.	500.	3.	9999.	64.	1.	E	.17E+02
200.	500.	5.	9999.	128.	1.	E	.19E+02
200.	500.	7.	9999.	256.	1.	E	.22E+02
200.	500.	9.	9999.	512.	1.	E	.28E+02
200.	500.	11.	9999.	1024.	1.	E	.35E+02
200.	500.	13.	9999.	2048.	1.	E	.46E+02
300.	500.	47.	11.	1.	1.	E	.12E+01
300.	500.	24.	11.	2.	1.	E	.16E+01
300.	500.	12.	10.	4.	1.	E	.25E+01
300.	500.	6.	9999.	8.	1.	E	.45E+01
300.	500.	3.	9999.	16.	1.	E	.89E+01

X	Y	RESISTIVITY	NEAR	FREQUENCY	TRANSMITTER	RECEIVER	R/S
-300.	-150.	51.	15.	1.	3.	E	.13E+01
-300.	-150.	7.	7.	4.	3.	E	.39E+01
-300.	-150.	5.	9999.	16.	3.	E	.91E+01
-300.	-150.	6.	9999.	32.	3.	E	.12E+02
-300.	-150.	7.	9999.	64.	3.	E	.15E+02
-300.	-150.	8.	9999.	128.	3.	E	.20E+02
-300.	-150.	10.	9999.	256.	3.	E	.26E+02
-300.	-150.	12.	9999.	512.	3.	E	.33E+02
-300.	-150.	15.	9999.	1024.	3.	E	.42E+02
-300.	-150.	16.	9999.	2048.	3.	E	.57E+02
-500.	-150.	261.	34.	1.	3.	E	.93E+00
-500.	-150.	84.	29.	2.	3.	E	.14E+01
-500.	-150.	31.	23.	4.	3.	E	.23E+01
-500.	-150.	10.	9999.	16.	3.	E	.69E+01
-500.	-150.	13.	9999.	32.	3.	E	.86E+01
-500.	-150.	13.	9999.	64.	3.	E	.12E+02
-500.	-150.	13.	9999.	128.	3.	E	.17E+02
-500.	-150.	14.	9999.	256.	3.	E	.23E+02
-500.	-150.	13.	9999.	512.	3.	E	.34E+02
-500.	-150.	13.	9999.	1024.	3.	E	.49E+02
-500.	-150.	12.	9999.	2048.	3.	E	.71E+02
100.	500.	79.	12.	1.	1.	E	.99E+00
100.	500.	39.	13.	2.	1.	E	.14E+01
100.	500.	20.	12.	4.	1.	E	.20E+01
100.	500.	10.	9.	8.	1.	E	.32E+01
100.	500.	5.	9999.	16.	1.	E	.62E+01
100.	500.	3.	9999.	32.	1.	E	.11E+02
100.	500.	3.	9999.	64.	1.	E	.16E+02
100.	500.	5.	9999.	128.	1.	E	.18E+02
100.	500.	7.	9999.	256.	1.	E	.21E+02
100.	500.	9.	9999.	512.	1.	E	.26E+02
100.	500.	11.	9999.	1024.	1.	E	.33E+02
100.	500.	12.	9999.	2048.	1.	E	.45E+02
50.	1500.	900.	46.	1.	2.	E	.62E+00
50.	1500.	440.	47.	2.	2.	E	.86E+00
50.	1500.	218.	50.	4.	2.	E	.12E+01
50.	1500.	114.	53.	8.	2.	E	.16E+01
50.	1500.	63.	49.	16.	2.	E	.24E+01
50.	1500.	38.	36.	32.	2.	E	.39E+01
50.	1500.	19.	9999.	64.	2.	E	.78E+01
50.	1500.	9.	9999.	128.	2.	E	.16E+02
50.	1500.	14.	9999.	256.	2.	E	.18E+02
50.	1500.	23.	9999.	512.	2.	E	.20E+02
50.	1500.	27.	9999.	1024.	2.	E	.26E+02
50.	1500.	24.	9999.	2048.	2.	E	.39E+02
200.	1500.	405.	33.	1.	2.	E	.77E+00
200.	1500.	210.	36.	2.	2.	E	.10E+01
200.	1500.	113.	39.	4.	2.	E	.14E+01
200.	1500.	61.	39.	8.	2.	E	.20E+01
200.	1500.	35.	32.	16.	2.	E	.31E+01
200.	1500.	21.	9999.	32.	2.	E	.55E+01
200.	1500.	12.	9999.	64.	2.	E	.10E+02
200.	1500.	10.	9999.	128.	2.	E	.16E+02
200.	1500.	18.	9999.	256.	2.	E	.17E+02

X	Y	RESISTIVITY	NEAR	FREQUENCY	TRANSMITTER	RECEIVER	R/S
700.	500.	3.	9999.	16.	1.	E	.11E+02
700.	500.	3.	9999.	32.	1.	E	.15E+02
700.	500.	3.	9999.	64.	1.	E	.17E+02
700.	500.	6.	9999.	128.	1.	E	.22E+02
700.	500.	7.	9999.	256.	1.	E	.28E+02
700.	500.	9.	9999.	512.	1.	E	.35E+02
700.	500.	10.	9999.	1024.	1.	E	.47E+02
700.	500.	14.	9999.	2048.	1.	E	.56E+02
1100.	500.	83.	20.	1.	1.	E	.12E+01
1100.	500.	36.	19.	2.	1.	E	.18E+01
1100.	500.	20.	17.	4.	1.	E	.26E+01
1100.	500.	12.	12.	8.	1.	E	.45E+01
1100.	500.	10.	9999.	16.	1.	E	.69E+01
1100.	500.	14.	9999.	32.	1.	E	.83E+01
1100.	500.	23.	9999.	64.	1.	E	.91E+01
1100.	500.	28.	9999.	128.	1.	E	.12E+02
1100.	500.	29.	9999.	256.	1.	E	.16E+02
1100.	500.	27.	9999.	512.	1.	E	.24E+02
1100.	500.	25.	9999.	1024.	1.	E	.35E+02
1100.	500.	20.	9999.	2048.	1.	E	.55E+02
1500.	500.	47.	18.	1.	1.	E	.15E+01
1500.	500.	31.	20.	2.	1.	E	.20E+01
1500.	500.	13.	12.	4.	1.	E	.36E+01
1500.	500.	11.	9999.	8.	1.	E	.54E+01
1500.	500.	13.	9999.	16.	1.	E	.70E+01
1500.	500.	23.	9999.	32.	1.	E	.74E+01
1500.	500.	39.	9999.	64.	1.	E	.80E+01
1500.	500.	48.	9999.	128.	1.	E	.10E+02
1500.	500.	48.	9999.	256.	1.	E	.14E+02
1500.	500.	51.	9999.	512.	1.	E	.20E+02
1500.	500.	49.	9999.	1024.	1.	E	.29E+02
1500.	500.	69.	9999.	2048.	1.	E	.34E+02
1300.	500.	53.	18.	1.	1.	E	.14E+01
1300.	500.	15.	14.	4.	1.	E	.31E+01
1300.	500.	10.	9999.	16.	1.	E	.74E+01
1300.	500.	16.	9999.	32.	1.	E	.83E+01
1300.	500.	26.	9999.	64.	1.	E	.92E+01
1300.	500.	32.	9999.	128.	1.	E	.12E+02
1300.	500.	34.	9999.	256.	1.	E	.16E+02
1300.	-325.	76.	21.	1.	1.	E	.13E+01
1300.	-325.	27.	22.	4.	1.	E	.25E+01
1300.	-325.	16.	15.	8.	1.	E	.42E+01
1300.	-325.	11.	9999.	16.	1.	E	.72E+01
1300.	-325.	11.	9999.	32.	1.	E	.10E+02
1300.	-325.	22.	9999.	64.	1.	E	.10E+02
1300.	-325.	26.	9999.	128.	1.	E	.13E+02
1300.	-325.	35.	9999.	256.	1.	E	.16E+02
1300.	-325.	36.	9999.	512.	1.	E	.22E+02
1300.	-325.	46.	9999.	1024.	1.	E	.28E+02
1300.	-325.	33.	9999.	2048.	1.	E	.47E+02
1100.	-325.	102.	22.	1.	1.	E	.12E+01
1100.	-325.	29.	22.	4.	1.	E	.23E+01
1100.	-325.	17.	16.	8.	1.	E	.39E+01
1100.	-325.	11.	9999.	16.	1.	E	.67E+01

