NOTICE

All drawings located at the end of the document.

8/1/87 E

REPORT OF GEOPHYSICAL INVESTIGATIONS
903 PAD, MOUND AND EAST TRENCHES AREAS
ROCKY FLATS PLANT
GOLDEN, COLORADO

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SECTION 1

INTRODUCTION

Geophysical surveys of the 903 Pad, Mound and East Trenches areas of the Rocky Flats Plant, Jefferson County, Colorado, have been completed as specified in the CEARP IGMP/SSMP Sampling Plan, dated February 1987, for the facility. The surveys were completed as part of the CEARP investigations of high priority sites at the Rocky Flats Plant.

The purpose of the geophysical surveys was to attempt to identify the location of known SWMUs or other potential sources, and/or plumes of environmental contaminants, by locating areas of high or low responses (anomalies) on various geophysical instruments. Once anomalies have been identified, borings and monitoring wells will be located to verify the significance of these anomalous areas as part of the overall site investigation program. In addition, electrical resistivity was used to provide information about site stratigraphy. Stratigraphic information was obtained by performing vertical electrical soundings (VES) at various locations across the site.

SECTION 2

SITE BACKGROUND

2.1 903 PAD AREA

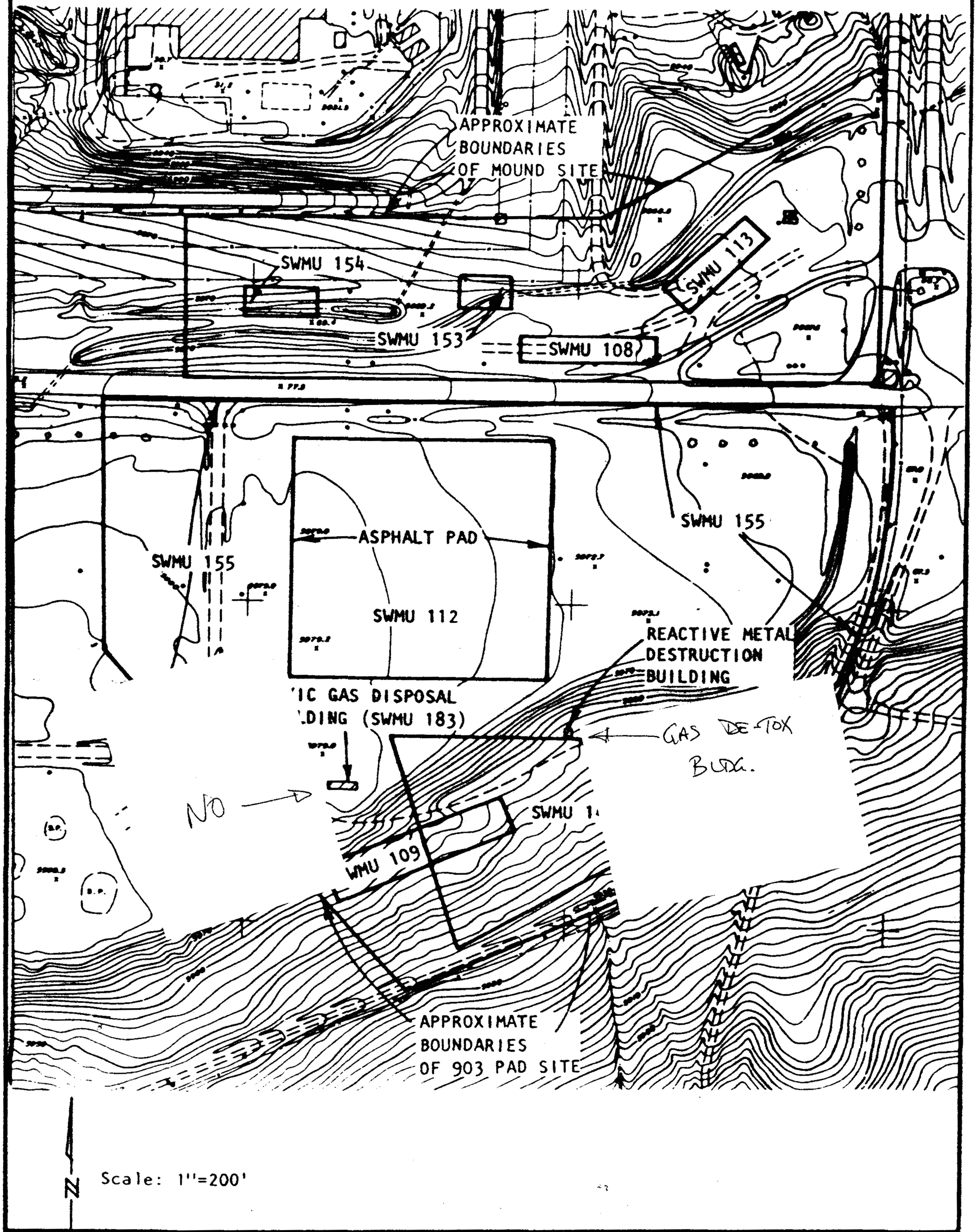
Information available at the time that the geophysical surveys were done indicate that surficial materials at the 903 Pad area consist of about 4 to 20 feet of Rocky Flats Alluvium. The Rocky Flats Alluvium is a poorly sorted deposit of sand, gravel, and cobbles that contains some clay horizons. The slope to the south, which is also included in the 903 Pad Area, is underlain by 15 to 22 feet of colluvium. The colluvium consists primarily of silty clay with a trace of gravel and contains discrete gravel layers (possibly lenses) from 1 to 4 feet thick. The valley fill, with which the colluvium merges to the south (downhill), consists of 3 to 8 feet of sandy gravel. Bedrock beneath the slope consists of interbedded claystones and sandstones of the Arapahoe Formation. The uppermost bedrock is claystone and the interbedded sandstones are on the order of 2 to 10 feet thick.

The Rocky Flats Alluvium and colluvial materials on the slope toward Woman Creek appear to be unsaturated at the 903 Pad Area site. The uppermost groundwater occurs in bedrock (at least during the winter months) at a depth of approximately 10 to 25 feet below ground surface beneath the center of the slope.

The results of groundwater sampling described by DOE (1986f) indicate highly variable groundwater quality conditions beneath the 903 Pad Area site. Data indicate that groundwater at this site has elevated TDS, sodium, radionuclides (plutonium and uranium), volatile organic compounds, and nitrates.

The 903 Pad Area is composed of five solid waste management units (SWMUs) as discussed below and identified on Figure 1.

- Trench T-2 (SWMU Ref. No. 109): Trench T-2 is located south of the 903 drum storage area and west of the reactive metal destruction site. The trench measures approximately 50 x 300 feet and was used prior to 1968 for disposal of sanitary sewage sludge and flattened drums contaminated with uranium and plutonium.



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LOCATION OF 903 PAD AND MOUNT SITES | Fig. 1

- 903 Drum Storage Area (SWMU Ref. No. 112): The 903 drum storage area was used from 1959 through the late 1960s for storage of drummed, radioactively contaminated liquid waste (primarily lathe coolant - a mixture of about 70% hydraulic oil and 30% carbon tetrachloride). Approximately 5,240 drums were in storage when removal began (about 3,570 of the drums also contained plutonium). After removal of the materials, plutonium contaminated soil in the vicinity was moved to a relatively small area and covered with asphalt (the 903 Pad). Remedial work was completed in November 1969.

- Reactive Metal Destruction Site (SWMU Ref. No. 140): An area south of the 903 drum storage area known as Area 952 was used during the 1950s and 1960s for disposal of reactive metals. The site was primarily used for trench burial of lithium metal as lithium carbonate (400 to 500 pounds). In addition, smaller quantities of sodium, calcium, magnesium, and unknown liquids were reportedly destroyed at this area.

- 903 Lip Area (SWMU Ref. No. 155): During drum removal and cleanup of the 903 drum storage area, winds redistributed plutonium beyond the pad to the south and east. The area was partially cleaned in 1976 and 1978 when about 4.7 million pounds of contaminated soil containing 0.56 Ci of plutonium was packaged and shipped to an off-site DOE disposal facility. Additional cleanup was performed along the eastern edge of the 903 Lip Area in 1984.

- Gas Detoxification Area (SWMU Ref. No. 183): Building 952, located south of the 903 drum storage area, was used to detoxify various gases from lecture bottles between June 1982 and August 1983. The lecture bottles held approximately one liter of compressed gas. Various gases were detoxified using commercial neutralization processes. After neutralization, glassware used in the process was triple-rinsed, crushed, and deposited in the present landfill. The neutralized gases released to the environment during detoxification would no longer be detectable.

2.2 MOUND AREA

All solid waste management units included in the Mound Area are located on and underlain by as much as 16 feet of Rocky Flats Alluvium. The alluvium consists of 11 feet of fine to medium sand on top of 5 feet of sandy gravel. Bedrock beneath the alluvium consists of interbedded claystone and sandstone of the Arapahoe Formation. Uppermost bedrock is claystone (1.5 feet thick) underlain by thin interbedded sandstones and claystones.

Groundwater occurs in bedrock at about 18 feet below ground surface. The alluvium is unsaturated. Flow in the bedrock is probably both north (along strike--toward the topographically lower drainage) and east (down dip).

Bedrock groundwater quality in the vicinity of the Mound Area is characterized by the presence of volatile organic compounds. The groundwater sampling results presented by DOE (1986f) indicate that major ion chemistry in bedrock groundwater at the Mound Area is slightly different from alluvial groundwater upgradient of the plant. However, this groundwater has low concentrations of radioactive constituents (at background or lower) and has generally nondetectable metals.

The Mound Area is composed of four solid waste management units (SWMUs) as described below and identified in Figure 1.

- Trench T-1 (Ref. No. 108): Trench T-1 is located just north of Central Avenue and immediately west of the old East Guard Gate (Gate 9). It was used from 1952 to 1962 and contains 125 drums filled with depleted uranium chips coated with small amounts of lathe coolant. The trench was covered with 2 feet of soil and the corners marked; however, two drums were uncovered during weed cutting operations in 1982. The contents of one of the drums were tested and found to contain an oily sludge with 4.3 picocuries per gram of plutonium and 1.2 microcuries per gram of uranium.

- Mound Area (SWMU Ref. No. 113): The Mound Area is located north of Central Avenue and west of the East Guard Gate. From 1954 to 1958, 1405 drums filled with depleted uranium and beryllium wastes were buried in the Mound Area. The wastes were mostly solid; however, some of the drums contained lathe coolant. The drums were removed between 1967 and 1970 and shipped off-site as radioactive waste. Although residual radioactive contamination may be present in the soils (0.8 to 112.5 dpm/g alpha activity), the contamination is thought to have come from the 903 drum storage area.

- Oil Burn Pit Number 2 (Ref. No. 153): Oil Burn Pit Number 2, west of the Mound Area, was used in 1957, and from 1961 to 1965, to burn approximately 1,083 drums of oil-containing uranium. The residues from the burning operations and some flattened drums were covered with soil. In 1978, the pit was excavated to a depth of approximately 5 feet and 239 boxes of contaminated material were removed and shipped off-site to a DOE disposal facility.

- Pallet Burn Site (Ref. No. 154): In 1965, an area southwest of oil burn pit number 2 was reportedly used to destroy wooden pallets. The nature of the contamination, if any, of the pallets is not known. Residues from the operation were removed in the 1970s.

2.3 EAST TRENCHES AREA

The East Trench area is underlain by variable but relatively thick Rocky Flats Alluvium (approximately 28 to 45 feet thick). The alluvium is predominantly sandy gravel with a few thin (2 to 3 feet thick) sand layers and thin (2 to 4 feet thick) clay layers. Bedrock consists of claystones and sandstones of the Arapahoe Formation. Both claystone and sandstone were found immediately beneath the alluvium in the vicinity of the trenches. Sandstones encountered in drilling well 40-86 were thicker than those encountered elsewhere at the plant (21 feet thick).

Groundwater occurs in both alluvium and bedrock. The depth to groundwater in the alluvium is approximately 20 to 25 feet below the ground surface. Much of the recharge to the alluvial system is probably from irrigation because the Rocky Flats Alluvium is unsaturated west of the trench area. Groundwater flow is in three directions: north toward South Walnut Creek, east toward the Plant boundary, and south toward Woman Creek. There is a spring on the south-facing slope between the terrace and Woman Creek that is fed by eastern and southern flows from the trench area.

Groundwater quality is characterized by the presence of volatile organic compounds. TDS concentrations are slightly elevated and radioactive constituent concentrations are roughly equal to those in upgradient alluvial groundwater. However, volatile organic compounds were detected in three of the four wells near the trenches. Specific information on the quality of groundwater in the bedrock is not available.

The East Trenches Area consists of nine burial trenches (Trenches T-3 through T-11) located just east of the East Access Gate (Figure 2). The trenches were used from 1954 to 1968 for disposal of depleted uranium, flattened depleted uranium and plutonium contaminated drums, and sanitary sewage sludge. Trench T-3 (SWMU Ref. No. 110) received radioactively-contaminated flattened drums and substantial quantities of sanitary sewage sludge. The drums placed in Trenches T-4 through T-11 (SWMU Ref. No. 111) had radioactivity ranging from 800 to 8,000 dpm/g. Trenches T-4 and T-11 also contain some uranium and plutonium-contaminated planks from the solar evaporation ponds and sanitary sewage sludge. The trenches are covered with soil.

SECTION 3

METHODS

3.1 GRID SURVEY

Grid systems were established on the 903 Pad, Mound, and East Trenches area in order to provide lateral control of measurement location. Survey stations were staked at 60-foot intervals and marked with a coordinate designation based on the Rocky Flats Plant grid system. All geophysical survey points were located based on this coordinate system.

3.2 ELECTROMAGNETIC CONDUCTIVITY

Electromagnetic conductivity (EM) surveys of the 903 Pad and Mound areas were conducted using both EM-34-3 and EM-31 Terrain Conductivity Meters manufactured by Geonics, Ltd. Electromagnetic techniques of measuring terrain conductivity operate by imparting an alternating current to a transmitter coil. Current passing through the transmitter coil produces a magnetic field which in turn induces small currents in the underlying strata. Currents within the geologic materials produce a secondary magnetic field which is sensed by the receiver coil. It ~~has been~~ shown that under certain constraints, the ratio of the secondary to the primary magnetic field is proportional to terrain conductivity (Geonics, 1980). This fact allows conductivity to be read directly from the instrument in units of millimhos per meter (mmhos/m).

The EM-34-3 unit measures the average conductivity of materials between two hand-held coils spaced 10, 20, or 40 meters apart. The effective depth of penetration is variable by altering intercoil spacing and coil orientation. EM-34-3 conductivity was measured at 377 survey stations in both horizontal and vertical dipole configurations, with a coil separation of 10 meters. Measurements taken in the horizontal dipole mode yielded an effective depth of exploration of 7.5 meters, with the largest single contribution from near-surface materials. Vertical dipole measurements yielded an effective depth of exploration of 15 meters with a smaller signal contribution from near-surface materials. The surveys were run on a 60-foot grid system. This spacing was chosen to allow nearly continuous conductivity data to be obtained along the survey lines.

The EM-31 unit measures the average conductivity of materials between two fixed coils spaced 3.7 meters apart. This configuration yields an effective depth of exploration of 6 meters. The survey was conducted at 15-foot intervals along east-west oriented survey lines. Survey lines were spaced at 30-foot intervals, except where examination of the data showed that additional data collection would aid in the definition of anomalous areas. A total of 3016 data points were collected with the EM-31.

Both EM-34-3 and EM-31 were utilized to characterize the sites because of the characteristic differences between the two instruments. The EM-34-3 is best suited to screen broad areas of a site for changes in conductivity. The EM-34-3 is less sensitive to small conductors, such as single drums or small pits, than is the EM-31 because of its relatively large coil spacing. However, the EM-34-3 is capable of surveying to a greater depth and is less sensitive to surficial materials (soils) in the vertical dipole configuration than is the EM-31. This gives the EM-34-3 the capability of identifying contaminant plumes, more readily than the EM-31, in areas were there is sufficient conductivity contrast.

3.3 MAGNETOMETRY

A total of 111 magnetic survey lines were completed at the four subject sites. The survey was conducted using an EG&G Geometrics Memory Proton Precession Magnetometer, Model G-856X, with a gradiometer option.

The magnetic method used to measure the earth's total magnetic field intensity temporarily polarizes spinning hydrocarbon protons in the magnetometer sensor. The temporary polarization is obtained through the amplification of a uniform magnetic field generated by a current passing through a coil of wire. When the current is removed, the spin of the protons causes them to revolve in the direction of the earth's magnetic field. The spinning protons then generate a small signal in the same coil used to polarize them. The signal is directly proportional to the magnetic field intensity by the proportionality constant known as the gyromagnetic ratio. The frequency of the spinning protons is then measured by a digital counter as the absolute value of the earth's magnetic field intensity within an accuracy of 0.1 gammas.

The presence of magnetic items in the near surface creates magnetic anomalies in the earth's magnetic field. The location and sensitivity of the magnetic sensors becomes paramount for detection of these metallic items. If the sensor is placed too close to the items, the magnetic anomaly may overwhelm the ability of the sensor to obtain a reading. By the same logic, if the sensor is too far away, the magnetic anomaly may not be large enough to affect the sensor.

The magnetometer used was equipped with a gradiometer option allowing two field readings at different heights and a gradient reading based on the two readings obtained. The unit makes a measurement of the earth's total magnetic field intensity and displays the result to an accuracy of 0.1 gammas. The reading is automatically stored along with the day, time of day, line number, and reading number in the digital memory. The data is then retrieved at the end of the day by transferring it to a computer through the computer's communication port.

The magnetic survey was conducted using three different grid spacings. The grid spacing used on the 903 Pad and Mound areas had a north-south spacing of 30 feet and an east-west spacing of 15 feet. The second grid system had a square pattern on a 10-foot by 10-foot spacing. This was conducted around the existing trenches in the East Trenches area.