X	Y	RESISTIVITY	NEAR	FREQUENCY	TRANSMITTER	RECEIVER	R/S
1100.	-325.	8.	9999.	32.	1.	E	.115+02
1100.	-325.	13.	9999.	64.	1.	E	.12E+02
1100.	-325.	18.	9999.	128.	1.	E	.15E+02
1100.	-325.	23.	9999.	256.	1.	E	.18E+02
1100.	-325.	26.	9999.	512.	1.	E	.25E+02
1100.	-325.	30.	9999.	1024.	1.	E	.32E+02
1100.	-325.	32.	9999.	2048.	1.	E	.44E+02
900.	-325.	170.	26.	1.	1.	E	.10E+01
900.	-325.	50.	29.	4.	1.	E	.19E+01
900.	-325.	29.	25.	8.	1.	E	.28E+01
900.	-325.	17.	9999.	16.	1.	E	.50E+01
900.	-325.	10.	9999.	32.	1.	E	.92E+01
900.	-325.	11.	9999.	64.	1.	E	.12E+02
900.	-325.	18.	9999.	128.	1.	E	.14E+02
900.	-325.	22.	9999.	256.	1.	E	.18E+02
900.	-325.	26.	9999.	512.	1.	E	.23E+02
900.	-325.	30.	9999.	1024.	1.	E	.30E+02
900.	-325.	26.	9999.	2048.	1.	E	.46E+02
700.	-325.	220.	27.	1.	1.	E	.91E+00
700.	-325.	122.	30.	2.	1.	E	.12E+01
700.	-325.	67.	32.	4.	1.	E	.17E+01
700.	-325.	36.	29.	8.	1.	E	.25E+01
700.	-325.	20.	19.	16.	1.	E	.43E+01
700.	-325.	10.	9999.	32.	1.	E	.85E+01
700.	-325.	7.	9999.	64.	1.	E	.14E+02
700.	-325.	12.	9999.	128.	1.	E	.15E+02
700.	-325.	17.	9999.	256.	1.	E	.18E+02
700.	-325.	20.	9999.	512.	1.	E	.24E+02
700.	-325.	22.	9999.	1024.	1.	E	.32E+02
700.	-325.	22.	9999.	2048.	1.	E	.46E+02
500.	-325.	396.	32.	1.	1.	E	.76E+00
500.	-325.	199.	34.	2.	1.	E	.10E+01
500.	-325.	105.	37.	4.	1.	E	.14E+01
500.	-325.	55.	36.	8.	1.	E	.20E+01
500.	-325.	28.	26.	16.	1.	E	.34E+01
500.	-325.	13.	9999.	32.	1.	E	.68E+01
500.	-325.	7.	9999.	64.	1.	E	.13E+02
500.	-325.	8.	9999.	128.	1.	E	.17E+02
500.	-325.	15.	9999.	256.	1.	E	.18E+02
500.	-325.	17.	9999.	512.	1.	E	.24E+02
500.	-325.	19.	9999.	1024.	1.	E	.32E+02
500.	-325.	23.	9999.	2048.	1.	E	.41E+02
400.	-275.	209.	23.	1.	2.	N	.86E+00
400.	-275.	64.	27.	4.	2.	N	.16E+01
400.	-275.	34.	26.	8.	2.	N	.23E+01
400.	-275.	17.	16.	16.	2.	N	.41E+01
400.	-275.	7.	9999.	32.	2.	N	.88E+01
400.	-275.	6.	9999.	64.	2.	N	.13E+02
400.	-275.	9.	9999.	128.	2.	N	.16E+02
400.	-275.	14.	9999.	256.	2.	N	.18E+02
400.	-275.	15.	9999.	512.	2.	N	.24E+02
400.	-275.	17.	9999.	1024.	2.	N	.32E+02
400.	-275.	117.	9999.	2048.	2.	N	.17E+02
400.	-275.	111.	25.	2.	2.	N	.12E+01

X	Y	RESISTIVITY	NEAR	FREQUENCY	TRANSMITTER	RECEIVER	R/S
400.	-275.	454.	32.	1.	1.	E	.72E+00
400.	-275.	116.	36.	4.	1.	E	.14E+01
400.	-275.	59.	36.	8.	1.	E	.19E+01
400.	-275.	30.	27.	14.	1.	E	.31E+01
400.	-275.	14.	9999.	32.	1.	E	.63E+01
400.	-275.	7.	9999.	64.	1.	E	.12E+02
400.	-275.	8.	9999.	128.	1.	E	.17E+02
400.	-275.	14.	9999.	256.	1.	E	.18E+02
400.	-275.	17.	9999.	512.	1.	E	.23E+02
400.	-275.	17.	9999.	1024.	1.	E	.32E+02
400.	-275.	17.	9999.	2048.	1.	E	.45E+02
300.	-325.	308.	26.	1.	1.	E	.77E+00
300.	-325.	77.	29.	4.	1.	E	.15E+01
300.	-325.	39.	27.	8.	1.	E	.21E+01
300.	-325.	19.	18.	16.	1.	E	.37E+01
300.	-325.	9.	9999.	32.	1.	E	.75E+01
300.	-325.	5.	9999.	64.	1.	E	.14E+02
300.	-325.	4.	9999.	128.	1.	E	.22E+02
300.	-325.	9.	9999.	256.	1.	E	.21E+02
300.	-325.	11.	9999.	512.	1.	E	.27E+02
300.	-325.	12.	9999.	1024.	1.	E	.37E+02
300.	-325.	17.	9999.	2048.	1.	E	.43E+02
200.	-325.	332.	25.	1.	1.	E	.74E+00
200.	-325.	87.	29.	4.	1.	E	.14E+01
200.	-325.	46.	29.	8.	1.	E	.20E+01
200.	-325.	24.	22.	16.	1.	E	.32E+01
200.	-325.	13.	9999.	32.	1.	E	.59E+01
200.	-325.	7.	9999.	64.	1.	E	.11E+02
200.	-325.	7.	9999.	128.	1.	E	.16E+02
200.	-325.	13.	9999.	256.	1.	E	.17E+02
200.	-325.	16.	9999.	512.	1.	E	.21E+02
200.	-325.	14.	9999.	1024.	1.	E	.32E+02
200.	-325.	10.	9999.	2048.	1.	E	.54E+02
100.	-325.	245.	21.	1.	2.	N	.78E+00
100.	-325.	61.	23.	4.	2.	N	.15E+01
100.	-325.	18.	17.	16.	2.	N	.35E+01
100.	-325.	35.	24.	8.	2.	N	.21E+01
100.	-325.	9.	9999.	32.	2.	N	.68E+01
100.	-325.	6.	9999.	64.	2.	N	.12E+02
100.	-325.	7.	9999.	128.	2.	N	.15E+02
100.	-325.	13.	9999.	256.	2.	N	.16E+02
100.	-325.	15.	9999.	512.	2.	N	.21E+02
100.	-325.	15.	9999.	1024.	2.	N	.30E+02
100.	-325.	19.	9999.	2048.	2.	N	.37E+02
100.	-325.	340.	24.	1.	1.	E	.72E+00
100.	-325.	85.	27.	4.	1.	E	.14E+01
100.	-325.	25.	22.	16.	1.	E	.30E+01
100.	-325.	15.	9999.	32.	1.	E	.52E+01
100.	-325.	10.	9999.	64.	1.	E	.91E+01
100.	-325.	8.	9999.	128.	1.	E	.14E+02
100.	-325.	15.	9999.	256.	1.	E	.15E+02
100.	-325.	19.	9999.	512.	1.	E	.19E+02
100.	-325.	18.	9999.	1024.	1.	E	.27E+02
100.	-325.	16.	9999.	2048.	1.	E	.40E+02

X	Y	RESISTIVITY	NEAR	FREQUENCY	TRANSMITTER	RECEIVER	R/S
700.	0.	7.	9999.	64.	1.	E	.14E+02
700.	0.	11.	9999.	128.	1.	E	.16E+02
700.	0.	13.	9999.	256.	1.	E	.21E+02
700.	0.	15.	9999.	512.	1.	E	.27E+02
700.	0.	17.	9999.	1024.	1.	E	.36E+02
700.	0.	23.	9999.	2048.	1.	E	.44E+02
900.	0.	92.	20.	1.	1.	E	.11E+01
900.	0.	50.	21.	2.	1.	E	.16E+01
900.	0.	29.	20.	4.	1.	E	.22E+01
900.	0.	17.	16.	8.	1.	E	.35E+01
900.	0.	9.	9999.	16.	1.	E	.67E+01
900.	0.	8.	9999.	32.	1.	E	.10E+02
900.	0.	14.	9999.	64.	1.	E	.11E+02
900.	0.	21.	9999.	128.	1.	E	.12E+02
900.	0.	23.	9999.	256.	1.	E	.17E+02
900.	0.	25.	9999.	512.	1.	E	.23E+02
900.	0.	24.	9999.	1024.	1.	E	.33E+02
900.	0.	33.	9999.	2048.	1.	E	.40E+02
1500.	1100.	31.	15.	1.	1.	E	.17E+01
1500.	1100.	13.	12.	4.	1.	E	.37E+01
1500.	1100.	9.	9999.	16.	1.	E	.87E+01
1500.	1100.	15.	9999.	32.	1.	E	.95E+01
1500.	1100.	24.	9999.	64.	1.	E	.11E+02
1500.	1100.	33.	9999.	128.	1.	E	.13E+02
1500.	1100.	31.	9999.	256.	1.	E	.19E+02
1500.	1100.	35.	9999.	512.	1.	E	.25E+02
1500.	1100.	34.	9999.	1024.	1.	E	.36E+02
1500.	1100.	36.	9999.	2048.	1.	E	.49E+02
1300.	1100.	47.	17.	1.	1.	E	.15E+01
1300.	1100.	14.	13.	4.	1.	E	.34E+01
1300.	1100.	9.	9999.	16.	1.	E	.81E+01
1300.	1100.	12.	9999.	32.	1.	E	.10E+02
1300.	1100.	22.	9999.	64.	1.	E	.10E+02
1300.	1100.	28.	9999.	128.	1.	E	.13E+02
1300.	1100.	28.	9999.	256.	1.	E	.18E+02
1300.	1100.	30.	9999.	512.	1.	E	.25E+02
1300.	1100.	29.	9999.	1024.	1.	E	.36E+02
1300.	1100.	48.	9999.	2048.	1.	E	.40E+02
1100.	1100.	42.	15.	1.	1.	E	.15E+01
1100.	1100.	15.	14.	4.	1.	E	.31E+01
1100.	1100.	8.	9999.	16.	1.	E	.81E+01
1100.	1100.	8.	9999.	32.	1.	E	.11E+02
1100.	1100.	15.	9999.	64.	1.	E	.12E+02
1100.	1100.	18.	9999.	128.	1.	E	.15E+02
1100.	1100.	18.	9999.	256.	1.	E	.22E+02
1100.	1100.	15.	9999.	512.	1.	E	.33E+02
1100.	1100.	13.	9999.	1024.	1.	E	.51E+02
1100.	1100.	10.	9999.	2048.	1.	E	.82E+02
900.	1100.	43.	14.	1.	1.	E	.14E+01
900.	1100.	14.	13.	4.	1.	E	.30E+01
900.	1100.	7.	9999.	16.	1.	E	.81E+01
900.	1100.	5.	9999.	32.	1.	E	.14E+02
900.	1100.	10.	9999.	64.	1.	E	.14E+02
900.	1100.	11.	9999.	128.	1.	E	.18E+02