3.4 RESISTIVITY

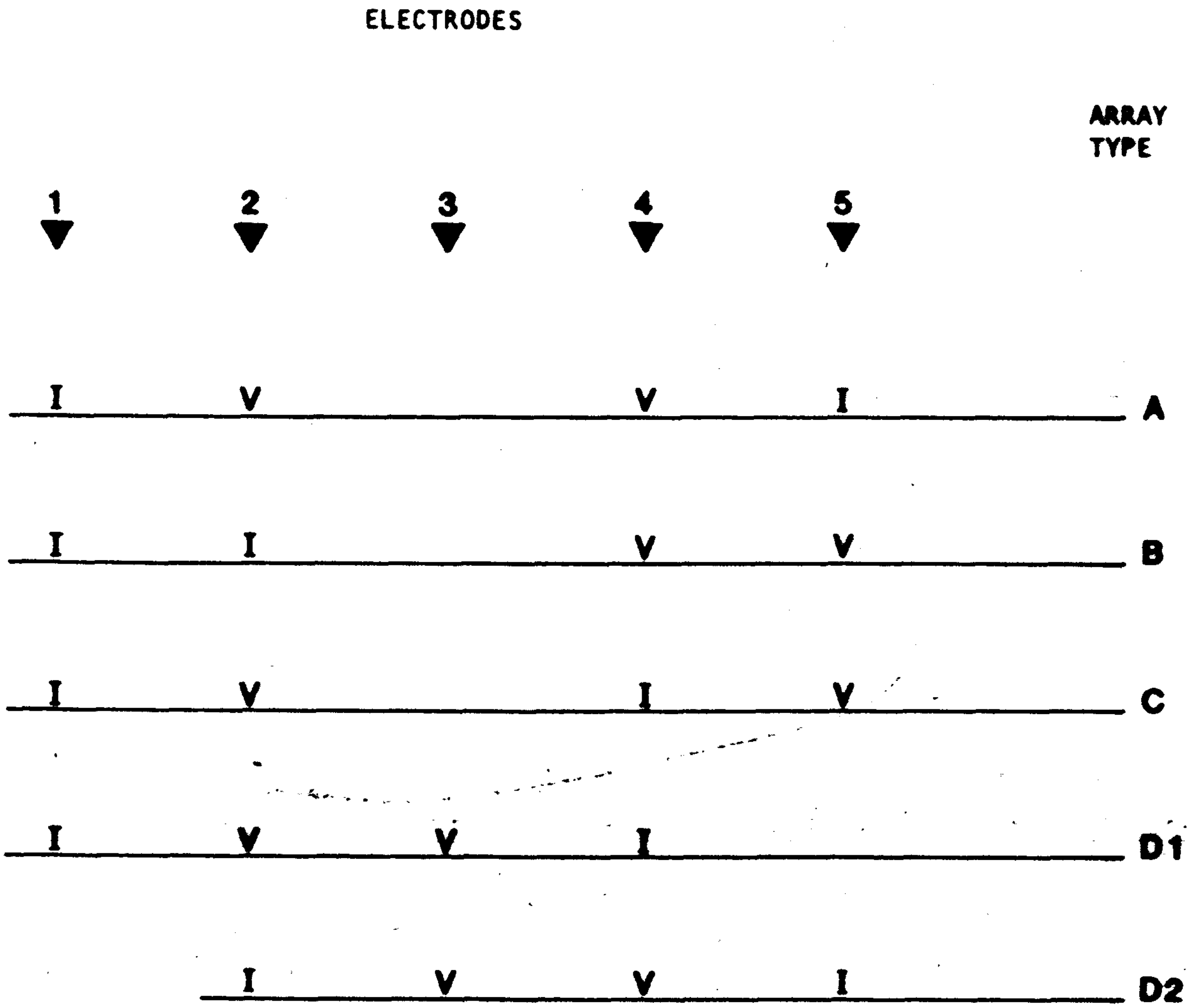
Vertical Electrical Soundings (VES) were made using a Bison Model 2390 transmitter and receiver. This system is a microprocessor controlled signal enhancement unit with automatic self-potential removal and current control. The unit displays the readings in the form of a four-decimal-place display in millivolts. The Bison offset sounding cable system (BOSS Model 2365) and steel electrodes were used for the VES surveys.

The VES method measures the electrical resistivity of the soil and bedrock by passing an electrode into the subsurface from a pair of electrodes and measuring the electrical voltage with a second pair of electrodes. Resistivity data is generally recorded as apparent resistivity, ρ_a, which can be found from the equation: ρ_a = K x V/I; where V is the observed voltage, I is the injected current, and K is the geometric shape factor. The basic unit of VES measurement and apparent resistivity is the ohm-meter. K is the shape factor of the geometry of the electrode arrangement typically called an array.

The Wenner array is the most commonly used array for hydrogeologic studies. The Wenner array was selected for its ease of field operation and data analysis, and its sensitivity to soil resistivity changes caused by stratigraphic variations and changes in moisture content. Its main advantages are that is has a much lower sensitivity to geologic noise and localized changes in soil resistivity unrelated to large-scale features of interest, and it returns a relatively high voltage for a small transmitter current. Its major disadvantage lies in having a somewhat lower vertical resolution and lower horizontal resolution than other arrays. For the Wenner array, the geometric shape factor is given by K = 2 ρ a, where a is the spacing between electrodes.

Apparent resistivity values are not indicative of the resistivity at any single depth but is an average soil resistivity over a range of depths. The depth of exploration is proportional to the a-spacing used with the principal response coming from a depth of about 1/3 to 1/2 of the a-spacing. VES surveys are conducted by making a series of measurements starting with a small a-spacing, usually less than 1 meter, and increasing the spacings logarithmically out to several tens or even hundreds of meters.

The BOSS system utilizes an array of cables designed to allow completion of Wenner soundings very quickly. The cables have electrode takeouts in a geometric series with the a-spacing increasing by a factor of two. Five different array measurements are made at each a-spacing as shown on Figure 3. Measurements D-1 and D-2 consist of a pair of overlapping or "offset" Wenner arrays. If the local stratigraphy consists of a series of flat layers, both arrays, D-1 and D-2, will give the same approximate apparent resistivities.



LEGEND

I Electrodes used as a transmitter.

V Electrodes used as a receiver.

WESTON

ARRAY TYPES USED IN BOSS SYSTEMS FOR VES SURVEYS

Fig. 3

Millivolt values from the five array measurements at each a-spacing are used to calculate a single Wenner resistivity reading. Unfortunately, the algebraic manipulations used to calculate the Wenner resistivity readings tend to amplify the effects of geologic noise and spread the noise over several a-spacings. Because of the amplification effects, only those VES survey points with a lateral difference error of less than 33% as measured in the field were used. The VES survey points which exceeded 33% were smoothed to reduce the error as much as possible and then were analyzed. The smoothing technique digitized the data curves by reducing the high and low resistivity spikes in the field data prior to analyses for layer thickness and layer resistivity.

Twenty-six vertical electrical soundings (VES) were completed at the 903 Pad, Mound and East Trenches areas. The locations of the VES survey points are presented in Table 1. (need to locate on a map) ref. Fig 4 for 903 Pad / Mound

VES-10 and VES-11 were completed at the approximate middle of SWMU 111.1, north of the east entrance road at the East Trenches site. Both surveys were conducted at right angles to one another. VES-12 and VES-13 were completed at the east end of SWMU 111.8 and at right angles to one another. VES-14 was completed at a magnetic anomaly at the reported location of SWMU 140, the reactive metal destruction trenches. VES-15 was completed at an electromagnetic conductivity anomaly in the middle of the Mound site. VES-16 was completed at a magnetic anomaly where a number of buried drums were exposed at the reported location of SWMU 109. VES-17, VES-18, VES-30, and VES-31 were completed at the middle of SWMU 110. VES-19 was located north of the northwest corner of the 903 asphalt pad in the Mound site as a background point. VES-21, VES-22, and VES-27 were completed in the East Trenches site at the location of SWMU 111.4. VES-23, VES-24, VES-25, and VES-26 were also completed in the East Trenches site at SWMUs 111.2 and 111.3, respectively. VES-28, VES-29, and VES-35 were completed at SWMU 111.6 at the far eastern end. VES-33 was completed at the eastern end of SWMU 111.2 to verify the length of SWMU 111.2. VES-34 was completed at the eastern end of SWMU 111.4.

TABLE 1

LOCATION OF VES SURVEYS

SURVEY NO.	ROCKY FLATS PLANT GRID SYSTEM COORDINATES
10	N-36730 E-24200
11	N-36730 E-24200
12	N-36675 E-23945
13	N-36675 E-23945
14	N-35720 E-22900
15	N-36440 E-23020
16	N-35640 E-22700
17	N-36810 E-23800
18	N-36810 E-23800
19	N-36380 E-22420
20	N-36660 E-23200
21	N-36560 E-24520
22	N-36560 E-24520
23	N-36700 E-24750

TABLE 1

LOCATION OF VES SURVEYS
(CONTINUED)

SURVEY NO.	ROCKY FLATS PLANT GRID SYSTEM COORDINATES
24	N-36700 E-24750
25	N-36700 E-24800
26	N-36700 E-24800
27	N-36560 E-24550
28	N-36560 E-24640
29	N-36560 E-24640
30	N-36810 E-23800
31	N-36810 E-23800
32	N-36600 E-24870
33	N-36700 E-24860
34	N-36680 E-24980
35	N-36560 E-24630

3.5 METAL DETECTION

Metal detector surveys were conducted at magnetometer and electromagnetic conductivity anomalies at the four subject sites. Additional surveys were completed at the reported locations of SWMUs and cultural features such as the underground utility vaults. The objective of these surveys was to accurately define the areal extent of buried metallic objects. A Whites' Treasuremaster TM600 Series 2 metal detector was used to conduct the survey.

A metal detector operates on a principle similar to a magnetometer. Both instruments measured the earth's magnetic field intensity with the principal difference being that the metal detector is adjusted to be in-phase with remnant magnetization present in the earth's magnetic field. Any magnetic anomaly with sufficient amplitude to create an out-of-phase response in the metal detector is detected. The in-phase adjustment allows the instrument to look at coarse measurements of the earth's magnetic field typically on the order of 10,000 gammas. Due to the nearness of the sensor to the items in question, significant changes in the magnetic field intensity can be sensed. Metal detectors are used exclusively to locate buried underground utilities and metallic items. They are not used to define subsurface conditions as magnetometers are used.

The TM600 is a two-coil unit with electrical null controls, sensitivity controls and a ground reject control. The ground reject control allows the unit to automatically adjust to eliminate false responses due to changing ground conditions, primarily from magnetite and associated minerals. A multi-purpose sensitivity meter is used to monitor the received target signals and a built-in speaker produces a tone which is proportional to the signal received.

A grid spacing on the order of 5 to 10 feet was instituted over the surveyed areas. Two passes were made over the area in question at orientations 90^{o} to one another. This resulted in pinpointing the item in question and aided in defining the areal extent. Upon location of the item, a pin flag was placed to mark the areal extent in the field of the signal from the metal detector. These areas were marked as locations to be avoided during subsequent soil sampling programs.

SECTION 4

DATA REDUCTION

4.1 ELECTROMAGNETIC CONDUCTIVITY

Conductivity data were processed on a Univac 1160 mainframe, Tektronix 4014 terminal, and Tektronix 4663 plotter, with a CPS-1 contouring program. Contour intervals used for plotting conductivity data were 10 and 20 mmhos/m. Intervals were chosen to show trends in areas of subtle changes, while maintaining distinction in areas of contrasting data.

The CPS-1 program contours data by dividing each grid cell into intermediate sub-cells. An intermediate grid value is then compared as the average of the four corner values and located at the center of the sub-cell with diagonals to each corner. The intersections of the contour locus with the sides and temporarily computed diagonals are determined using inverse linear interpolation. The process continues until each chosen contour interval is completed.

Interpretation of the electromagnetic conductivity data was based on visual examination of the contour plots. Comparison of anomalous readings with magnetometric results and areas of known cultural interferences, such as pipelines or fences, was used to assist in interpretation.

4.2 MAGNETOMETRY

Reduction of the magnetic data consisted of three phases. The first phase removed diurnal variations in the earth's magnetic field from the field data using a linear interpolation method. The field data were also checked for regional gradient effects. Due to the small size of the subject sites, this was not a problem. The second phase generated the gradient data from the field data by dividing the difference between the top and bottom sensors by the distance between sensors. During the third phase, contour plots of equal magnetic intensity were generated.

The contour plots of the 903 Pad and Mound sites were generated as described above for electromagnetic data. The contour plots of the East Trenches site were generated using the "SURFER" contouring software produced by Golden Software, Golden, Colorado. Interpretation of the contour map and data was based on a visual comparison of published magnetic curves to determine whether the anomalies defined by the contour plots were due to geologic conditions or cultural features. They were also compared to the electromagnetic conductivity survey plots to identify corresponding anomalies.

4.3 ELECTRICAL RESISTIVITY

VES data were analyzed using one-dimensional modelling. One-dimensional modelling assumes that the earth in the vicinity of the VES survey point can be represented by a series of flat-lying layers, each with a different electrical resistivity. This interpretation yields accurate results assuming certain criteria:

- the geologic structure to be located has a significant resistivity contrast from its background;
- the lateral extent of these structures must be larger than their depths; and,
- the layers must be relatively thick compared with their depths.

The interpretations were determined using an automatic inverse resistivity modelling program similar to one developed by Dr. Adel A.R. Zodhy of the Water Resource Division, U.S. Geological Survey. The inverse resistivity modelling program begins with a best-fit estimation based on Ghosh coefficients and tentatively converges to the inverse resistivity (geoelectric) model which gives the least sum of square residuals for the field data. The program then generates layer thicknesses, depths, and resistivities.

For geologic environments, such as that at the subject sites, where more than four layers are present and the layers are not flat-lying, lateral interference affects calculations of both the layer thicknesses and layer resistivities. Wherever the lateral difference error exceeded 33%, the data was smoothed to reduce the lateral effects as much as possible and then were analyzed. The smoothing technique used digitized data curves by reducing high and low resistivities prior to analysis for layer thicknesses and resistivities.

4.4 METAL DETECTION

No data reduction was required for the metal detector survey. Areas of buried metallic items were located in the field and marked with pin flags.

CDH has requested a definition of "anomaly." How are these 2 areas anomalous? This is not clear when the locations are checked on the EM-Magnetometer maps of Appendix I. If the anomaly was detected by the magnetrometry survey a map showing this anomaly should be provided. Is there a reason the source of the anomaly can not be determined at this time? Is this also VES-20? Need to correlate if possible.

SECTION 5

SURVEY RESULTS

5.1 903 PAD AND MOUND AREAS

5.1.1 Electromagnetic Conductivity

The results of the electromagnetic conductivity surveys of the 903 Pad and Mound Areas are presented as contour plots in Appendix 1. Examination of the contour plots indicates two areas of anomalous conductivity which are not readily explainable by the occurrence of cultural interferences. The approximate locations, based on the Rocky Flats grid system, of the anomalous conductivity values for each instrument are as follows and as indicated on Figure 4.

EM-34 Vertical	EM-34 Horizontal	EM-31
N-36860 E-23200	N-36860 E-23200	N-36860 E-23160
N-36470 E-23080	N-36440 E-23080	-----

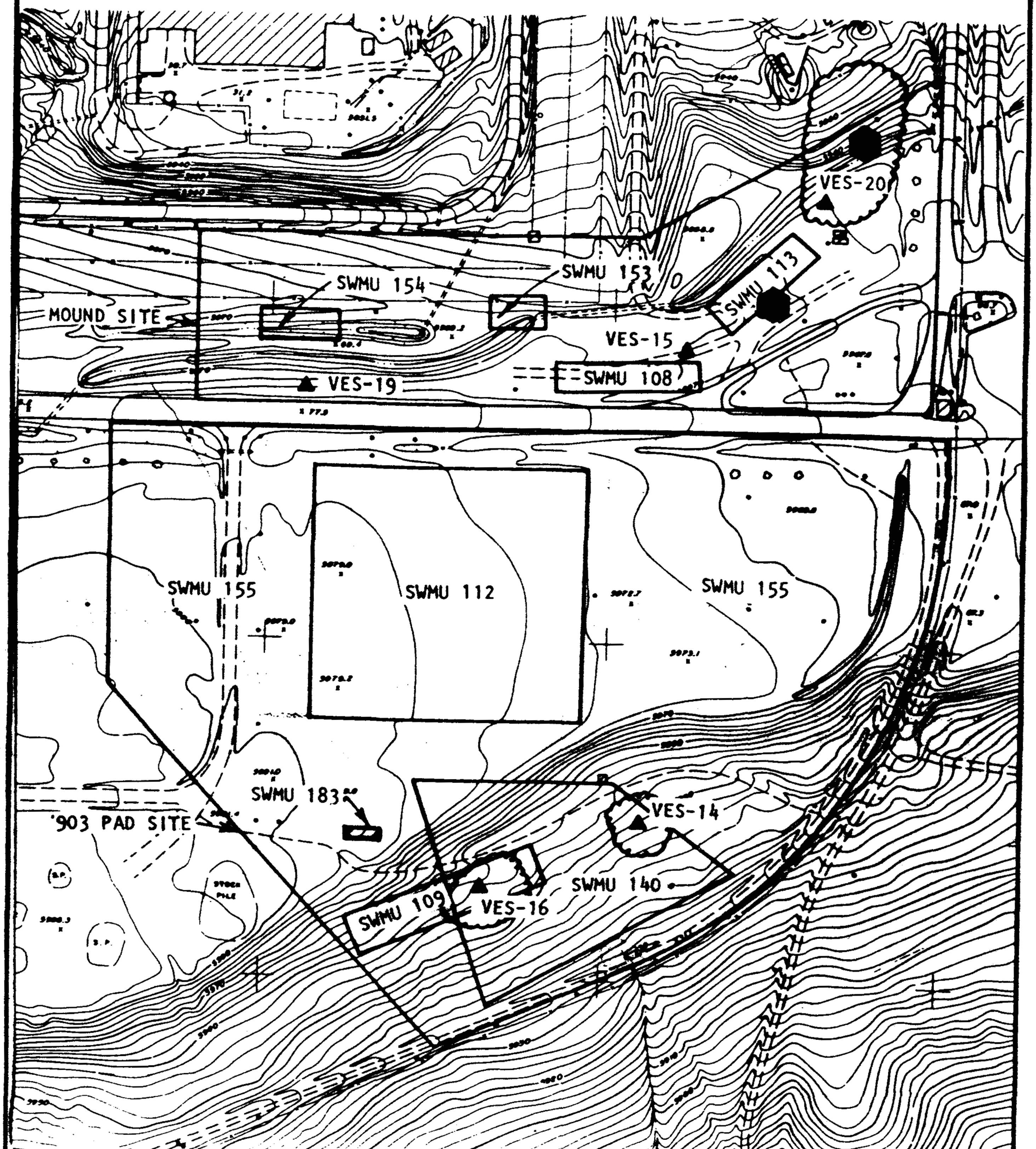
The first anomalous area is located at the northeast corner of the survey area between the Mound Area (SWMU 113) and the wastewater treatment plant. This anomaly was detected by both electromagnetic instruments and magnetometry. The source of this anomaly is unknown.

Need to locate SWMU on the maps for easier reference (the maps in the Appendix)

A second area of anomalous conductivity values was indicated by the EM-34 in the vicinity of grid station N-36470 E-23080. The location suggests a correlation between this anomaly and the Mound Area (SWMU 113). As can be seen on the EM-34 contour plots, this anomaly is strongest on the vertical dipole contour plot, weakly indicated on the horizontal dipole contour plot, and absent on the EM-31 plot. This suggests that the source of the anomaly is located at depth (>10 feet) rather than the near surface.

A general trend toward higher conductivity values is evident on the southeast corner of the survey area. This trend, evident in each contour plot, is thought to be the result of disturbed soils and increased moisture content on the slope south of the 903 Pad Area.

EM - conductivity (mmhos/m) Mag - gamma



EXPLANATION

▲ VES-16 — **Vertical Electrical Sounding Point**

Electromagnetic Anomaly

Magnetic Anomaly

N

Scale: 1''=200'

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Location of VES Survey Points, Electromagnetic and Magnetic Anomalies at 903 Pad and Mound Sites

Fig. 4

5.1.2 Magnetometry

903 Pad and Mound Sites: The results of the magnetic survey of the 903 Pad and Mound areas are presented as a contour plot in Appendix 2. Three magnetic anomalies were detected in the 903 Pad and Mound areas, as shown on Figure 4. Two of the anomalies were located south-southeast of the 903 asphalt pad at approximately N-35600 E-22720 and N-35700 E-22900. These anomalies are thought to be associated with Trench T-2 (SWMU 109) and the Reactive Metal Destruction Trenches (SWMU 140), respectively. The third anomaly, located at the northeastern portion of the Mound site (N-36830 E-23185), was not readily explainable and corresponded to electromagnetic conductivity anomalies in this area.

5.1.3 Electrical Resistivity

The results of the VES surveys conducted at the 903 Pad and Mound areas are presented as resistivity models, Figures 3-3, 3-4, 3-5, 3-7, and 3-8, in Appendix 3. The VES surveys were analyzed for stratigraphic interpretations as geoelectric models.

At VES-14 (Figure 3-3), a layer approximately 1.5 feet thick with a resistivity of 347 ohm-meters appears to represent colluvium. This layer overlies a less resistive layer of 282 ohm-meters with a thickness of 3 feet. This appears to be composed of a slightly moist gravel. Underlying this layer is a more resistive layer, 330 ohm-meters, indicating a weathered bedrock. An additional layer was analyzed at 186 ohm-meters below the weathered bedrock which appears to represent claystone bedrock.

At VES-15 (Figure 3-4), two highly resistive zones are present at the surface. This appears to be the result of abandoned roadway materials and the resulting compaction due to wheel loads and the lower layer appears to be the result of dry gravel. Below 15 feet, the resistivity varies from 218 to 302 ohm-meters, which appears to represent a claystone bedrock sequence with increasing sand content at depth.

The survey at VES-16 (Figure 3-5) indicates two highly resistive layers, 2369 and 1156 ohm-meters near the surface. No plausible explanation could be developed based on visual observations of the area and a review of other geophysical data. The presence of partially exposed drums may have induced significant lateral effects causing the two highly resistive layers to be developed in the computer model. Below these resistive

These interpretations should be referred to in the hydrogeology section and used in the subsurface interpretation.

layers, a similar response to VES-14 was analyzed. These layers appear to be a sandstone and claystone bedrock sequence.

VES-19 (Figure 3-7) was conducted as a background survey point for the Mound area. Two highly resistive layers, 892 and 749 ohm-meters, were analyzed at the surface. These appear to present colluvium overlying a dry gravel to a depth of 7 feet. Below these layers are two other layers, 410 and 390 ohm-meters, representing a sandstone sequence. Underlying these layers appears to be a claystone sequence with a resistance of 164 ohm-meters.

VES-20 (Figure 3-8) was conducted at a series of electromagnetic conductivity and magnetic anomalies. The response at VES-20 was similar to that of VES-19. The layers representing bedrock appeared to be a claystone bedrock sequence rather than a sandstone and claystone bedrock sequence.

5.1.4 Metal Detection

Metal detector surveys in the 903 Pad and Mound areas consisted of investigating electromagnetic conductivity and magnetic anomalies and the reported locations of SWMU 108, 109, 113, 140, 153, and 154. Due to the presence of the electrified security fence around the PSZ and various underground utilities, metal detector surveys in the Mound area could not be conducted. Generation of magnetic noise affected the detector, resulting in false readings.

Buried metallic items were detected during the surveys of SWMU 109 and 140 in the 903 Pad area. The items appear to be buried drums in SWMU 109 and metallic residues in SWMU 140 from the destruction of reactive metals. The areas were located in the field and marked with pin flags for reference.

5.2 EAST TRENCHES AREA

? so is Fig 2-6 (SWMU #111.8) the map referred to and 5.1.2? I am confused, I think c DH w/ be too.

5.2.1 Magnetometry

The results of the magnetic surveys within the fenced areas at the East Trenches area are presented as contour plots (Figures 2-1 through 2-5) in Appendix 2. The purpose of conducting the surveys with the fenced areas was to better define the reported locations of the existing trenches. The contour plots define the locations of concentrations of metallic items reported to be buried drums. In general, the existing trenches traverse east and west. SWMU 110 (Figure 2-1) has an approximate length of 80 feet and an approximate width of 20 feet. Two areas within the trench appear to have higher concentrations of metallic items than the rest of the trench. SWMU 111.1 (Figure 2-2) has an approximate length of 120 feet and an approximate width of 20 feet. Three areas within the trench appear to have higher concentrations of metallic items with the eastern and middle areas having the highest concentrations. SWMU 111.2 and SWMU 111.3 (Figure 2-3) reportedly are next to one another. SWMU 111.2 does not appear to have any significant quantities of metallic items and is poorly defined. SWMU 111.3 has an approximate length of 60 feet and an approximate width of 20 feet. Two areas within the trench appear to have higher concentrations of metallic items than the rest of the trench. The western end of the trench has the highest concentration of metallic items. SWMU 111.4, SWMU 111.5, and SWMU 111.6 (Figure 2-4) appear to have similar concentrations of metallic items. These trenches are each approximately 80 feet in length and 15 to 20 feet in width. SWMU 111.7 (Figure 2-5 was not well defined except for a small concentration of metallic items in the approximate middle of the trench. SWMU 111.8 (Figure 2-6) was also poorly defined except for a high concentration of metallic items in the western end of the trench.

5.2.2 Electrical Resistivity

Results of the VES surveys conducted at the East Trenches area are presented as resistivity models (Figures 3-1, 3-2, 3-6, and 3-9 to 3-17) in Appendix B. Data interpretation of these VES surveys were limited to the determination of the depths to the bottoms of existing trenches. Table 2 presents the results of the determination of the trench bottom depths for the East Trenches area.

5.2.3 Metal Detection

Metal detector surveys within the fenced areas at the East Trenches area were conducted to better define the locations of buried metallic items. The metal detector was adjusted to maximize its sensitivity. The fenced areas were then surveyed and locations of responses corresponding to buried metallic items were marked with pin flags in the field. All of the fenced areas exhibited responses corresponding to buried metallic items. Due to the design of the metal detector, individual metallic items could not be located and only the boundaries of the areas could be defined and marked using pin flags.

TABLE 2

TRENCH BOTTOM DEPTHS

VES NO.	Depth (ft)	SWMU NO.
10 & 11	12	111.7
12 & 13	13	111.8
17 & 18	11	110
21 & 22	14	111.6
23 & 24	6	111.2
27	8	111.6
28 & 29	11	111.5
30 & 31	16	110
32	8	111.4
33	18	111.2
34	9	111.3
35	9	111.5

NOTES:

(1) Due to lateral effects VES 25 & 26 were not analyzed for SWMU 111.2
(2) Trench bottoms are not consistent in depth.

SECTION 6

CONCLUSIONS

Geophysical surveys of the 903 Pad, Mound, and East Trenches areas of the Rocky Flats Plant were carried out in order to investigate and identify, as possible, the location of SWMUs and to provide information about subsurface conditions upon which to plan subsequent portions of the RI/FS investigation. The data obtained resulted in the identification of areas of anomalous geophysical response to be investigated as specified in the CEARP IGMP/SSMP Sampling Plans. Geophysical surveys, in conjunction with soil gas results, were used to plan areas for subsurface investigation, monitoring well installation, and groundwater sampling.

The geophysical surveying techniques utilized in the 903 Pad and Mound Areas were apparently successful in identifying the locations of SWMUs 109, 113, and 140. In addition, an area of anomalous electromagnetic conductivity and magnetometry responses, of unknown origin, was identified on the northeast corner of the area. Vertical electrical soundings were completed at five location across the 903 Pad and Mound areas. The VES data was analyzed to provide a stratigraphic model of each location. Metal detection was utilized at SWMUs 109 and 140 to identify buried metallic objects.

Has drilling provided any clue to the anomaly? Try to tie together

Cross-sections should be provided if a stratigraphic "model" is presented.

Geophysical investigations of the East Trenches area included magnetometer surveys, VES soundings, and metal detection. Magnetometer surveys of the trenches were successful in identifying those portions of the trenches which contain the highest concentrations of metallic objects. VES soundings in the trenches were able to provide information on the depths of the trenches. Identification of individual metallic objects through the use of a metal detector could not be accomplished.

Quality control data for each instrument were collected as specified in the CEARP Quality Assurance Plan. The resulting data indicates that instrument functions and operating procedures were properly conducted. Details of quality control procedures are provided in Section 7.

SECTION 7

QUALITY CONTROL

7.1 ELECTROMAGNETICS

The EM-31 and EM-34-3 instruments were operated in accordance with the operating instructions provided by the manufacturer, Geonics, Ltd. In order to detect and correct for any drift of the instruments during the course of the surveys, base stations were designated at the beginning of each survey. Prior to beginning each day's survey, measurements were taken at the base station and compared with previous readings. Base station readings were repeated at frequent intervals throughout the survey day. Other instrument functions checked during base station visits included meter null, sensitivity checks, and battery charge. Quality control data from each instrument is provided in Table 3.

7.2 RESISTIVITY

The VES system was operated in accordance with the operating instructions provided by the manufacturer, Bison Instruments, Inc. The system was checked for drift at the base station established for the electromagnetic conductivity instruments (N-36200, E-22300). The system was set up and two sets of readings were obtained. The two sets of readings were always within +/- 5% of one another.

Upon completion of each VES survey, the data were cross-checked according to procedures provided by the manufacturer. Millivolt readings were obtained from the five array patterns (see Figure 3) for each a-spacing. The cross checks were as follows:

- A>C>D1;
- D1~D2; and
- A-C~B

TABLE 3
QUALITY CONTROL DATA

Instrument: EM-34-3
Base Station: N36200, E22300

Date	Time	Vertical Dipole	Horizontal Dipole	Battery	Null
3/31/87	0830	39	38	OK	OK
3/31/87	1150	35	36	OK	OK
3/31/87	1603	39	37	OK	OK
4/1/87	0850	37	37	OK	OK
4/1/87	1225	36	39	OK	OK
4/1/87	1520	12*	12*	OK	OFF 1 mmho/m
4/2/87	1250	40	38	OK	OK
4/2/87	1500	37	34	OK	OK
4/3/87	0845	40	38	OK	OK
4/3/87	1111	38	38	OK	OK
4/3/87	1600	36	38	OK	OK

Instrument: EM-31
Base Station: N36200, E22300

Date	Time	Reading	Battery	Null
4/14/87	0810	32	OK	OK
4/14/87	1255	32	OK	OK
4/14/87	1620	31	OK	OK
4/15/87	0810	31	OK	OK
4/15/87	1245	31	OK	OK
4/15/87	1620	30	OK	OK
4/16/87	0830	31	OK	OK
4/16/87	1230	32	OK	OK

*NOTE: Readings collected prior to this base station check were retaken due to instrument drift.

No repeat readings were required for any of the twenty-six VES survey points. A battery check was also conducted each morning and at the end of the survey day. When the battery indicators approached 11.4 volts, the batteries were recharged overnight.

7.3 MAGNETOMETRY

The magnetometer was operated in accordance with the operating instructions provided by the manufacturer, EG&G Geometrics. Prior to beginning the magnetic survey, a swing test was conducted at the base station to detect any directional sensitivity of the sensor. Each swing test consists of three sets of four readings, each taken with the sensor oriented at 90° from the other. If directional sensitivities were detected, they were corrected by scrubbing the sensors with detergent and water. The sensors were then retested. The results of the swing tests are presented in Table 4.

The magnetometer was held in a north-south direction with the operator standing to the west of the sensors in an attempt to standardize any effects the operator and mode of operation would have on the instruments. Batteries used in the instrument were industrial heavy-duty D-cell batteries with cardboard jackets to further reduce any effects to the instrument from metal clad batteries. The batteries were changed whenever the voltage indicator fell below 8.5 volts.

During the survey, base station readings were obtained at the beginning and end of the day and at every 45 to 60 minutes throughout the survey. The base station readings were used to remove diurnal effects of the earth's magnetic field from the field data. Two sequential readings were also taken at the base station at the beginning and end of the survey day. The sequential readings were obtained within three seconds of one another. If the readings differed by more than 0.1 gamma from one another, the readings were recorded in the field books. All sequential readings differed by less than 0.1 gammas.

The use of the digital memory in the magnetometer required that the beginning and ending stations along with the corresponding magnetometer readings be recorded at the start and finish of a traverse. Upon "downloading" of the magnetometer, these readings were cross-checked for accuracy. With the exception of an operator error, all data cross-checked satisfactorily.

TABLE 4

SWING TEST RESULTS

Swing Test No.	Date	Swing	North (gammas)	East (gammas)	South (gammas)	West (gammas)
IV	4-21-87	1	54,856.2	54,855.9	54,855.9	54,856.0
		2	54,855.7	54,855.8	54,855.6	54,855.6
		3	54,856.1	54,856.0	54,855.9	54,856.0
V	4-30-87	1	54,856.2	54,856.3	54,853.3	54,853.1
		2	54,856.3	54,856.4	54,856.5	54,856.4
		3	54,856.6	54,856.5	54,856.6	54,856.7
VI	5-5-87	1	54,875.2	54,875.0	54,875.0	54,875.0
		2	54,875.8	54,875.7	54,875.7	54,875.6
		3	54,875.4	54,875.3	54,875.5	54,875.3
VII	5-12-87	1	54,877.7	54,877.9	54,877.9	54,877.8
		2	54,876.9	54,876.9	54,876.9	54,876.9
		3	54,876.9	54,877.0	54,876.9	54,875.9

Notes: 1) Swing test IV accepted.
2) Swing test V accepted.
3) Swing test VI accepted.
4) Swing test VII accepted.

7.4 METAL DETECTOR

The metal detector was operated in accordance with operating instructions by the manufacturer, White's, Inc. Each survey day began with adjusting the null controls and maximizing the sensitivity of the metal detector at the magnetometer base station. The instrument was continuously adjusted until the nulling controls were at a maximum. The sensitivity control was then adjusted to maximize the depth of signal reception. During the surveys, occasional minor adjustments were made to the ground reject control to fine-tune the instrument when changing ground conditions were encountered.

SECTION 8

REFERENCES

DOE, 1986f: "Resource Conservation and Recovery Act Part B--Operating Permit Application for USDOE Rocky Flats Plant, Hazardous and Radioactive Mixed Wastes," U.S. Department of Energy Unnumbered Report, November 1986.

DOE, 1987a: "Phase 2: Rocky Flats Plant Site-Specific Monitoring Plan (Work Plan for Performance of Remedial Investigations and Feasibility Studies for all High-Priority Sites)", U.S. Department of Energy Draft Report, February 1987.

DOE, 1987b: "Phase 2: Rocky Flats Plant Installation Generic Monitoring Plan," U.S. Department of Energy Draft Report, February 1987.

Geonics, Ltd. (1980): "Electromagnetic Terrain Conductivity Measurement at Low Induction Numbers." *Edited by* J.D. McNeil, October 1980.