X	Y	RESISTIVITY	WEAR	FREQUENCY	TRANSMITTER	RECEIVER	R.F.
900.	1100.	11.	9999.	512.	1.	E	.31E+01
900.	1100.	10.	9999.	512.	1.	E	.31E+01
900.	1100.	10.	9999.	1024.	1.	E	.31E+01
900.	1100.	12.	9999.	2048.	1.	E	.31E+01
700.	1100.	13.	11.	1.	1.	E	.13E+01
700.	1100.	15.	13.	4.	1.	E	.27E+01
700.	1100.	8.	9999.	16.	1.	E	.30E+01
700.	1100.	4.	9999.	32.	1.	E	.14E+02
700.	1100.	9.	9999.	64.	1.	E	.13E+02
700.	1100.	9.	9999.	128.	1.	E	.15E+02
700.	1100.	8.	9999.	256.	1.	E	.28E+02
700.	1100.	3.	9999.	512.	1.	E	.40E+02
700.	1100.	6.	9999.	1024.	1.	E	.55E+02
700.	1100.	7.	9999.	2048.	1.	E	.85E+02
500.	1100.	32.	14.	1.	1.	E	.12E+01
500.	1100.	20.	15.	4.	1.	E	.23E+01
500.	1100.	14.	9999.	16.	1.	E	.49E+01
500.	1100.	6.	9999.	32.	1.	E	.11E+02
500.	1100.	10.	9999.	64.	1.	E	.12E+02
500.	1100.	11.	9999.	128.	1.	E	.14E+02
500.	1100.	13.	9999.	256.	1.	E	.20E+02
500.	1100.	12.	9999.	512.	1.	E	.30E+02
500.	1100.	14.	9999.	1024.	1.	E	.39E+02
500.	1100.	13.	9999.	2048.	1.	E	.58E+02
500.	1100.	31.	11.	1.	2.	N	.14E+01
500.	1100.	8.	7.	4.	2.	N	.33E+01
500.	1100.	16.	10.	2.	2.	N	.20E+01
500.	1100.	3.	9999.	16.	2.	N	.11E+02
500.	1100.	3.	9999.	32.	2.	N	.15E+02
500.	1100.	4.	9999.	64.	2.	N	.15E+02
500.	1100.	7.	9999.	128.	2.	N	.20E+02
500.	1100.	7.	9999.	256.	2.	N	.28E+02
500.	1100.	8.	9999.	512.	2.	N	.37E+02
500.	1100.	10.	9999.	1024.	2.	N	.46E+02
500.	1100.	11.	9999.	2048.	2.	N	.63E+02
400.	1100.	43.	12.	1.	2.	N	.13E+01
400.	1100.	11.	10.	4.	2.	N	.29E+01
400.	1100.	4.	9999.	16.	2.	N	.83E+01
400.	1100.	4.	9999.	32.	2.	N	.12E+02
400.	1100.	7.	9999.	64.	2.	N	.13E+02
400.	1100.	9.	9999.	128.	2.	N	.17E+02
400.	1100.	10.	9999.	256.	2.	N	.22E+02
400.	1100.	12.	9999.	512.	2.	N	.29E+02
400.	1100.	13.	9999.	1024.	2.	N	.39E+02
400.	1100.	13.	9999.	2048.	2.	N	.55E+02
300.	1100.	46.	12.	1.	1.	E	.12E+01
300.	1100.	11.	9.	4.	1.	E	.27E+01
300.	1100.	4.	9999.	16.	1.	E	.85E+01
300.	1100.	5.	9999.	32.	1.	E	.11E+02
300.	1100.	6.	9999.	64.	1.	E	.14E+02
300.	1100.	3.	9999.	128.	1.	E	.17E+02
300.	1100.	9.	9999.	256.	1.	E	.23E+02
300.	1100.	11.	9999.	512.	1.	E	.29E+02
300.	1100.	12.	9999.	1024.	1.	E	.39E+02

A	RESISTIVITY	NEAR FREQUENCY	TRANSMITTER	RECEIVER	AVE
300. 1100.	11.	9999. 1048.	1.	E	.11E+01
200. 1100.	31.	9999. 1.	1.	E	.13E+01
200. 1100.	3.	9999. 4.	1.	E	.14E+01
200. 1100.	1.	9999. 16.	1.	E	.14E+01
200. 1100.	4.	9999. 3.	1.	E	.17E+01
200. 1100.	3.	9999. 32.	1.	E	.10E+01
200. 1100.	3.	9999. 64.	1.	E	.11E+01
200. 1100.	9.	9999. 128.	1.	E	.14E+02
200. 1100.	3.	9999. 256.	1.	E	.13E+02
200. 1100.	10.	9999. 512.	1.	E	.15E+02
200. 1100.	11.	9999. 1024.	1.	E	.18E+02
200. 1100.	10.	9999. 2048.	1.	E	.13E+02
100. 1100.	115.	13. 1.	1.	E	.94E+00
100. 1100.	26.	16. 4.	1.	E	.15E+01
100. 1100.	3.	9999. 16.	1.	E	.39E+01
100. 1100.	4.	9999. 32.	1.	E	.11E+02
100. 1100.	12.	9999. 64.	1.	E	.89E+01
100. 1100.	11.	9999. 128.	1.	E	.13E+02
100. 1100.	12.	9999. 256.	1.	E	.18E+02
100. 1100.	15.	9999. 512.	1.	E	.23E+02
100. 1100.	19.	9999. 1024.	1.	E	.28E+02
100. 1100.	10.	9. 3.	1.	E	.33E+01
100. 1100.	31.	9999. 2048.	1.	E	.31E+02
-100. 200.	20.	9. 1.	3.	E	.14E+01
-100. 200.	10.	9. 2.	3.	E	.23E+01
-100. 200.	4.	9999. 4.	3.	E	.47E+01
-100. 200.	2.	9999. 8.	3.	E	.93E+01
-100. 200.	3.	9999. 16.	3.	E	.11E+02
-100. 200.	4.	9999. 32.	3.	E	.13E+02
-100. 200.	3.	9999. 64.	3.	E	.17E+02
-100. 200.	6.	9999. 128.	3.	E	.21E+02
-100. 200.	6.	9999. 256.	3.	E	.30E+02
-100. 200.	6.	9999. 512.	3.	E	.43E+02
-100. 200.	3.	9999. 1024.	3.	E	.63E+01
-100. 200.	8.	9999. 2048.	3.	E	.74E+01
-200. 200.	34.	12. 1.	3.	E	.14E+01
-200. 200.	15.	10. 2.	3.	E	.21E+01
-200. 200.	6.	6. 4.	3.	E	.40E+01
-200. 200.	3.	9999. 8.	3.	E	.75E+01
-200. 200.	4.	9999. 16.	3.	E	.97E+01
-200. 200.	5.	9999. 32.	3.	E	.12E+02
-200. 200.	6.	9999. 64.	3.	E	.14E+02
-200. 200.	6.	9999. 128.	3.	E	.22E+02
-200. 200.	7.	9999. 256.	3.	E	.29E+02
-200. 200.	7.	9999. 512.	3.	E	.41E+02
-200. 200.	5.	9999. 1024.	3.	E	.69E+02
-200. 200.	4.	9999. 2048.	3.	E	.11E+03
-300. 200.	77.	13. 1.	3.	E	.12E+01
-300. 200.	33.	17. 2.	3.	E	.17E+01
-300. 200.	13.	12. 4.	3.	E	.29E+01
-300. 200.	7.	9999. 8.	3.	E	.34E+01
-300. 200.	8.	9999. 16.	3.	E	.71E+01
-300. 200.	9.	9999. 32.	3.	E	.95E+01
-300. 200.	8.	9999. 64.	3.	E	.14E+02