APPENDIX 1

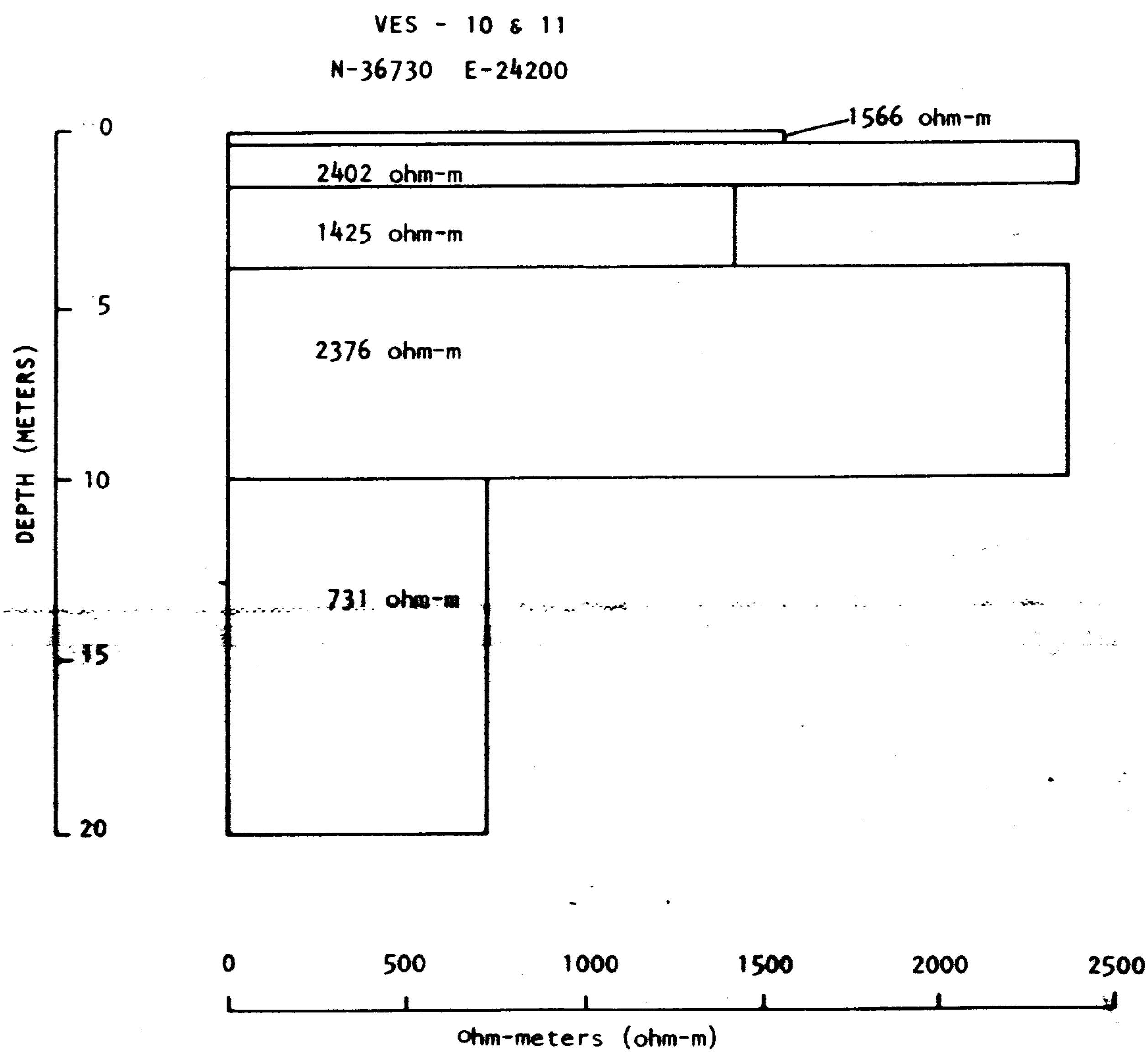
ELECTROMAGNETIC DATA

APPENDIX 2

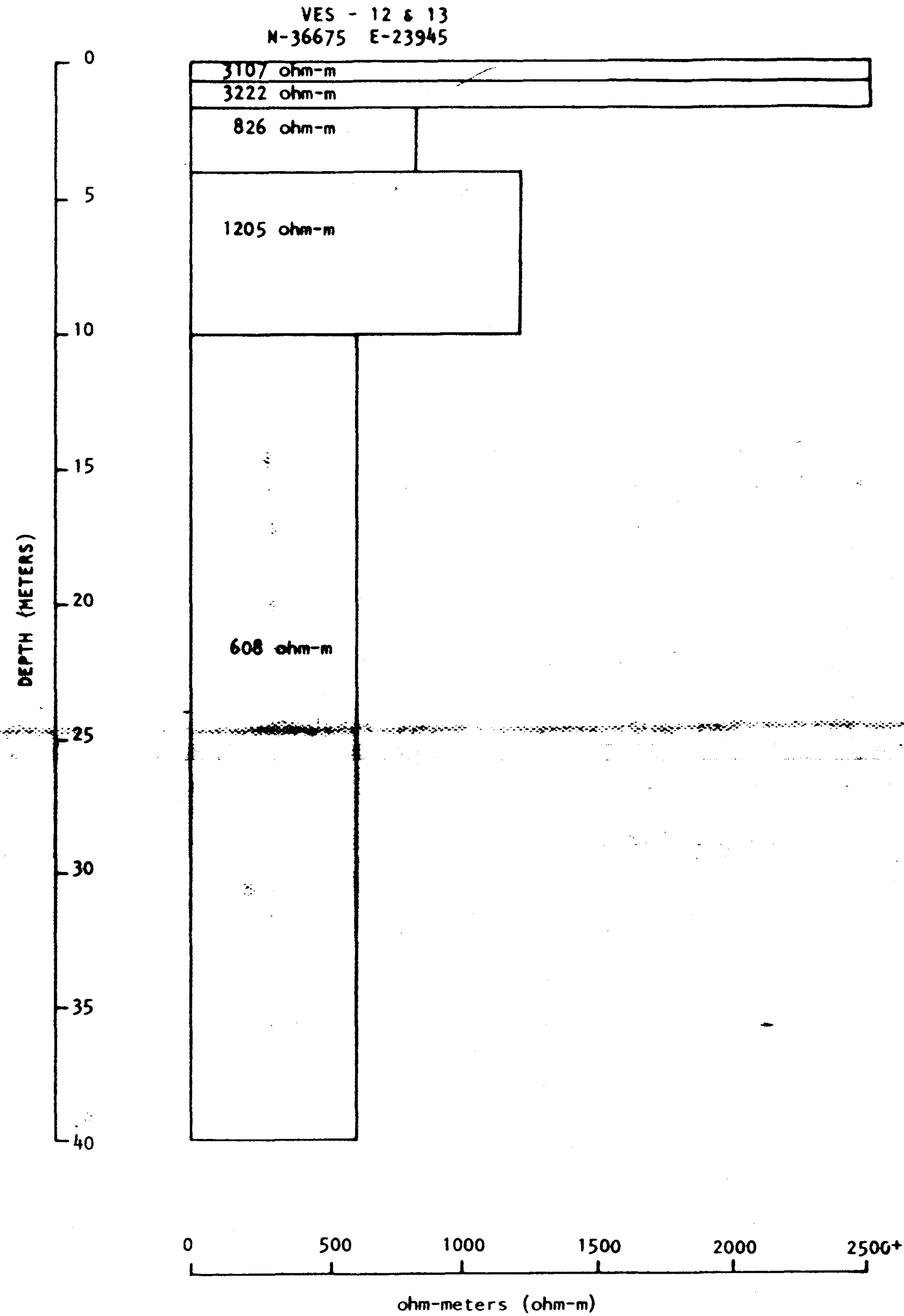
MAGNETOMETRY DATA

APPENDIX 3

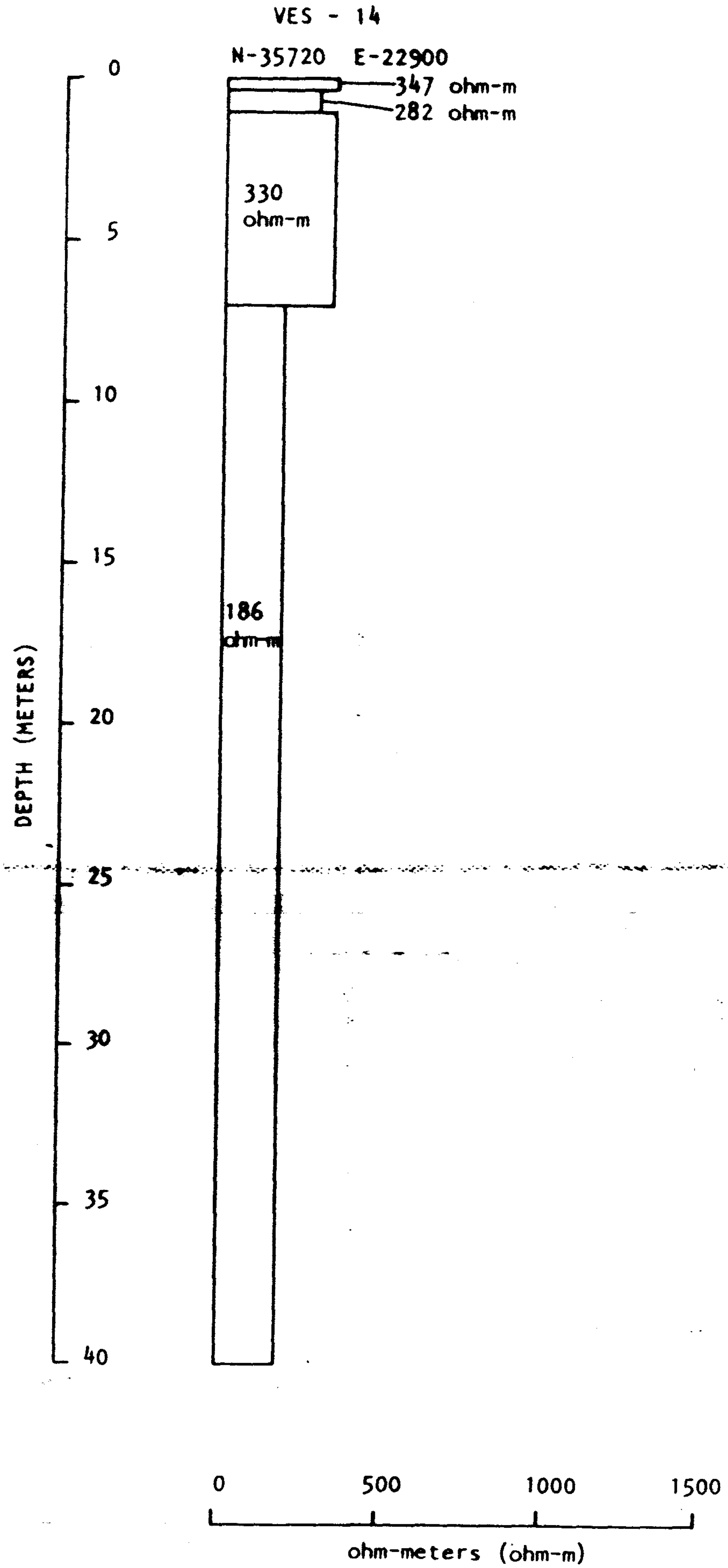
ELECTRICAL RESISTIVITY (VES) DATA



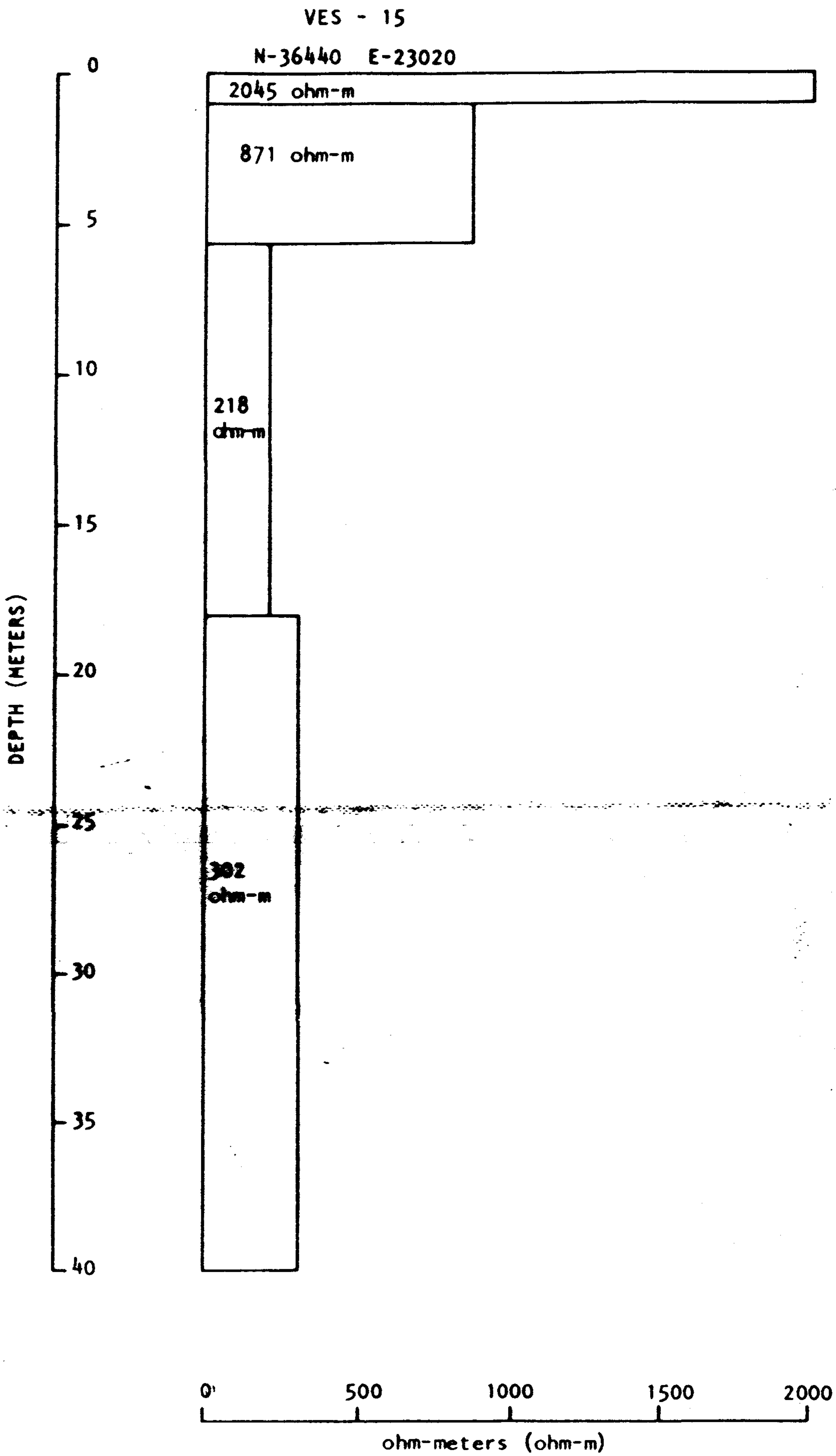
6 007 87	Chen & Associates	INVERSION RESULTS FOR VES-10 & 11	Fig. 3-1



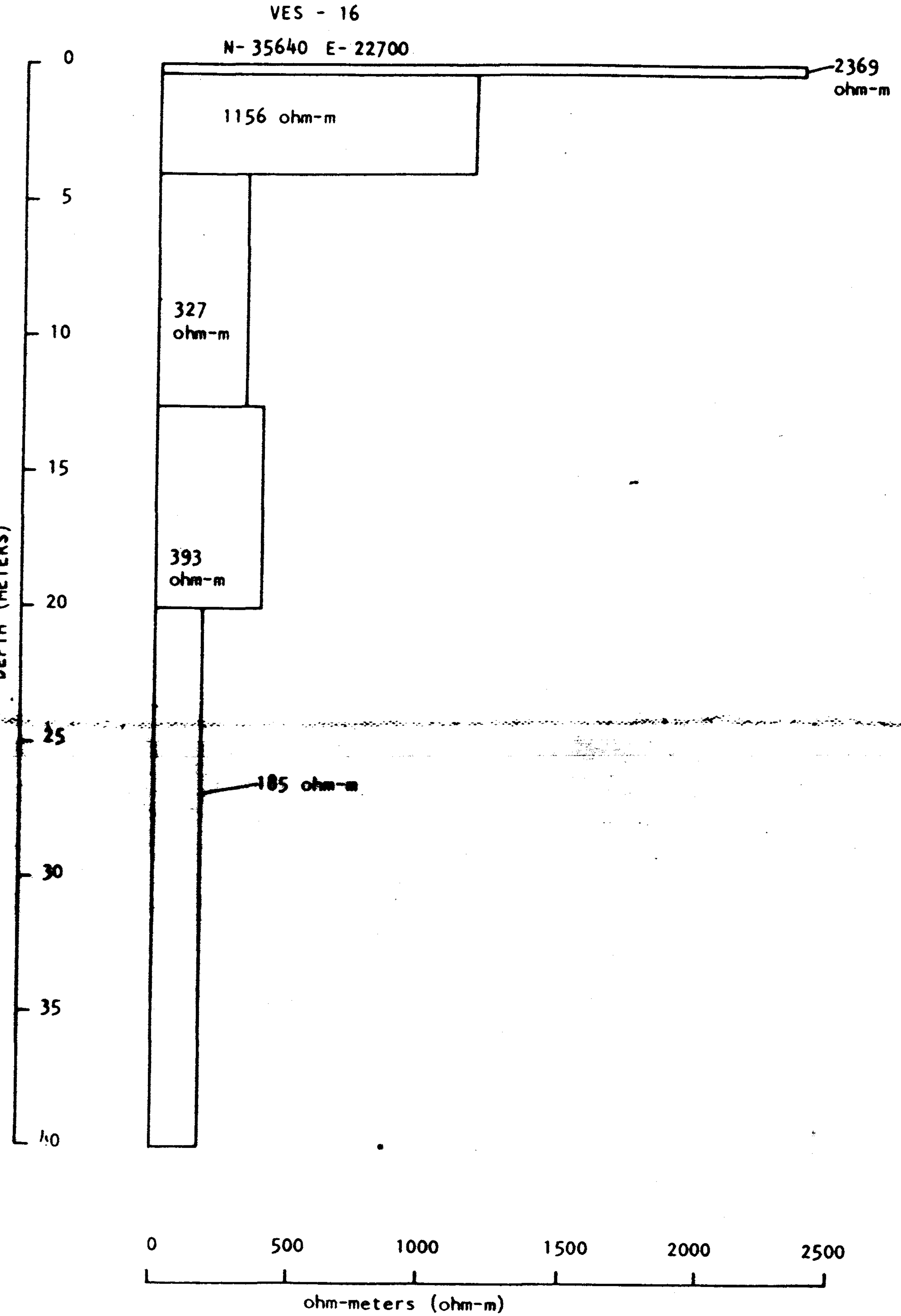
6 007 87	**Chen & Associates**	INVERSION RESULTS FOR VES-12 & 13	Fig. 3-2



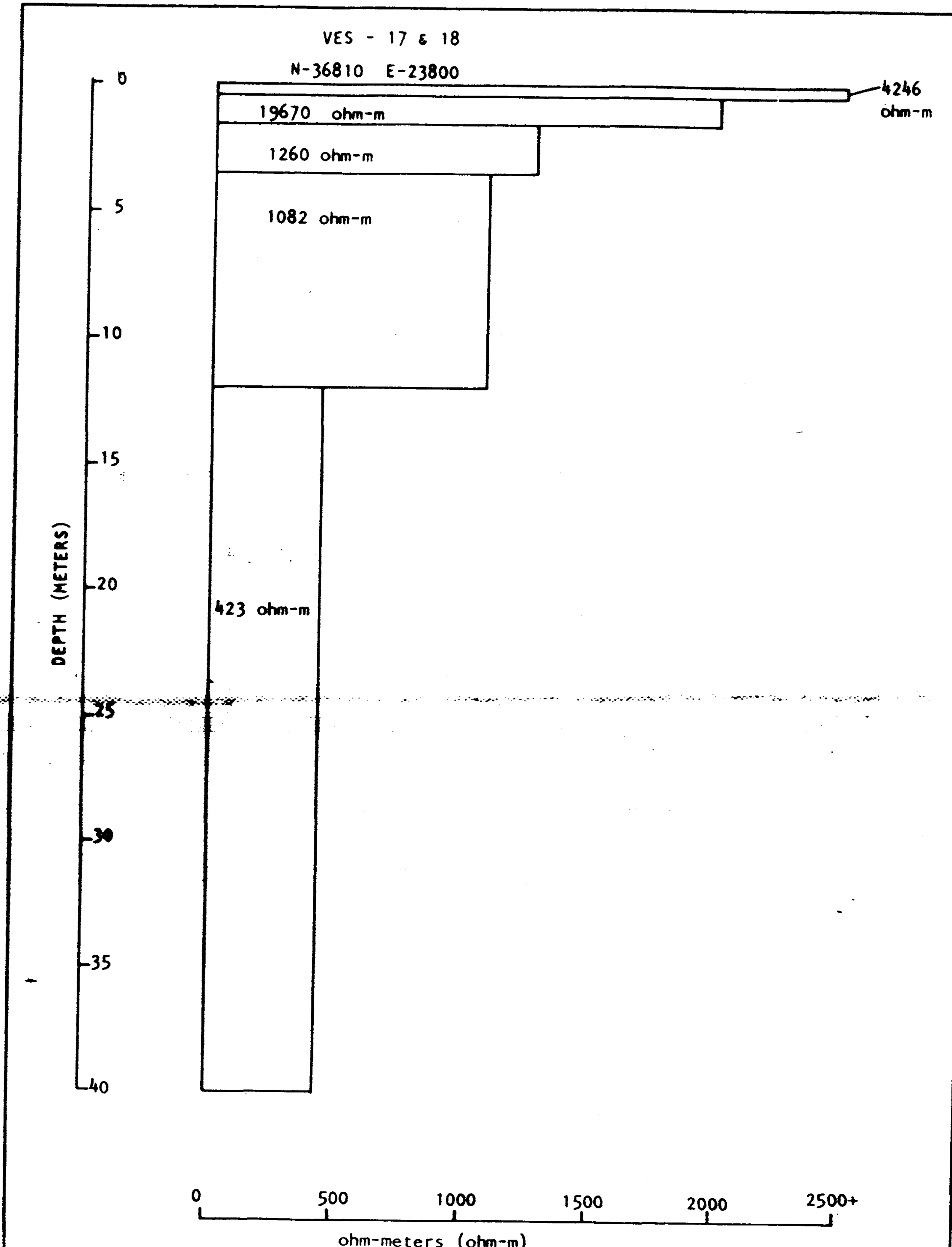
6 007 87	Chen & Associates	INVERSION RESULTS FOR VES-14	Fig. 3-3