X	Y	RESISTIVITY	NEAR	FREQUENCY	TRANSMITTER	RECEIVER	R/S
100.	200.	9.	7.	2.	3.	E	.23E+01
100.	200.	4.	4.	4.	3.	E	.43E+01
100.	200.	2.	9999.	8.	3.	E	.84E+01
100.	200.	1.	9999.	16.	3.	E	.17E+02
100.	200.	2.	9999.	32.	3.	E	.17E+02
200.	200.	29.	9.	1.	3.	E	.13E+01
200.	200.	14.	9.	2.	3.	E	.19E+01
200.	200.	5.	5.	4.	3.	E	.37E+01
200.	200.	2.	9999.	8.	3.	E	.80E+01
200.	200.	2.	9999.	16.	3.	E	.11E+02
200.	200.	2.	9999.	32.	3.	E	.16E+02
300.	200.	27.	8.	1.	3.	E	.13E+01
300.	200.	11.	7.	2.	3.	E	.20E+01
300.	200.	4.	4.	4.	3.	E	.39E+01
300.	200.	2.	9999.	8.	3.	E	.76E+01
300.	200.	1.	9999.	16.	3.	E	.15E+02
300.	200.	1.	9999.	32.	3.	E	.22E+02
400.	200.	20.	7.	1.	3.	E	.14E+01
400.	200.	10.	6.	2.	3.	E	.20E+01
400.	200.	4.	4.	4.	3.	E	.37E+01
400.	200.	2.	9999.	8.	3.	E	.72E+01
400.	200.	1.	9999.	16.	3.	E	.14E+02
400.	200.	1.	9999.	32.	3.	E	.20E+02
500.	200.	13.	5.	1.	3.	E	.15E+01
500.	200.	6.	4.	2.	3.	E	.23E+01
500.	200.	2.	9999.	4.	3.	E	.49E+01
500.	200.	1.	9999.	8.	3.	E	.97E+01
500.	200.	1.	9999.	16.	3.	E	.14E+02
500.	200.	1.	9999.	32.	3.	E	.19E+02
600.	200.	9.	4.	1.	3.	E	.16E+01
600.	200.	4.	3.	2.	3.	E	.25E+01
600.	200.	2.	9999.	4.	3.	E	.46E+01
600.	200.	1.	9999.	8.	3.	E	.91E+01
600.	200.	1.	9999.	16.	3.	E	.13E+02
600.	200.	2.	9999.	32.	3.	E	.13E+02
-800.	500.	172.	31.	1.	3.	E	.11E+01
-800.	500.	74.	30.	2.	3.	E	.15E+01
-800.	500.	29.	23.	4.	3.	E	.25E+01
-800.	500.	13.	9999.	8.	3.	E	.48E+01
-800.	500.	12.	9999.	16.	3.	E	.70E+01
-800.	500.	13.	9999.	32.	3.	E	.95E+01
-800.	500.	11.	9999.	64.	3.	E	.15E+02
-800.	500.	8.	9999.	128.	3.	E	.24E+02
-800.	500.	8.	9999.	256.	3.	E	.34E+02
-800.	500.	8.	9999.	512.	3.	E	.48E+02
-800.	500.	8.	9999.	1024.	3.	E	.69E+02
-800.	500.	2.	9999.	2048.	3.	E	.19E+03
-650.	500.	8.	9999.	2048.	3.	E	.92E+02
-650.	500.	10.	9999.	1024.	3.	E	.58E+02
-650.	500.	9.	9999.	512.	3.	E	.43E+02
-650.	500.	5.	9999.	256.	3.	E	.41E+02
-650.	500.	7.	9999.	128.	3.	E	.25E+02
-650.	500.	8.	9999.	64.	3.	E	.16E+02
-650.	500.	12.	9999.	32.	3.	E	.94E+01

X	Y	RESISTIVITY	NEAR	FREQUENCY	TRANSMITTER	RECEIVER	R/S
-100.	500.	10.	9999.	512.	3.	E	.33E+02
-100.	500.	7.	9999.	256.	3.	E	.28E+02
-100.	500.	7.	9999.	128.	3.	E	.20E+02
-100.	500.	5.	9999.	64.	3.	E	.17E+02
-100.	500.	5.	9999.	32.	3.	E	.12E+02
-100.	500.	4.	9999.	16.	3.	E	.93E+01
-100.	500.	3.	9999.	8.	3.	E	.76E+01
-100.	500.	5.	5.	4.	3.	E	.42E+01
-100.	500.	12.	9.	2.	3.	E	.22E+01
-100.	500.	30.	11.	1.	3.	E	.14E+01
200.	500.	3.	9999.	32.	3.	E	.13E+02
200.	500.	2.	9999.	16.	3.	E	.12E+02
200.	500.	2.	9999.	8.	3.	E	.81E+01
200.	500.	4.	4.	4.	3.	E	.41E+01
200.	500.	8.	6.	2.	3.	E	.23E+01
200.	500.	17.	7.	1.	3.	E	.15E+01
400.	500.	2.	9999.	32.	3.	E	.15E+02
400.	500.	7.	9999.	16.	3.	E	.56E+01
400.	500.	2.	9999.	8.	3.	E	.73E+01
400.	500.	4.	4.	4.	3.	E	.37E+01
400.	500.	8.	6.	2.	3.	E	.22E+01
400.	500.	17.	6.	1.	3.	E	.15E+01
600.	500.	4.	9999.	32.	3.	E	.93E+01
600.	500.	2.	9999.	16.	3.	E	.93E+01
600.	500.	2.	9999.	8.	3.	E	.66E+01
600.	500.	5.	5.	4.	3.	E	.31E+01
600.	500.	20.	9.	2.	3.	E	.16E+01
600.	500.	20.	6.	1.	3.	E	.13E+01
-200.	1000.	13.	9999.	32.	3.	E	.80E+01
-200.	1000.	8.	9999.	16.	3.	E	.72E+01
-200.	1000.	7.	9999.	8.	3.	E	.55E+01
-200.	1000.	13.	12.	4.	3.	E	.30E+01
-200.	1000.	21.	13.	2.	3.	E	.20E+01
-200.	1000.	30.	12.	1.	3.	E	.15E+01
100.	1100.	3.	9999.	32.	3.	E	.15E+02
100.	1100.	1.	9999.	16.	3.	E	.18E+02
100.	1100.	1.	9999.	8.	3.	E	.13E+02
100.	1100.	1.	9999.	4.	3.	E	.92E+01
100.	1100.	1.	9999.	2.	3.	E	.65E+01
100.	1100.	1.	9999.	1.	3.	E	.46E+01
200.	1100.	5.	9999.	32.	3.	E	.11E+02
200.	1100.	4.	9999.	16.	3.	E	.88E+01
200.	1100.	2.	9999.	8.	3.	E	.88E+01
200.	1100.	1.	9999.	4.	3.	E	.88E+01
200.	1100.	1.	9999.	2.	3.	E	.62E+01
200.	1100.	4.	3.	1.	3.	E	.24E+01
300.	1100.	5.	9999.	32.	3.	E	.11E+02
300.	1100.	3.	9999.	16.	3.	E	.98E+01
300.	1100.	3.	9999.	8.	3.	E	.69E+01
300.	1100.	6.	6.	4.	3.	E	.35E+01
300.	1100.	12.	8.	2.	3.	E	.21E+01
300.	1100.	17.	7.	1.	3.	E	.16E+01
400.	1100.	3.	9999.	32.	3.	E	.13E+02
400.	1100.	2.	9999.	16.	3.	E	.11E+02