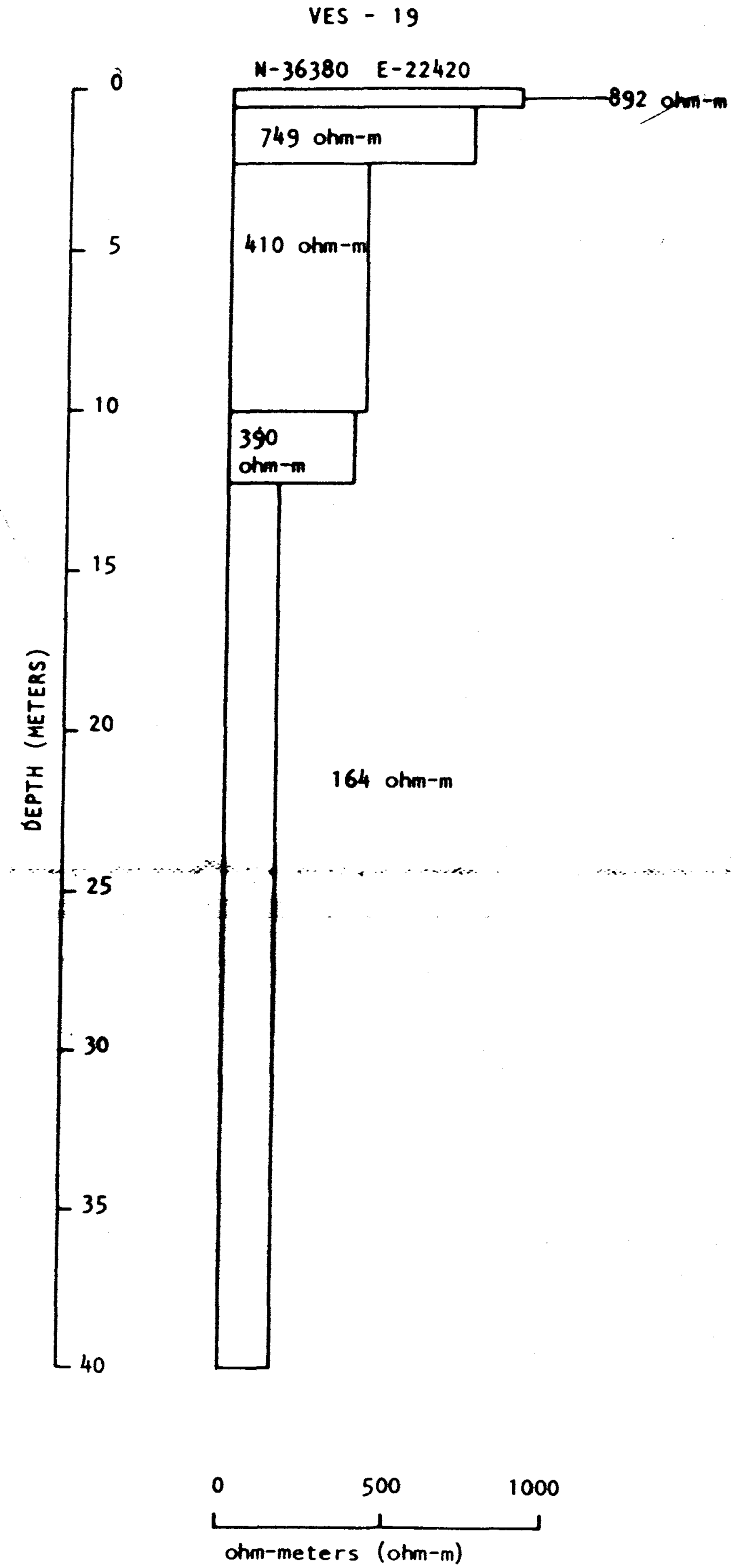
6 007 87	**Chen & Associates**	INVERSION RESULTS FOR VES-15	Fig. 3-4



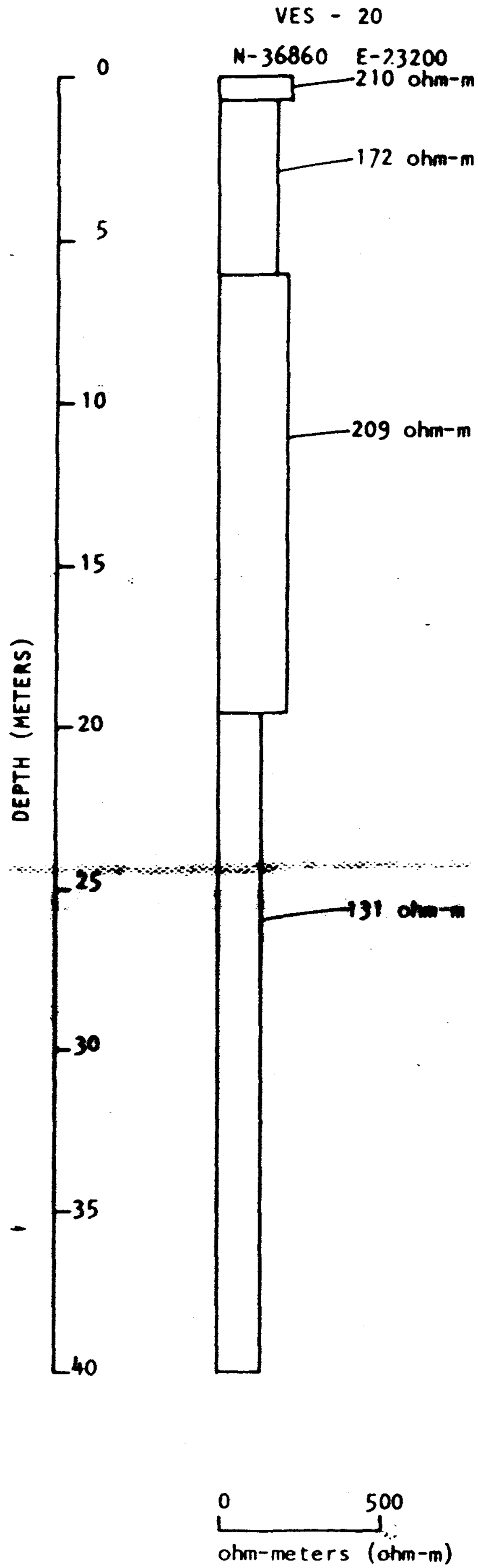
6 007 87	Chen & Associates	INVERSION RESULTS FOR VES-16	Fig. 3-5



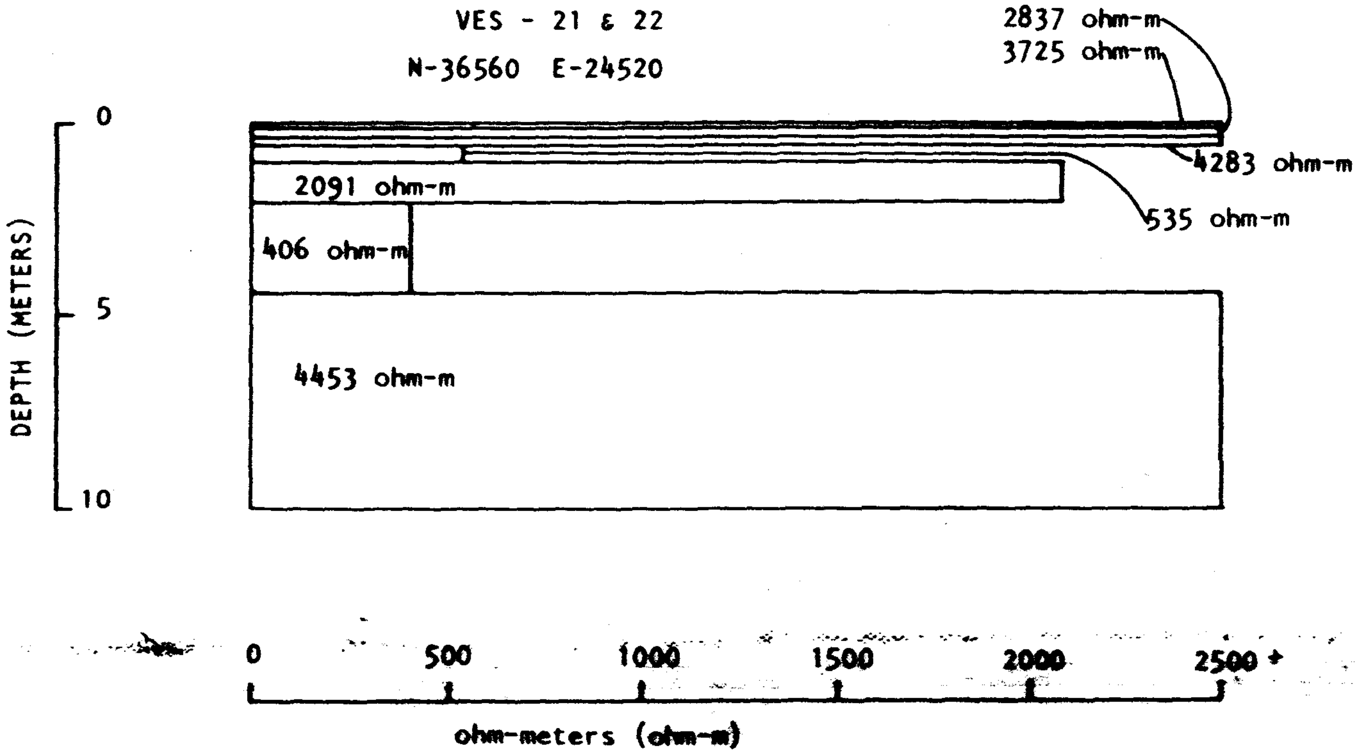
6 007 87	**Chen & Associates**	INVERSION RESULTS FOR VES - 17 & 18	Fig. 3-6



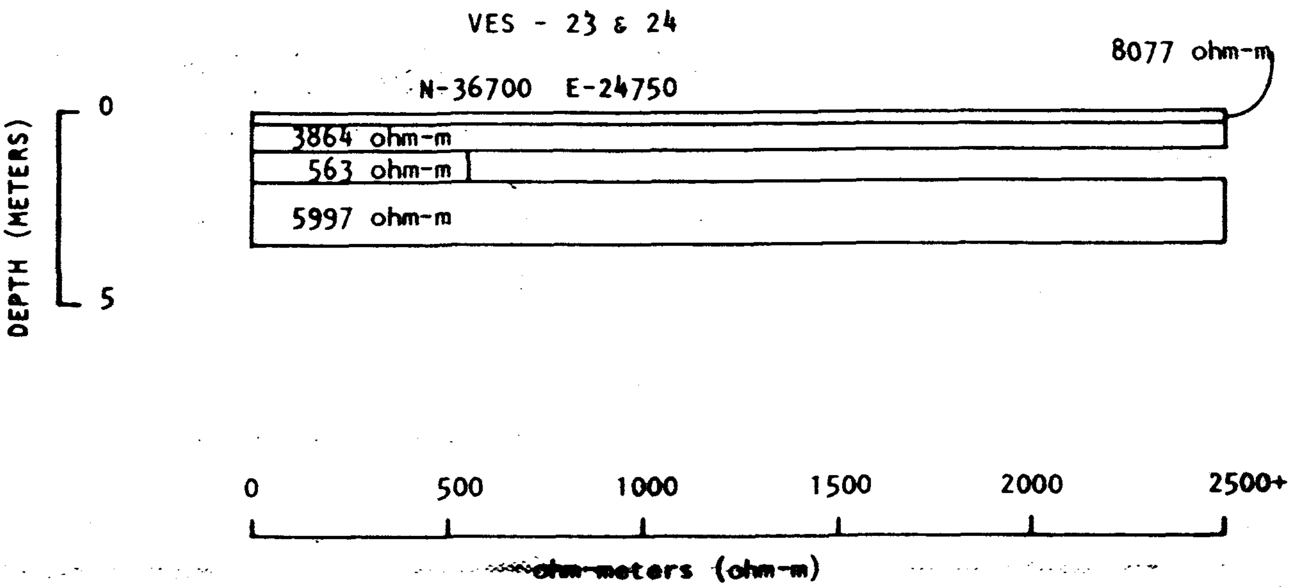
6 007 87	**Chen & Associates**	INVERSION RESULTS FOR VES - 19	Fig. 3-7



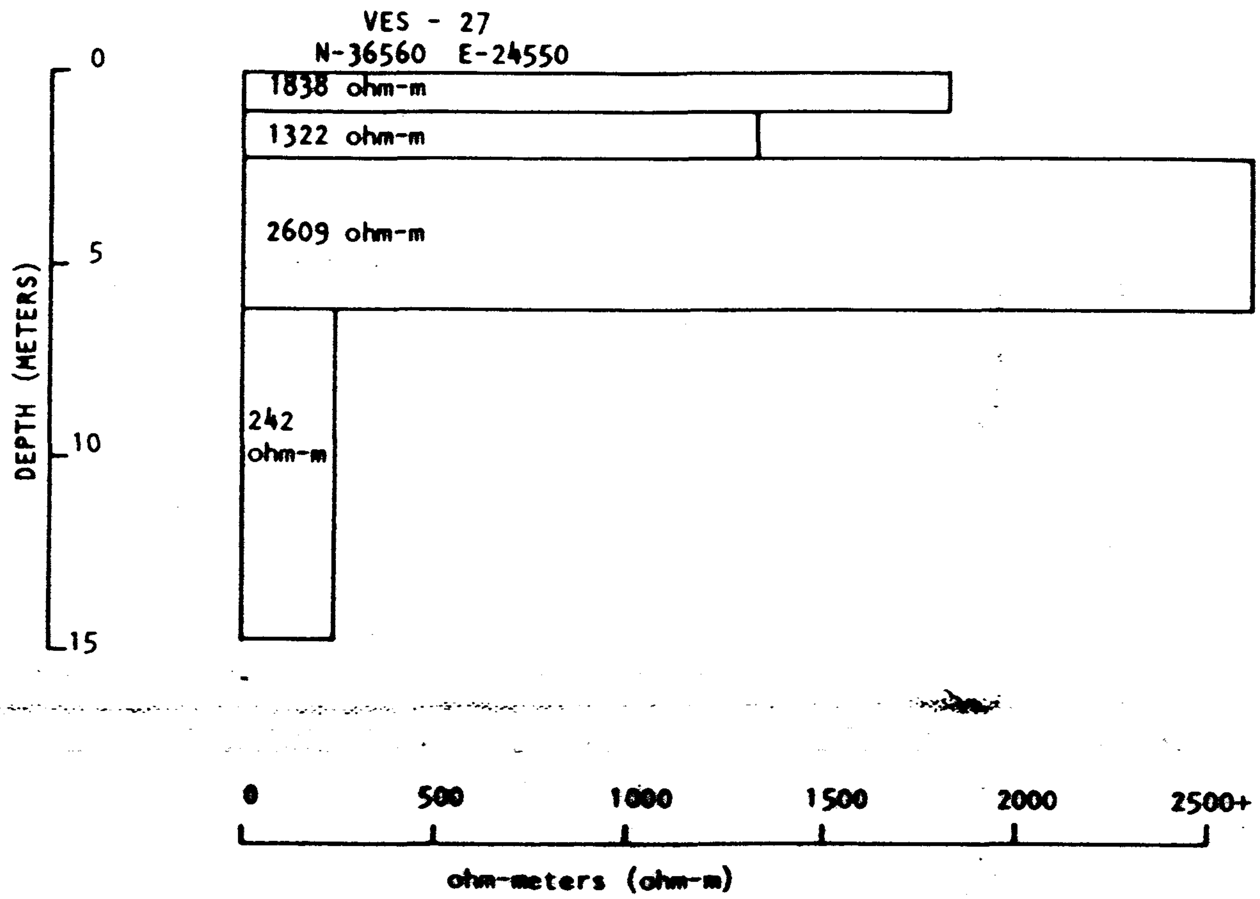
6 007 87	Chen & Associates	INVERSION RESULTS FOR VES - 20	Fig. 3-8



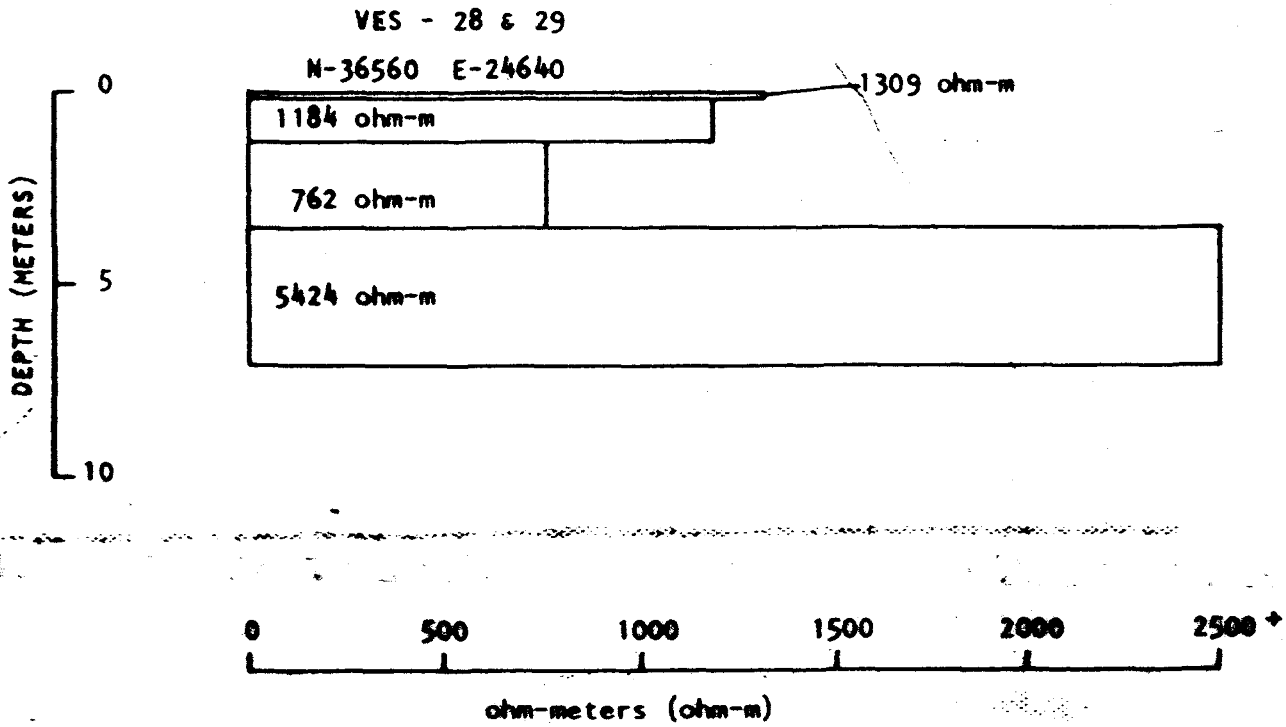
6 007 87	Chen & Associates	INVERSION RESULTS FOR VES- 21 & 22	Fig. 3-9