X	Y	RESISTIVITY	NEAR	FREQUENCY	TRANSMITTER	RECEIVER	R/S
400.	1100.	3.	9999.	8.	3.	E	.66E+01
400.	1100.	3.	9999.	4.	3.	E	.47E+01
400.	1100.	7.	6.	2.	3.	E	.24E+01
400.	1100.	12.	6.	1.	3.	E	.17E+01
600.	1100.	4.	9999.	32.	3.	E	.10E+02
600.	1100.	3.	9999.	16.	3.	E	.85E+01
600.	1100.	4.	9999.	8.	3.	E	.52E+01
600.	1100.	4.	4.	4.	3.	E	.38E+01
600.	1100.	12.	7.	2.	3.	E	.19E+01
600.	1100.	28.	8.	1.	3.	E	.13E+01
-900.	-325.	603.	9999.	2048.	3.	E	.12E+02
-900.	-325.	695.	9999.	1024.	3.	E	.77E+01
-900.	-325.	722.	9999.	512.	3.	E	.53E+01
-900.	-325.	683.	652.	256.	3.	E	.39E+01
-900.	-325.	623.	558.	128.	3.	E	.30E+01
-900.	-325.	673.	497.	64.	3.	E	.22E+01
-900.	-325.	462.	304.	32.	3.	E	.20E+01
-900.	-325.	358.	196.	16.	3.	E	.18E+01
-900.	-325.	313.	91.	4.	3.	E	.13E+01
-900.	-325.	2646.	117.	1.	3.	E	.58E+00
-700.	-325.	199.	9999.	2048.	3.	E	.19E+02
-700.	-325.	305.	9999.	1024.	3.	E	.11E+02
-700.	-325.	428.	9999.	512.	3.	E	.65E+01
-700.	-325.	374.	9999.	256.	3.	E	.49E+01
-700.	-325.	340.	322.	128.	3.	E	.37E+01
-700.	-325.	340.	293.	64.	3.	E	.27E+01
-700.	-325.	305.	223.	32.	3.	E	.22E+01
-700.	-325.	238.	147.	16.	3.	E	.19E+01
-700.	-325.	295.	119.	8.	3.	E	.15E+01
-700.	-325.	980.	143.	4.	3.	E	.98E+00
-700.	-325.	2562.	155.	2.	3.	E	.67E+00
-700.	-325.	4629.	144.	1.	3.	E	.49E+00
-500.	-325.	26.	9999.	2048.	3.	E	.49E+02
-500.	-325.	39.	9999.	1024.	3.	E	.28E+02
-500.	-325.	56.	9999.	512.	3.	E	.17E+02
-500.	-325.	50.	9999.	256.	3.	E	.13E+02
-500.	-325.	33.	9999.	128.	3.	E	.11E+02
-500.	-325.	55.	9999.	64.	3.	E	.60E+01
-500.	-325.	57.	55.	32.	3.	E	.42E+01
-500.	-325.	55.	50.	16.	3.	E	.31E+01
-500.	-325.	47.	38.	8.	3.	E	.25E+01
-500.	-325.	60.	35.	4.	3.	E	.19E+01
-500.	-325.	211.	45.	2.	3.	E	.12E+01
-500.	-325.	1199.	70.	1.	3.	E	.66E+00
-300.	-325.	2.	9999.	2048.	3.	E	.16E+03
-300.	-325.	4.	9999.	1024.	3.	E	.82E+02
-300.	-325.	5.	9999.	512.	3.	E	.52E+02
-300.	-325.	20.	9999.	256.	3.	E	.18E+02
-300.	-325.	11.	9999.	128.	3.	E	.18E+02
-300.	-325.	12.	9999.	64.	3.	E	.12E+02
-300.	-325.	10.	9999.	32.	3.	E	.92E+01
-300.	-325.	9.	9999.	16.	3.	E	.69E+01
-300.	-325.	11.	11.	8.	3.	E	.44E+01
-300.	-325.	27.	20.	4.	3.	E	.23E+01

X	Y	RESISTIVITY	NEAR	FREQUENCY	TRANSMITTER	RECEIVER	R/S
-200.	1000.	18.	9999.	512.	1.	E	.17E+02
-200.	1000.	15.	9999.	256.	1.	E	.13E+02
-200.	1000.	12.	9999.	128.	1.	E	.11E+02
-200.	1000.	5.	9999.	64.	1.	E	.12E+02
-200.	1000.	6.	9999.	32.	1.	E	.75E+01
-200.	1000.	12.	11.	16.	1.	E	.38E+01
-200.	1000.	25.	18.	8.	1.	E	.22E+01
-200.	1000.	51.	19.	4.	1.	E	.15E+01
-200.	1000.	100.	18.	2.	1.	E	.11E+01
-200.	1000.	200.	17.	1.	1.	E	.78E+00
100.	-700.	494.	38.	1.	3.	E	.74E+00
100.	-700.	198.	36.	2.	3.	E	.11E+01
100.	-700.	66.	31.	4.	3.	E	.16E+01
100.	-700.	29.	24.	8.	3.	E	.26E+01
100.	-700.	21.	20.	16.	3.	E	.41E+01
100.	-700.	22.	9999.	32.	3.	E	.56E+01
100.	-700.	20.	9999.	64.	3.	E	.82E+01
100.	-700.	14.	9999.	128.	3.	E	.14E+02
100.	-700.	23.	9999.	256.	3.	E	.15E+02
100.	-700.	27.	9999.	512.	3.	E	.20E+02
100.	-700.	28.	9999.	1024.	3.	E	.28E+02
100.	-700.	5.	9999.	2048.	3.	E	.93E+02
200.	-700.	271.	27.	1.	3.	E	.84E+00
200.	-700.	120.	27.	2.	3.	E	.12E+01
200.	-700.	38.	22.	4.	3.	E	.19E+01
200.	-700.	16.	15.	8.	3.	E	.32E+01
200.	-700.	14.	9999.	16.	3.	E	.47E+01
200.	-700.	14.	9999.	32.	3.	E	.67E+01
200.	-700.	14.	9999.	64.	3.	E	.94E+01
200.	-700.	15.	9999.	128.	3.	E	.13E+02
200.	-700.	18.	9999.	256.	3.	E	.17E+02
200.	-700.	21.	9999.	512.	3.	E	.22E+02
200.	-700.	21.	9999.	1024.	3.	E	.31E+02
200.	-700.	24.	9999.	2048.	3.	E	.41E+02
300.	-700.	273.	26.	1.	3.	E	.82E+00
300.	-700.	104.	24.	2.	3.	E	.12E+01
300.	-700.	38.	21.	4.	3.	E	.18E+01
300.	-700.	16.	15.	8.	3.	E	.31E+01
300.	-700.	14.	9999.	16.	3.	E	.46E+01
300.	-700.	16.	9999.	32.	3.	E	.60E+01
300.	-700.	19.	9999.	64.	3.	E	.78E+01
300.	-700.	20.	9999.	128.	3.	E	.11E+02
300.	-700.	23.	9999.	256.	3.	E	.14E+02
300.	-700.	25.	9999.	512.	3.	E	.19E+02
300.	-700.	26.	9999.	1024.	3.	E	.27E+02
300.	-700.	25.	9999.	2048.	3.	E	.38E+02
400.	-700.	224.	23.	1.	3.	E	.84E+00
400.	-700.	111.	24.	2.	3.	E	.12E+01
400.	-700.	37.	20.	4.	3.	E	.18E+01
400.	-700.	17.	15.	8.	3.	E	.29E+01
400.	-700.	16.	15.	16.	3.	E	.41E+01
400.	-700.	19.	9999.	32.	3.	E	.53E+01
400.	-700.	25.	9999.	64.	3.	E	.65E+01
400.	-700.	27.	9999.	128.	3.	E	.88E+01