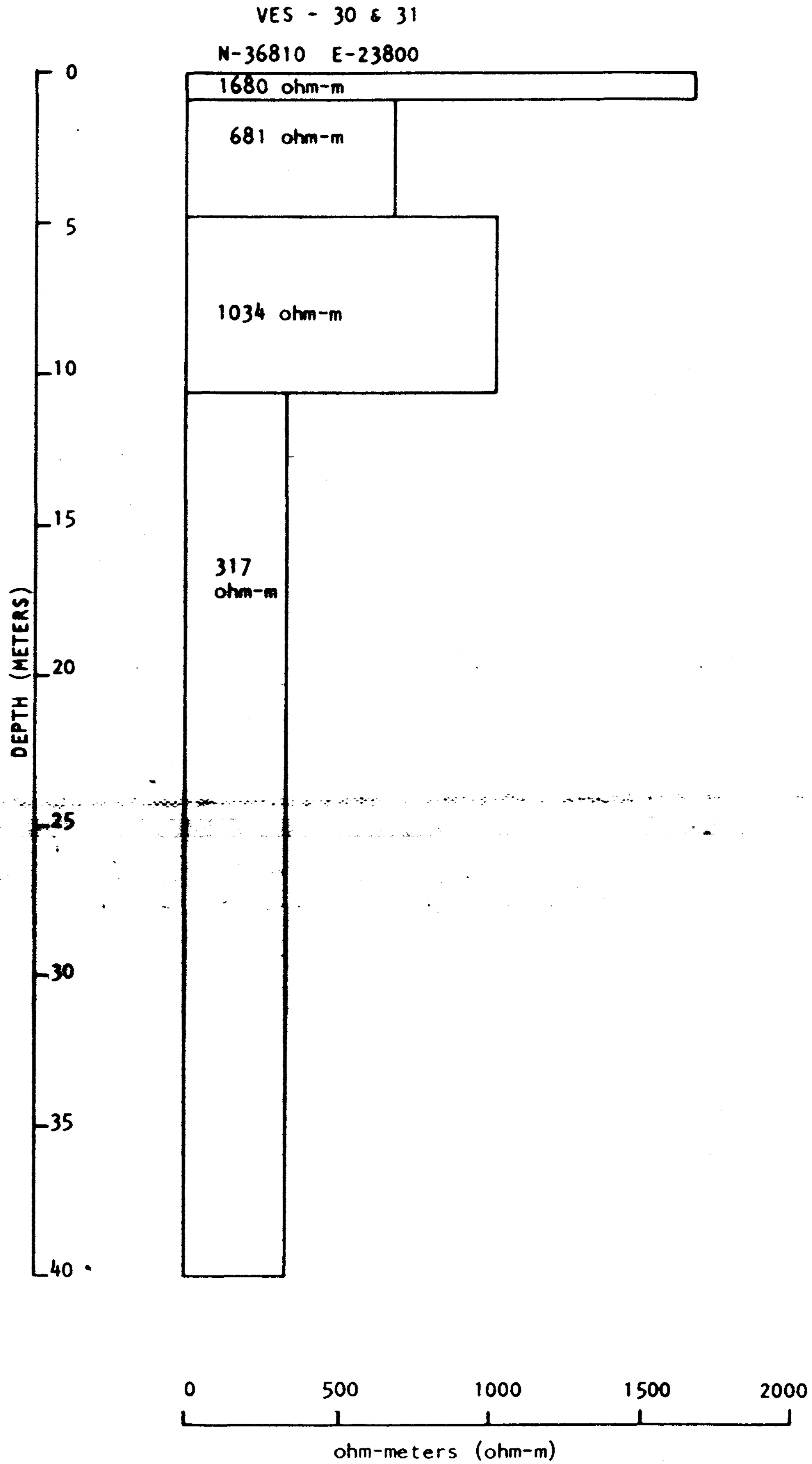
6 007 87	**Chen & Associates**	INVERSION RESULTS FOR VES- 23 & 24	Fig. 3-10



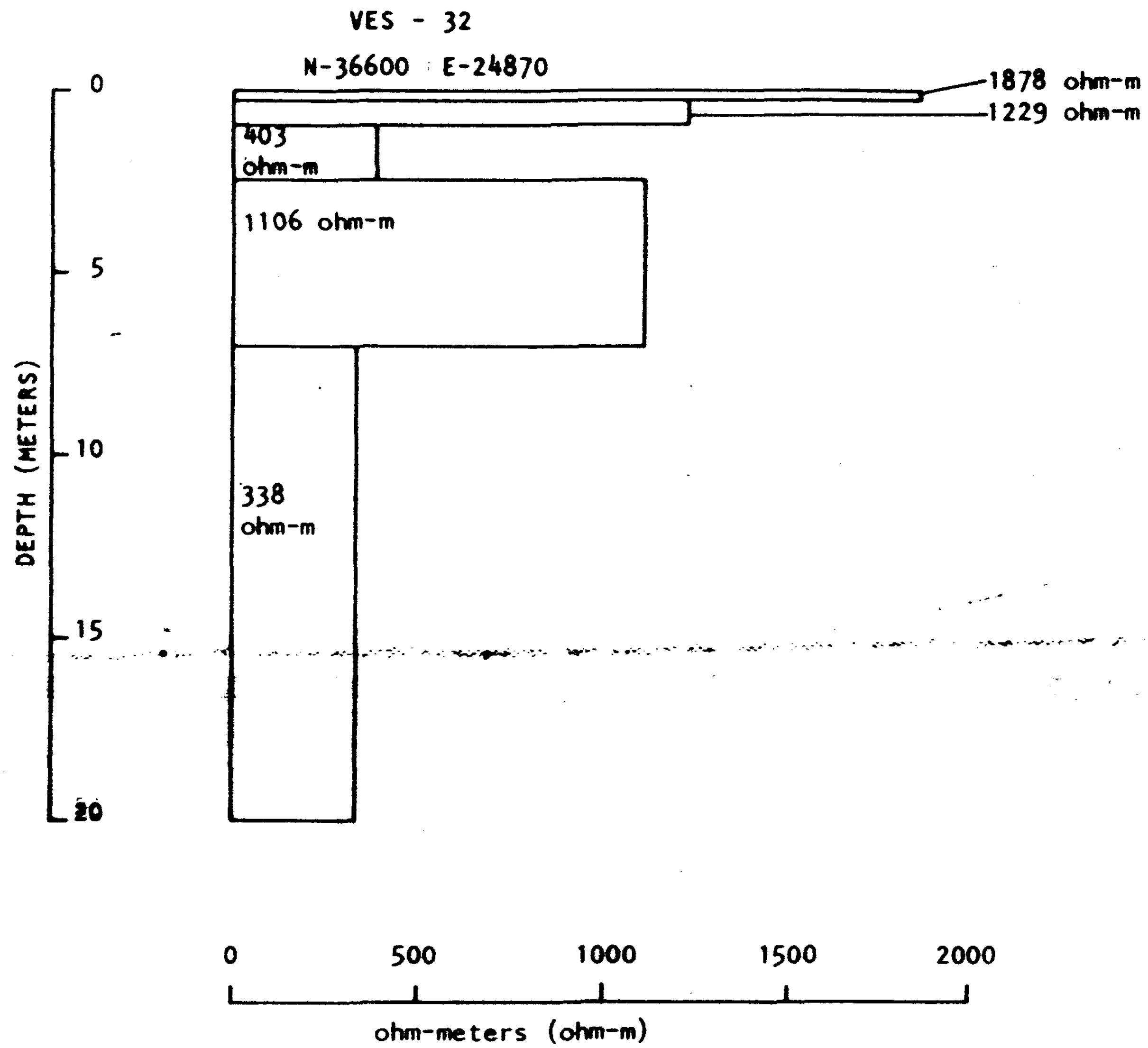
6 007 87	Chen & Associates	INVERSION RESULTS FOR VES- 27	Fig. 3-11



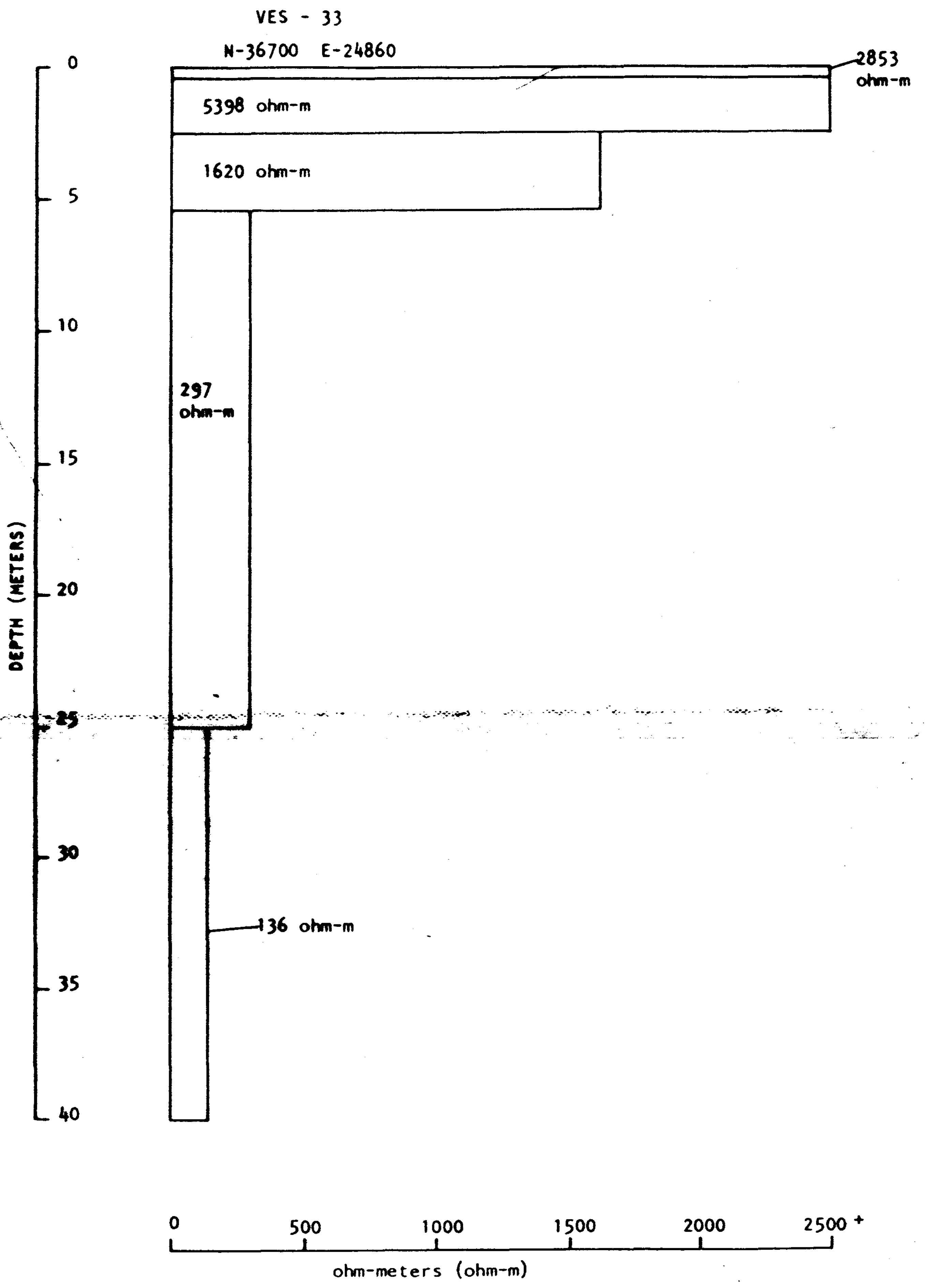
6 007 87	Chen & Associates	INVERSION RESULTS FOR VES-28 & 29	Fig. 3-12



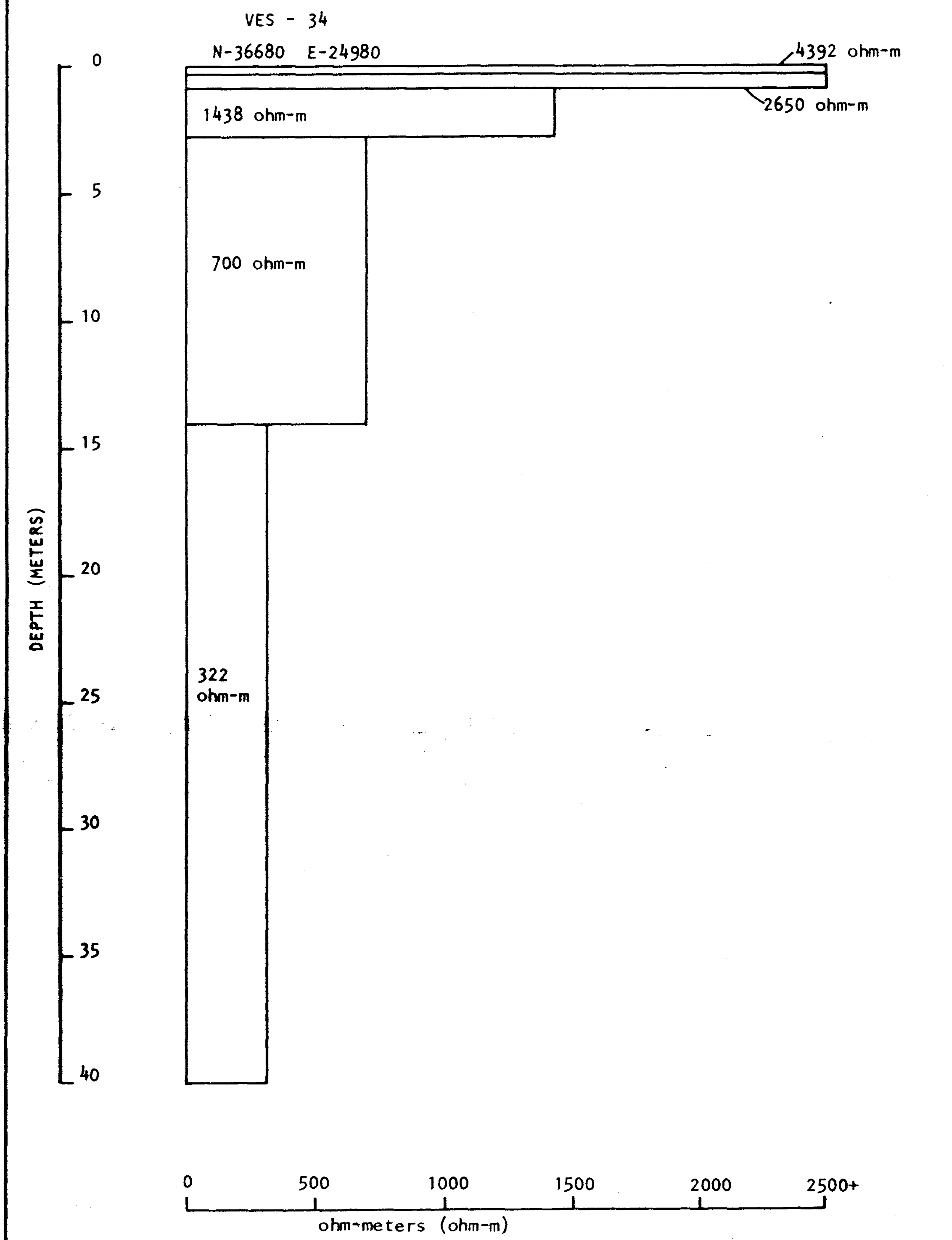
6 007 87	**Chen & Associates**	INVERSION RESULTS FOR VES-30 & 31	Fig. 3-13



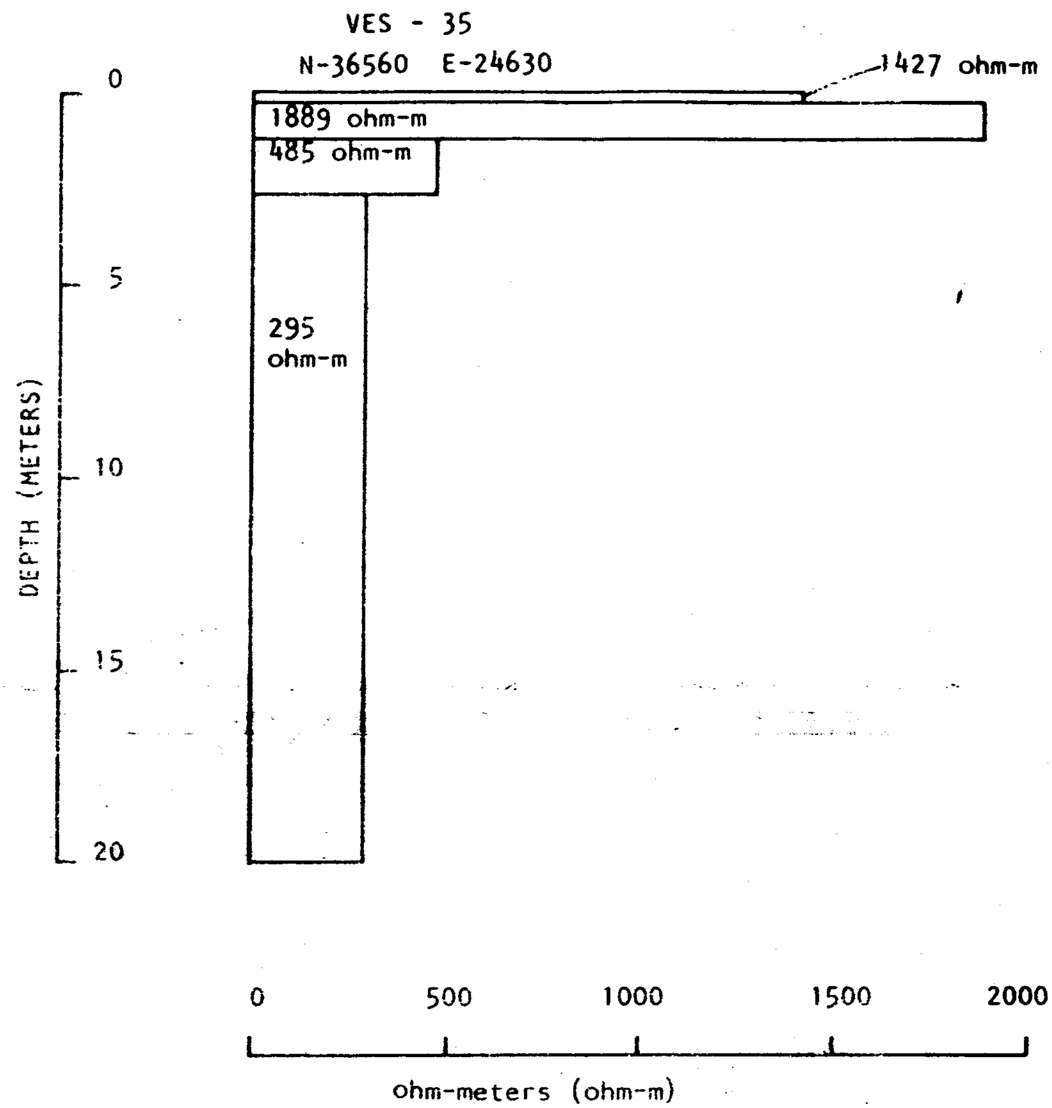
6 007 87	**Chen & Associates**	INVERSION RESULTS FOR VES-32	Fig. 3-14