X	Y	RESISTIVITY	NEAR	FREQUENCY	TRANSMITTER	RECEIVER	R/S
-300.	-325.	69.	25.	2.	3.	E	.14E+01
-300.	-325.	141.	24.	1.	3.	E	.10E+01
100.	-325.	6.	9999.	32.	3.	E	.10E+02
100.	-325.	5.	9999.	16.	3.	E	.78E+01
100.	-325.	5.	9999.	8.	3.	E	.55E+01
100.	-325.	10.	9.	4.	3.	E	.29E+01
100.	-325.	26.	13.	2.	3.	E	.17E+01
100.	-325.	61.	14.	1.	3.	E	.12E+01
300.	-325.	7.	9999.	32.	3.	E	.85E+01
300.	-325.	6.	9999.	16.	3.	E	.65E+01
300.	-325.	7.	7.	8.	3.	E	.43E+01
300.	-325.	15.	11.	4.	3.	E	.23E+01
300.	-325.	38.	14.	2.	3.	E	.15E+01
300.	-325.	84.	14.	1.	3.	E	.10E+01
500.	-325.	7.	9999.	32.	3.	E	.77E+01
500.	-325.	5.	9999.	16.	3.	E	.64E+01
500.	-325.	5.	9999.	8.	3.	E	.46E+01
500.	-325.	10.	8.	4.	3.	E	.25E+01
500.	-325.	25.	10.	2.	3.	E	.16E+01
500.	-325.	54.	10.	1.	3.	E	.11E+01
-800.	0.	4500.	145.	1.	3.	E	.50E+00
-800.	0.	1589.	183.	4.	3.	E	.89E+00
-800.	0.	341.	183.	16.	3.	E	.18E+01
-800.	0.	437.	284.	32.	3.	E	.20E+01
-800.	0.	499.	394.	64.	3.	E	.24E+01
-800.	0.	492.	450.	128.	3.	E	.32E+01
-800.	0.	473.	458.	256.	3.	E	.45E+01
-800.	0.	400.	9999.	512.	3.	E	.68E+01
-800.	0.	349.	9999.	1024.	3.	E	.10E+02
-800.	0.	282.	9999.	2048.	3.	E	.16E+02
-900.	0.	5629.	167.	1.	3.	E	.48E+00
-900.	0.	761.	135.	4.	3.	E	.11E+01
-900.	0.	275.	167.	16.	3.	E	.19E+01
-900.	0.	350.	253.	32.	3.	E	.22E+01
-900.	0.	358.	311.	64.	3.	E	.28E+01
-900.	0.	346.	330.	128.	3.	E	.39E+01
-900.	0.	327.	9999.	256.	3.	E	.55E+01
-900.	0.	303.	9999.	512.	3.	E	.81E+01
-900.	0.	374.	9999.	1024.	3.	E	.10E+02
-900.	0.	212.	9999.	2048.	3.	E	.19E+02
-700.	0.	30.	9999.	2048.	3.	E	.48E+02
-700.	0.	52.	9999.	1024.	3.	E	.26E+02
-700.	0.	65.	9999.	512.	3.	E	.16E+02
-700.	0.	85.	9999.	256.	3.	E	.10E+02
-700.	0.	97.	9999.	128.	3.	E	.67E+01
-700.	0.	100.	9999.	64.	3.	E	.47E+01
-700.	0.	90.	85.	32.	3.	E	.36E+01
-700.	0.	75.	66.	16.	3.	E	.28E+01
-700.	0.	80.	57.	8.	3.	E	.22E+01
-700.	0.	150.	59.	4.	3.	E	.15E+01
-700.	0.	500.	71.	2.	3.	E	.97E+00
-700.	0.	1000.	68.	1.	3.	E	.70E+00
-600.	0.	13.	9999.	2048.	3.	E	.71E+02
-600.	0.	10.	9999.	1024.	3.	E	.57E+02

X	Y	RESISTIVITY	NEAR	FREQUENCY	TRANSMITTER	RECEIVER	R/S
100.	50.	2.	9999.	8.	3.	E	.85E+01
100.	50.	6.	6.	4.	3.	E	.35E+01
100.	50.	13.	9.	2.	3.	E	.20E+01
100.	50.	40.	11.	1.	3.	E	.13E+01
200.	50.	4.	9999.	2048.	3.	E	.91E+02
200.	50.	4.	9999.	1024.	3.	E	.65E+02
200.	50.	4.	9999.	512.	3.	E	.46E+02
200.	50.	3.	9999.	256.	3.	E	.37E+02
200.	50.	3.	9999.	128.	3.	E	.26E+02
200.	50.	3.	9999.	64.	3.	E	.19E+02
200.	50.	2.	9999.	32.	3.	E	.16E+02
200.	50.	3.	9999.	8.	3.	E	.66E+01
200.	50.	2.	9999.	16.	3.	E	.11E+02
200.	50.	7.	6.	4.	3.	E	.32E+01
200.	50.	15.	9.	2.	3.	E	.19E+01
200.	50.	38.	10.	1.	3.	E	.13E+01
300.	50.	2.	9999.	2048.	3.	E	.12E+03
300.	50.	3.	9999.	1024.	3.	E	.71E+02
300.	50.	3.	9999.	512.	3.	E	.50E+02
300.	50.	3.	9999.	256.	3.	E	.35E+02
300.	50.	2.	9999.	128.	3.	E	.31E+02
300.	50.	2.	9999.	64.	3.	E	.22E+02
300.	50.	1.	9999.	32.	3.	E	.22E+02
300.	50.	1.	9999.	16.	3.	E	.15E+02
300.	50.	2.	9999.	8.	3.	E	.77E+01
300.	50.	6.	6.	4.	3.	E	.32E+01
300.	50.	14.	8.	2.	3.	E	.19E+01
300.	50.	35.	9.	1.	3.	E	.13E+01
400.	-25.	8.	9999.	2048.	3.	E	.58E+02
400.	-25.	8.	9999.	1024.	3.	E	.41E+02
400.	-25.	7.	9999.	512.	3.	E	.31E+02
400.	-25.	6.	9999.	256.	3.	E	.24E+02
400.	-25.	5.	9999.	128.	3.	E	.18E+02
400.	-25.	4.	9999.	64.	3.	E	.15E+02
400.	-25.	3.	9999.	32.	3.	E	.12E+02
400.	-25.	2.	9999.	16.	3.	E	.10E+02
400.	-25.	3.	9999.	8.	3.	E	.60E+01
400.	-25.	8.	7.	4.	3.	E	.27E+01
400.	-25.	20.	10.	2.	3.	E	.17E+01
400.	-25.	40.	9.	1.	3.	E	.12E+01
-400.	1000.	12.	9999.	2048.	1.	E	.38E+02
-400.	1000.	12.	9999.	1024.	1.	E	.27E+02
-400.	1000.	12.	9999.	512.	1.	E	.19E+02
-400.	1000.	10.	9999.	256.	1.	E	.15E+02
-400.	1000.	6.	9999.	128.	1.	E	.13E+02
-400.	1000.	3.	9999.	64.	1.	E	.13E+02
-400.	1000.	6.	9999.	32.	1.	E	.67E+01
-400.	1000.	13.	12.	16.	1.	E	.33E+01
-400.	1000.	28.	17.	8.	1.	E	.20E+01
-400.	1000.	56.	18.	4.	1.	E	.14E+01
-400.	1000.	113.	17.	2.	1.	E	.99E+00
-400.	1000.	230.	16.	1.	1.	E	.72E+00
-200.	1000.	33.	9999.	2048.	1.	E	.26E+02
-200.	1000.	21.	9999.	1024.	1.	E	.23E+02