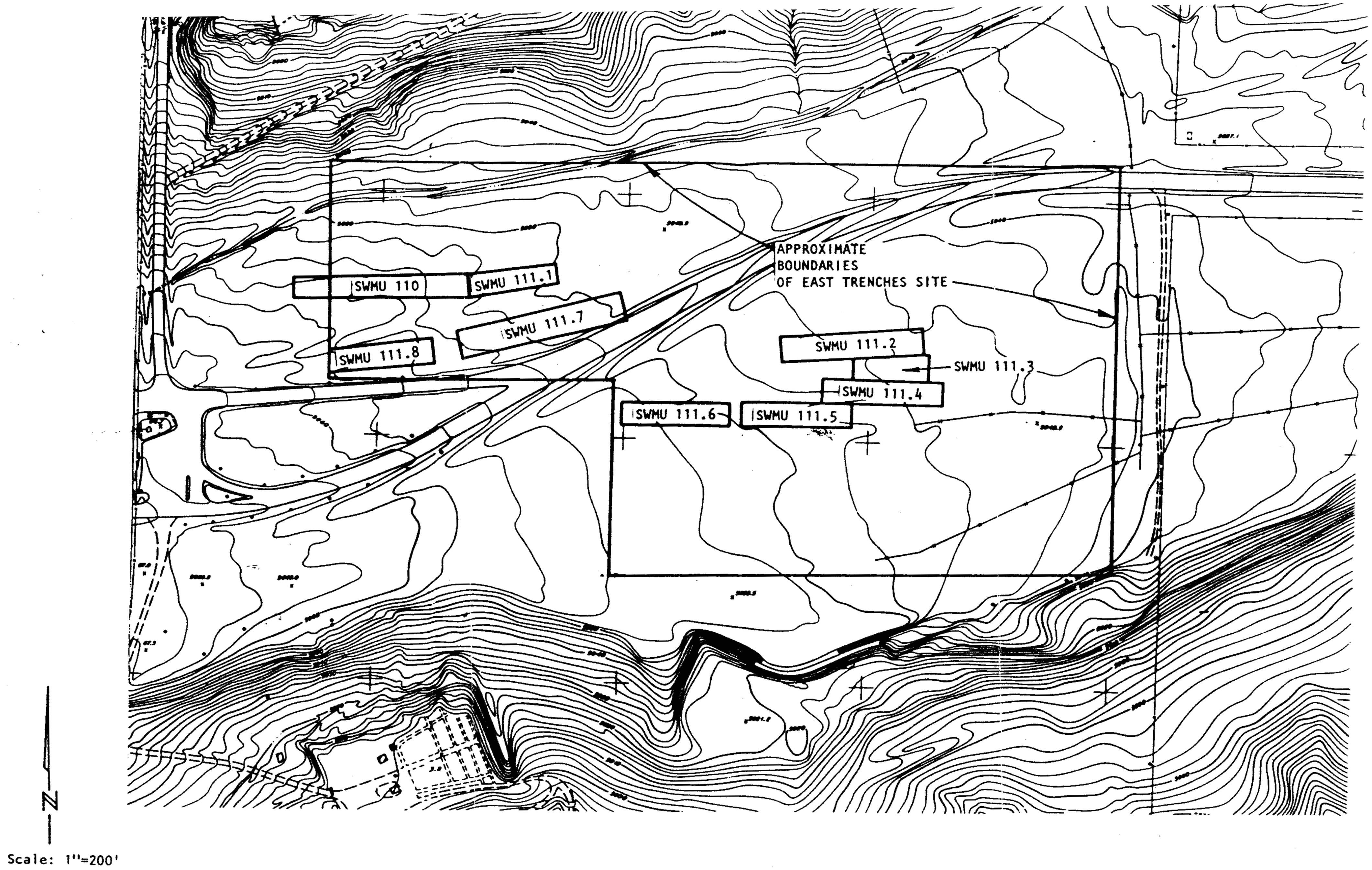
6 007 87	**Chen & Associates**	INVERSION RESULTS FOR VES-33	Fig. 3-15



6 007 87	**Chen & Associates**	INVERSION RESULTS FOR VES-34	Fig. 3-16



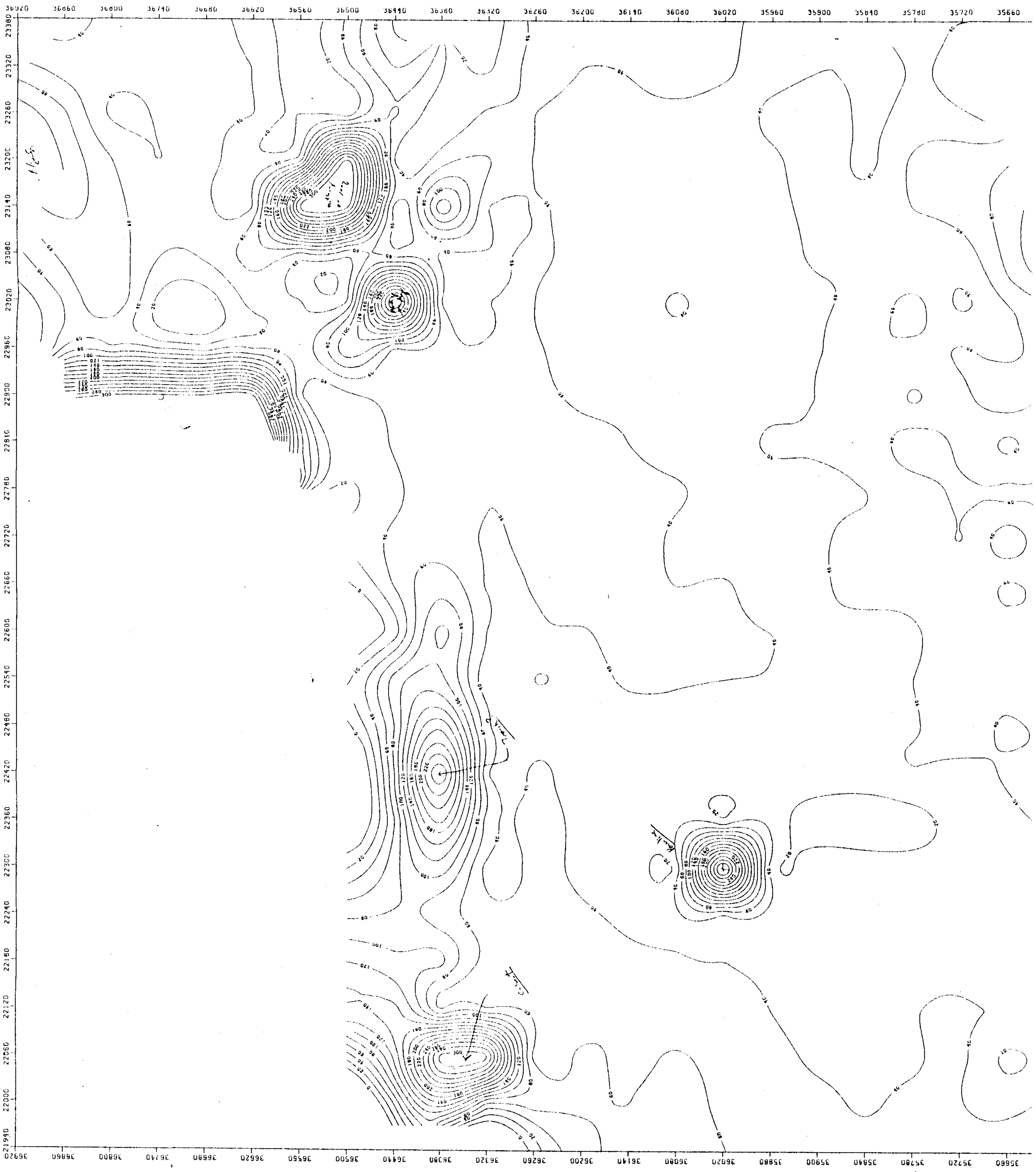
6 007 87	Chen & Associates	INVERSION RESULTS FOR VES-35	Fig. 3-17



WESTON

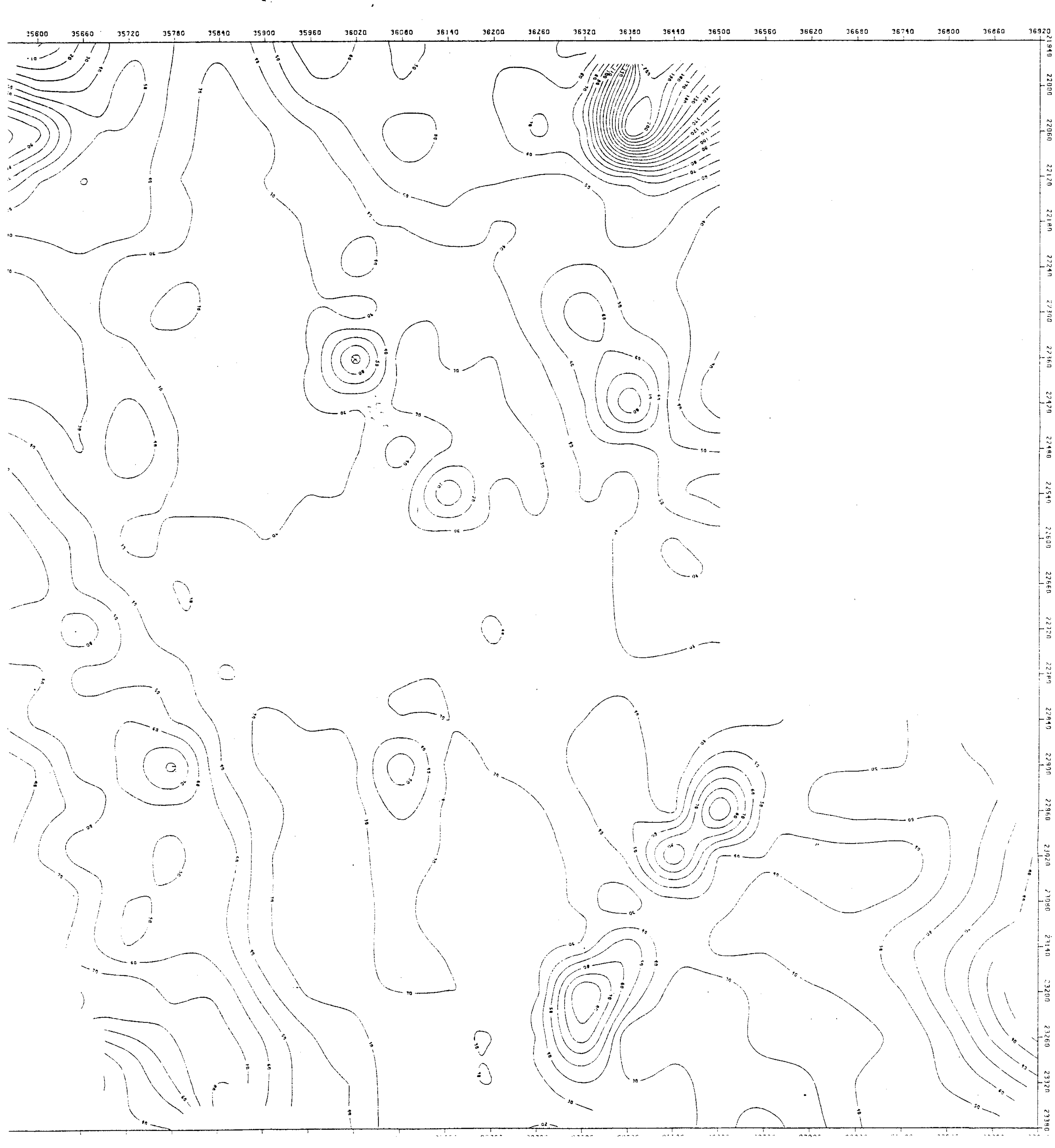
LOCATION OF EAST TRENCHES SITE

Fig. 2



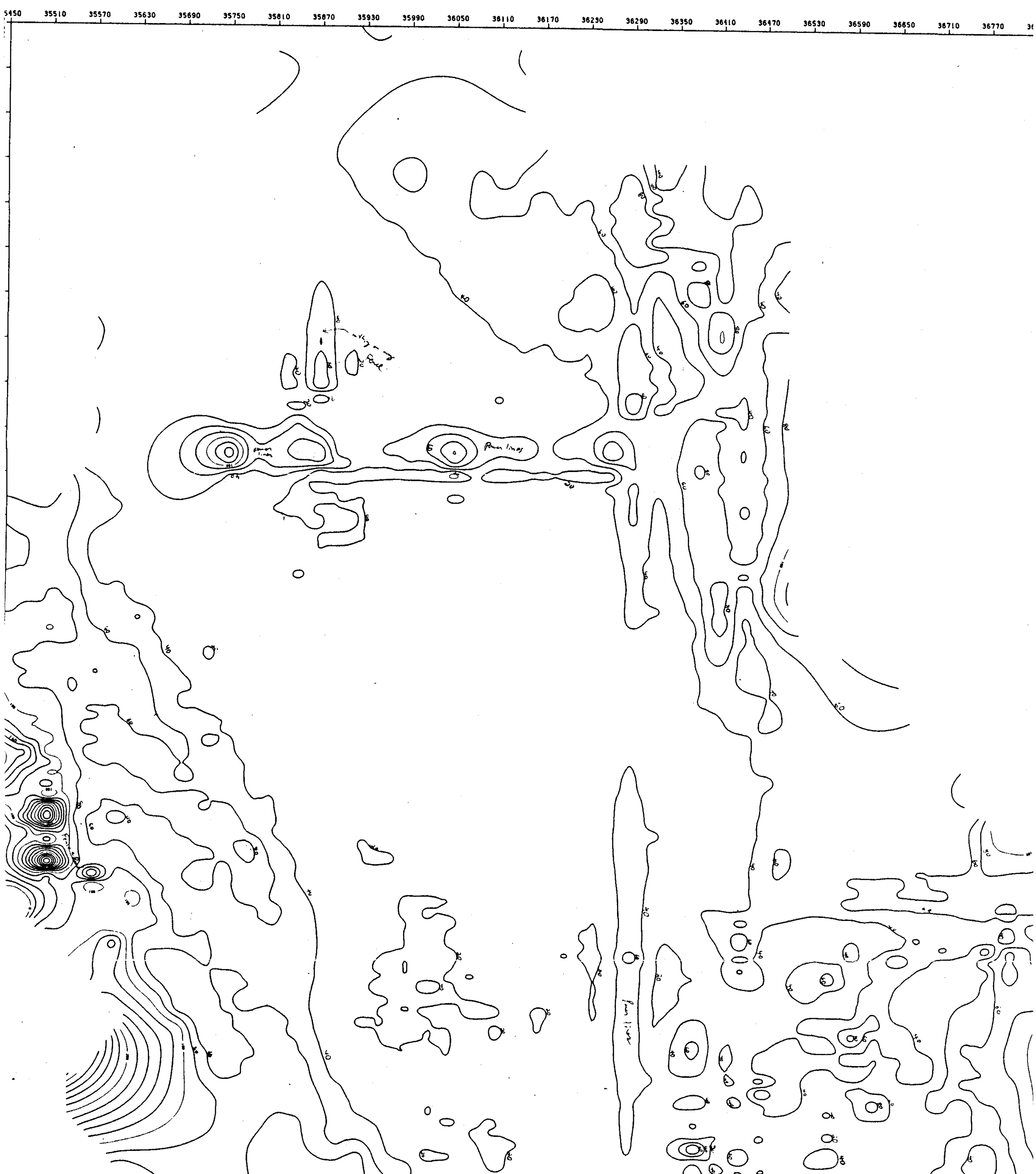
AND MOUND AREAS - EM34 VERTICAL DIPOLE (4/14/82)