X	Y	RESISTIVITY	NEAR	FREQUENCY	TRANSMITTER	RECEIVER	R/S
-600.	0.	11.	9999.	512.	3.	E	.35E+02
-600.	0.	11.	9999.	256.	3.	E	.27E+02
-600.	0.	14.	9999.	128.	3.	E	.17E+02
-600.	0.	13.	9999.	64.	3.	E	.13E+02
-600.	0.	12.	9999.	32.	3.	E	.92E+01
-600.	0.	13.	9999.	16.	3.	E	.63E+01
-600.	0.	13.	13.	8.	3.	E	.45E+01
-600.	0.	25.	20.	4.	3.	E	.25E+01
-600.	0.	49.	23.	2.	3.	E	.17E+01
-600.	0.	50.	16.	1.	3.	E	.14E+01
-500.	0.	9.	9999.	2048.	3.	E	.82E+02
-500.	0.	9.	9999.	1024.	3.	E	.58E+02
-500.	0.	9.	9999.	512.	3.	E	.41E+02
-500.	0.	9.	9999.	256.	3.	E	.29E+02
-500.	0.	9.	9999.	128.	3.	E	.21E+02
-500.	0.	11.	9999.	64.	3.	E	.13E+02
-500.	0.	11.	9999.	32.	3.	E	.93E+01
-500.	0.	9.	9999.	16.	3.	E	.73E+01
-500.	0.	9.	9999.	8.	3.	E	.52E+01
-500.	0.	15.	13.	4.	3.	E	.29E+01
-500.	0.	35.	19.	2.	3.	E	.18E+01
-500.	0.	50.	16.	1.	3.	E	.14E+01
-300.	0.	20.	9999.	2048.	3.	E	.51E+02
-300.	0.	13.	9999.	1024.	3.	E	.45E+02
-300.	0.	12.	9999.	512.	3.	E	.33E+02
-300.	0.	10.	9999.	256.	3.	E	.26E+02
-300.	0.	7.	9999.	128.	3.	E	.22E+02
-300.	0.	7.	9999.	64.	3.	E	.15E+02
-300.	0.	6.	9999.	32.	3.	E	.12E+02
-300.	0.	4.	9999.	16.	3.	E	.10E+02
-300.	0.	5.	9999.	8.	3.	E	.64E+01
-300.	0.	7.	7.	4.	3.	E	.39E+01
-300.	0.	20.	13.	2.	3.	E	.20E+01
-300.	0.	40.	13.	1.	3.	E	.14E+01
-200.	0.	15.	9999.	2048.	3.	E	.57E+02
-200.	0.	12.	9999.	1024.	3.	E	.45E+02
-200.	0.	11.	9999.	512.	3.	E	.33E+02
-200.	0.	13.	9999.	256.	3.	E	.21E+02
-200.	0.	7.	9999.	128.	3.	E	.21E+02
-200.	0.	5.	9999.	64.	3.	E	.17E+02
-200.	0.	4.	9999.	32.	3.	E	.14E+02
-200.	0.	4.	9999.	16.	3.	E	.97E+01
-200.	0.	3.	9999.	8.	3.	E	.79E+01
-200.	0.	5.	5.	4.	3.	E	.44E+01
-200.	0.	16.	11.	2.	3.	E	.21E+01
-200.	0.	33.	11.	1.	3.	E	.14E+01
100.	50.	12.	9999.	2048.	3.	E	.55E+02
100.	50.	6.	9999.	1024.	3.	E	.55E+02
100.	50.	5.	9999.	512.	3.	E	.43E+02
100.	50.	4.	9999.	256.	3.	E	.34E+02
100.	50.	3.	9999.	128.	3.	E	.28E+02
100.	50.	2.	9999.	64.	3.	E	.24E+02
100.	50.	2.	9999.	32.	3.	E	.17E+02
100.	50.	2.	9999.	16.	3.	E	.12E+02

X	Y	RESISTIVITY	NEAR	FREQUENCY	TRANSMITTER	RECEIVER	R/S
200.	300.	2.	9999.	32.	3.	E	.16E+02
200.	300.	3.	9999.	64.	3.	E	.19E+02
200.	300.	3.	9999.	128.	3.	E	.24E+02
200.	300.	4.	9999.	256.	3.	E	.32E+02
200.	300.	4.	9999.	512.	3.	E	.46E+02
200.	300.	5.	9999.	1024.	3.	E	.58E+02
200.	300.	6.	9999.	2048.	3.	E	.74E+02
200.	400.	20.	7.	1.	3.	E	.15E+01
200.	400.	3.	9999.	4.	3.	E	.47E+01
200.	400.	2.	9999.	16.	3.	E	.11E+02
200.	400.	2.	9999.	32.	3.	E	.16E+02
200.	400.	3.	9999.	64.	3.	E	.19E+02
200.	400.	4.	9999.	128.	3.	E	.23E+02
200.	400.	5.	9999.	256.	3.	E	.29E+02
200.	400.	6.	9999.	512.	3.	E	.37E+02
200.	400.	6.	9999.	1024.	3.	E	.53E+02
200.	400.	8.	9999.	2048.	3.	E	.65E+02
200.	600.	11.	6.	1.	3.	E	.17E+01
200.	600.	2.	9999.	4.	3.	E	.58E+01
200.	600.	2.	9999.	16.	3.	E	.12E+02
200.	600.	3.	9999.	32.	3.	E	.13E+02
200.	600.	5.	9999.	64.	3.	E	.15E+02
200.	600.	5.	9999.	128.	3.	E	.21E+02
200.	600.	7.	9999.	256.	3.	E	.25E+02
200.	600.	8.	9999.	512.	3.	E	.33E+02
200.	600.	12.	9999.	1024.	3.	E	.38E+02
200.	600.	33.	9999.	2048.	3.	E	.32E+02
-200.	700.	58.	15.	1.	3.	N	.13E+01
-200.	700.	13.	11.	4.	3.	N	.29E+01
-200.	700.	9.	9999.	16.	3.	N	.66E+01
-200.	700.	8.	9999.	32.	3.	N	.99E+01
-200.	700.	7.	9999.	64.	3.	N	.15E+02
-200.	700.	6.	9999.	128.	3.	N	.23E+02
-200.	700.	2.	9999.	256.	3.	N	.56E+02
-200.	700.	1.	9999.	512.	3.	N	.11E+03
-200.	700.	1.	9999.	1024.	3.	N	.16E+03
-200.	700.	5.	9999.	2048.	3.	N	.10E+03
-200.	700.	64.	16.	1.	3.	E	.12E+01
-200.	700.	12.	11.	4.	3.	E	.30E+01
-200.	700.	7.	9999.	16.	3.	E	.75E+01
-200.	700.	7.	9999.	32.	3.	E	.11E+02
-200.	700.	6.	9999.	64.	3.	E	.16E+02
-200.	700.	8.	9999.	128.	3.	E	.20E+02
-200.	700.	10.	9999.	256.	3.	E	.25E+02
-200.	700.	13.	9999.	512.	3.	E	.31E+02
-200.	700.	15.	9999.	1024.	3.	E	.41E+02
-200.	700.	15.	9999.	2048.	3.	E	.58E+02
-200.	900.	15.	8.	1.	3.	N	.18E+01
-200.	900.	5.	9999.	4.	3.	N	.45E+01
-200.	900.	4.	9999.	16.	3.	N	.10E+02
-200.	900.	5.	9999.	32.	3.	N	.13E+02
-200.	900.	9.	9999.	64.	3.	N	.13E+02
-200.	900.	11.	9999.	128.	3.	N	.17E+02
-200.	900.	10.	9999.	256.	3.	N	.25E+02

TO LOG IN ENTER: ADM FOR 11/70

RES FOR RESEARCH VAX

INS FOR INSTRUCTIONAL VAX