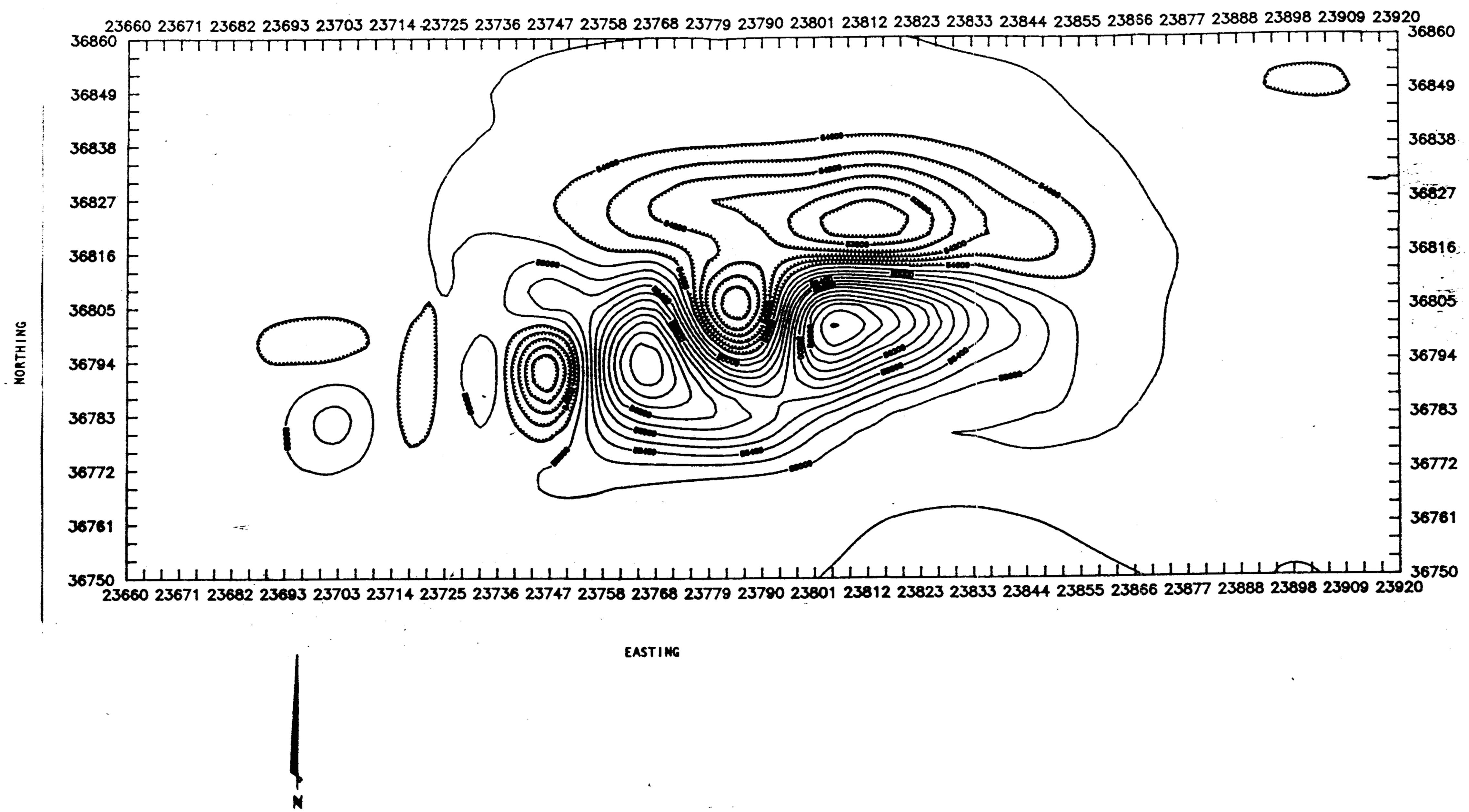
TS 903 PAD AND MOUND AREAS - EM34 HORIZONTAL DIPOLE (4/14/87)



EM-31 903 Pad and Mound Sites

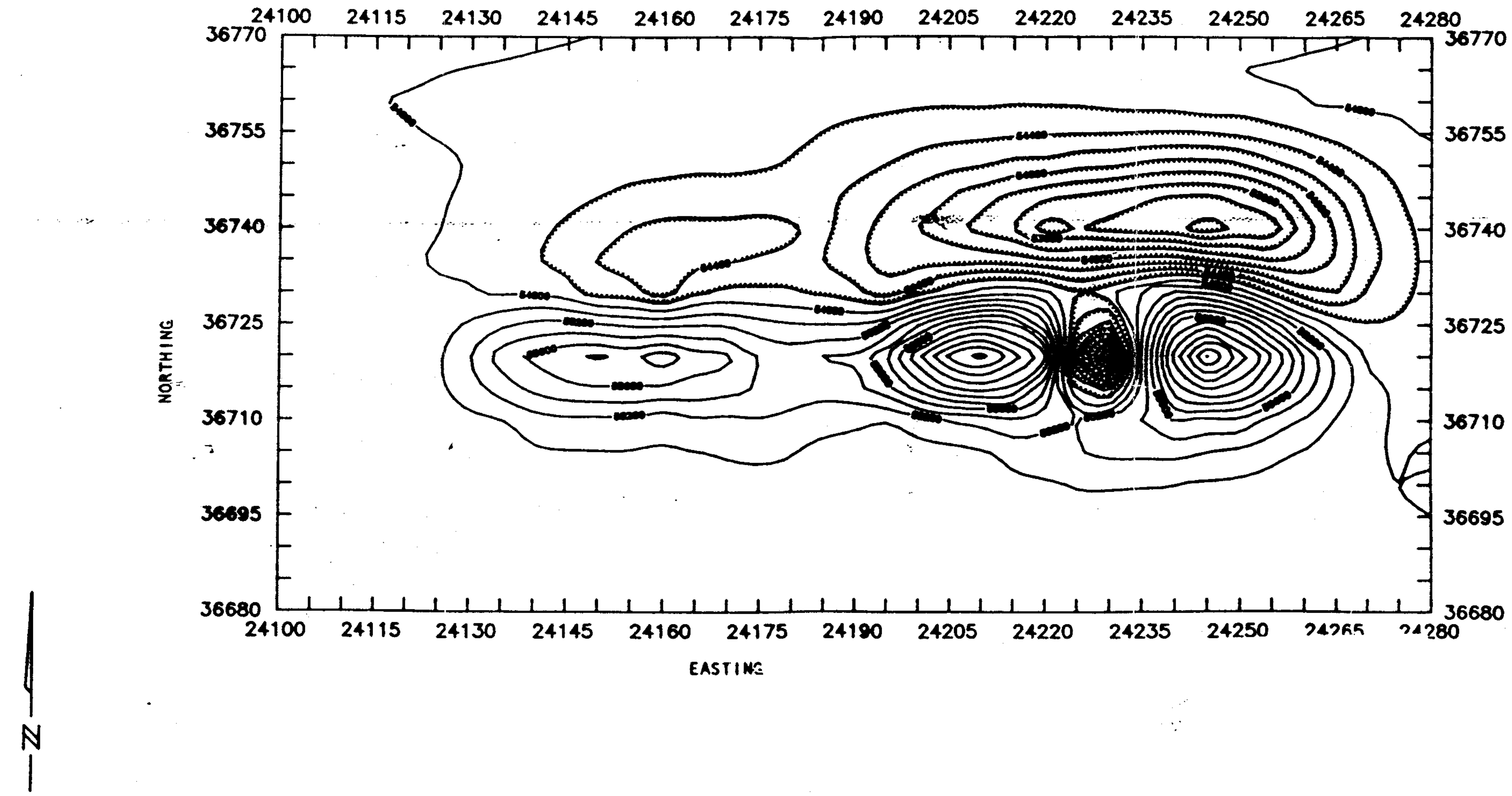
ROCKY FLATS ROY F WESTON SCALE 1 INCH = 60 FEET CI = 20 MMHOS/METER





Scale: 1"=20'
Contour Interval: 400 gammas

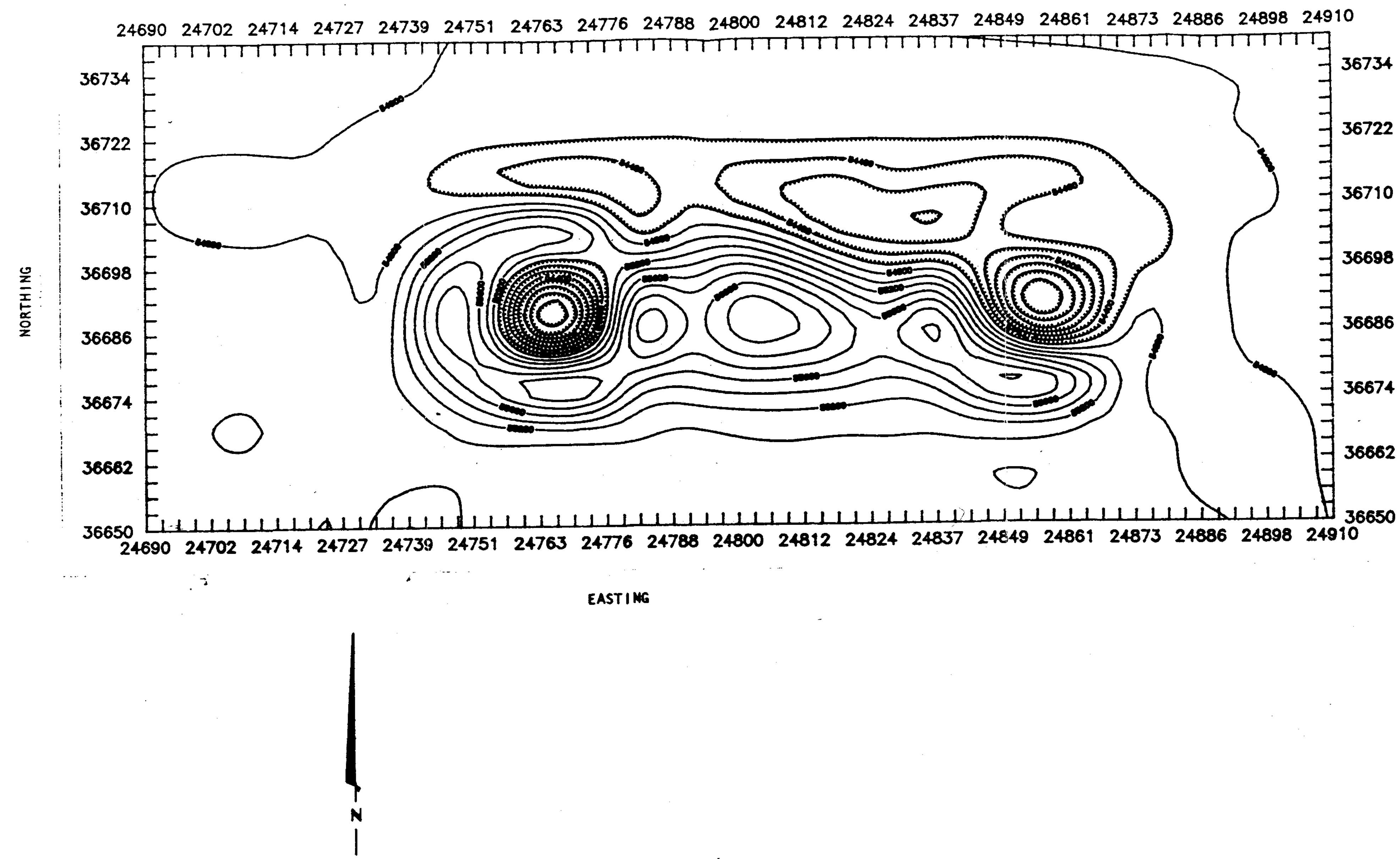
6 007 87	Chen & Associates		MAGNETIC CONTOUR MAP OF SWMU # 110	Fig.



Scale: 1"=20'

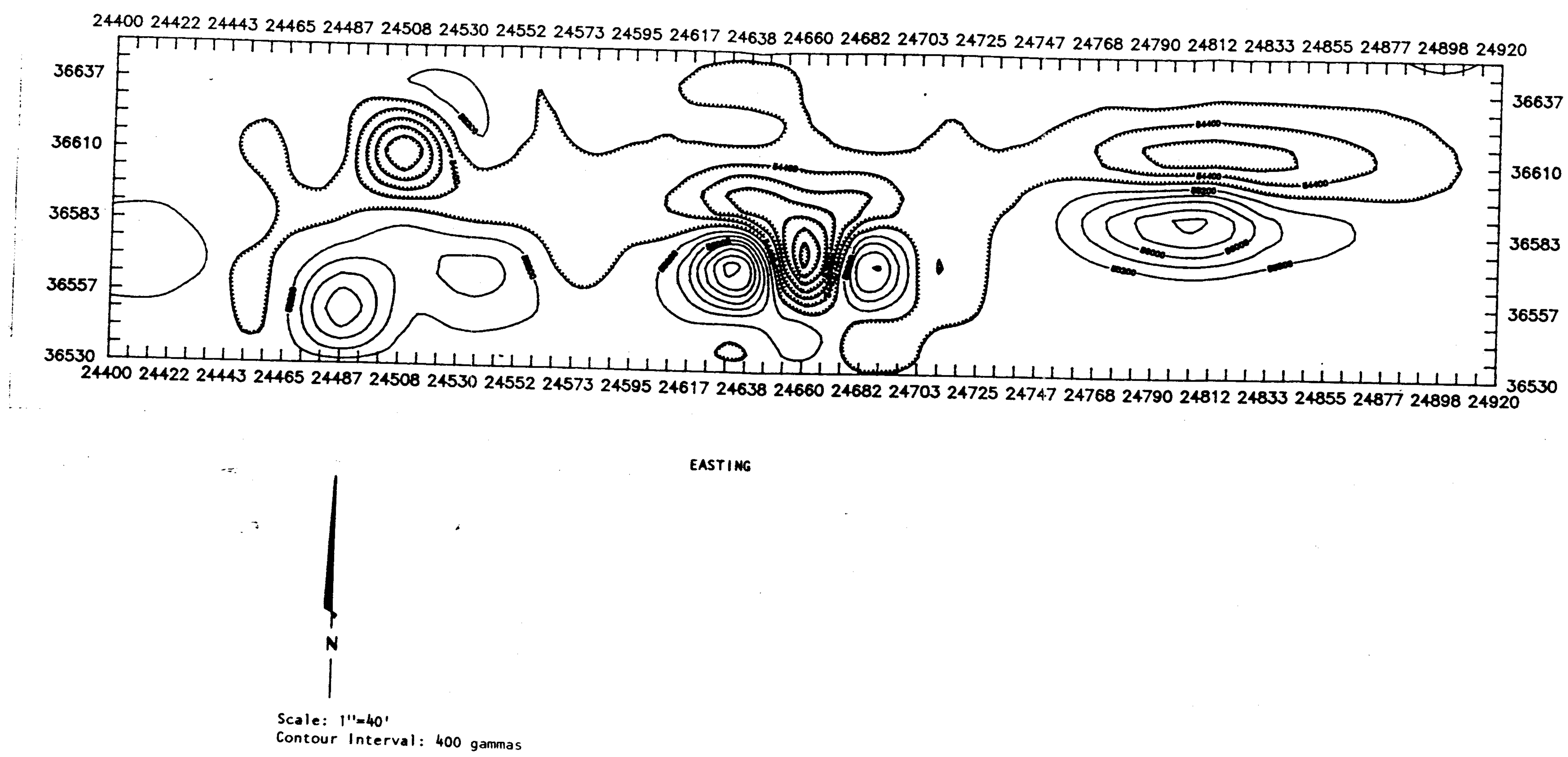
Contour Interval:200 gammas

6 007 87	Chen & Associates	MAGNETIC CONTOUR MAP OF SWMU #111.1	Fig. 2

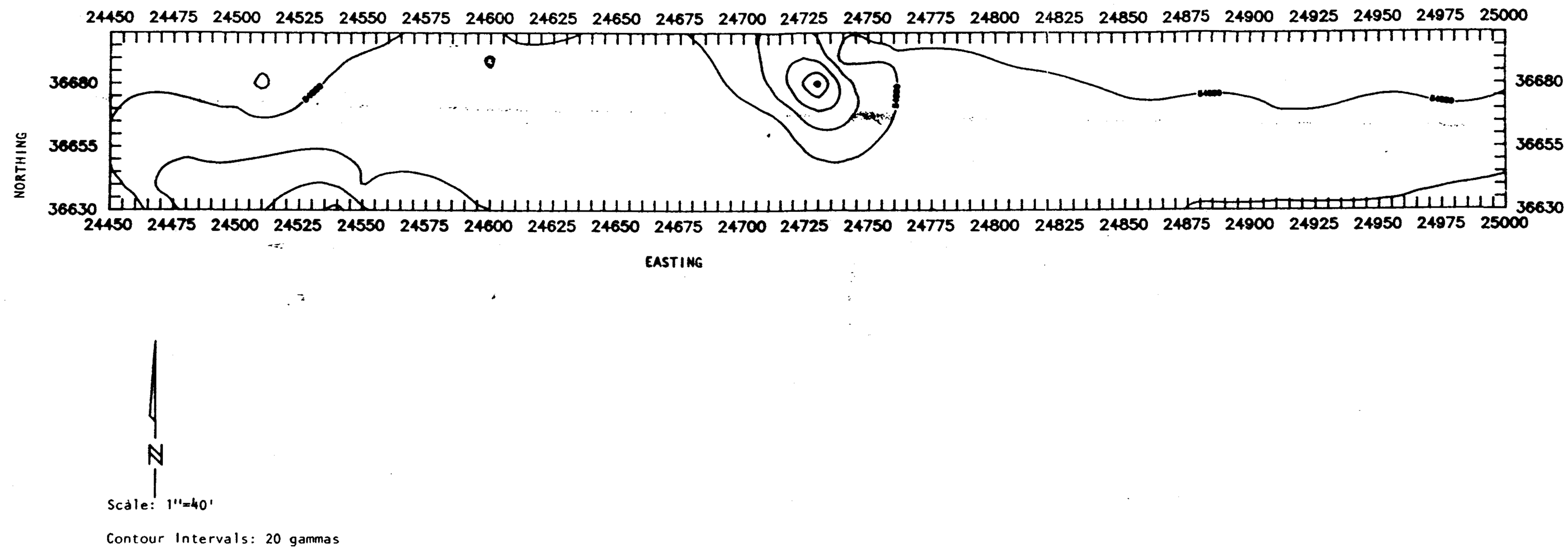


Scale: 1"=20'
Contour Interval: 200 gammas

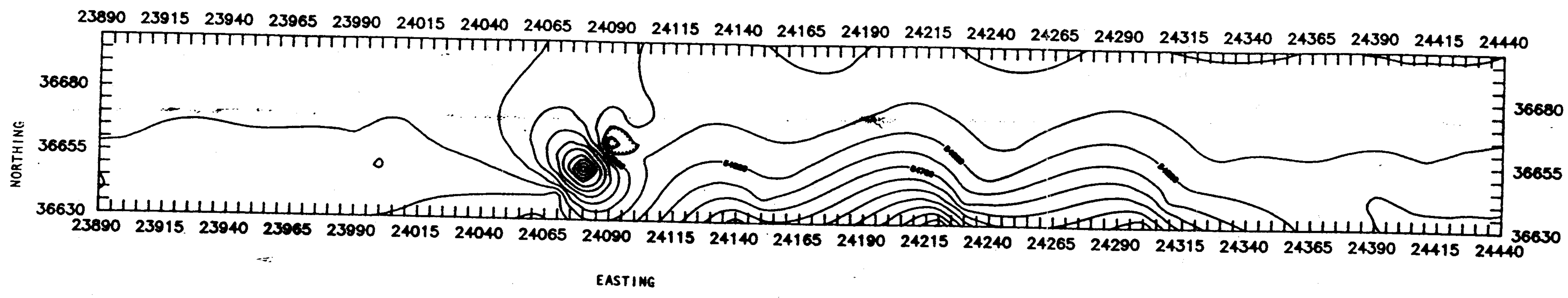
6 007 87	Chen & Associates	MAGNETIC CONTOUR MAP OF SWMU # 111.2 and 111.3	Fig. 2-



6 007 87 | **Chen & Associates** | MAGNETIC CONTOUR MAP OF SWMU'S #111.4, 111.5 and 111.6 | Fig. 2



6 007 87 | Chen & Associates | MAGNETIC CONTOUR MAP OF SWMU #111.7 | Fig. 2-5

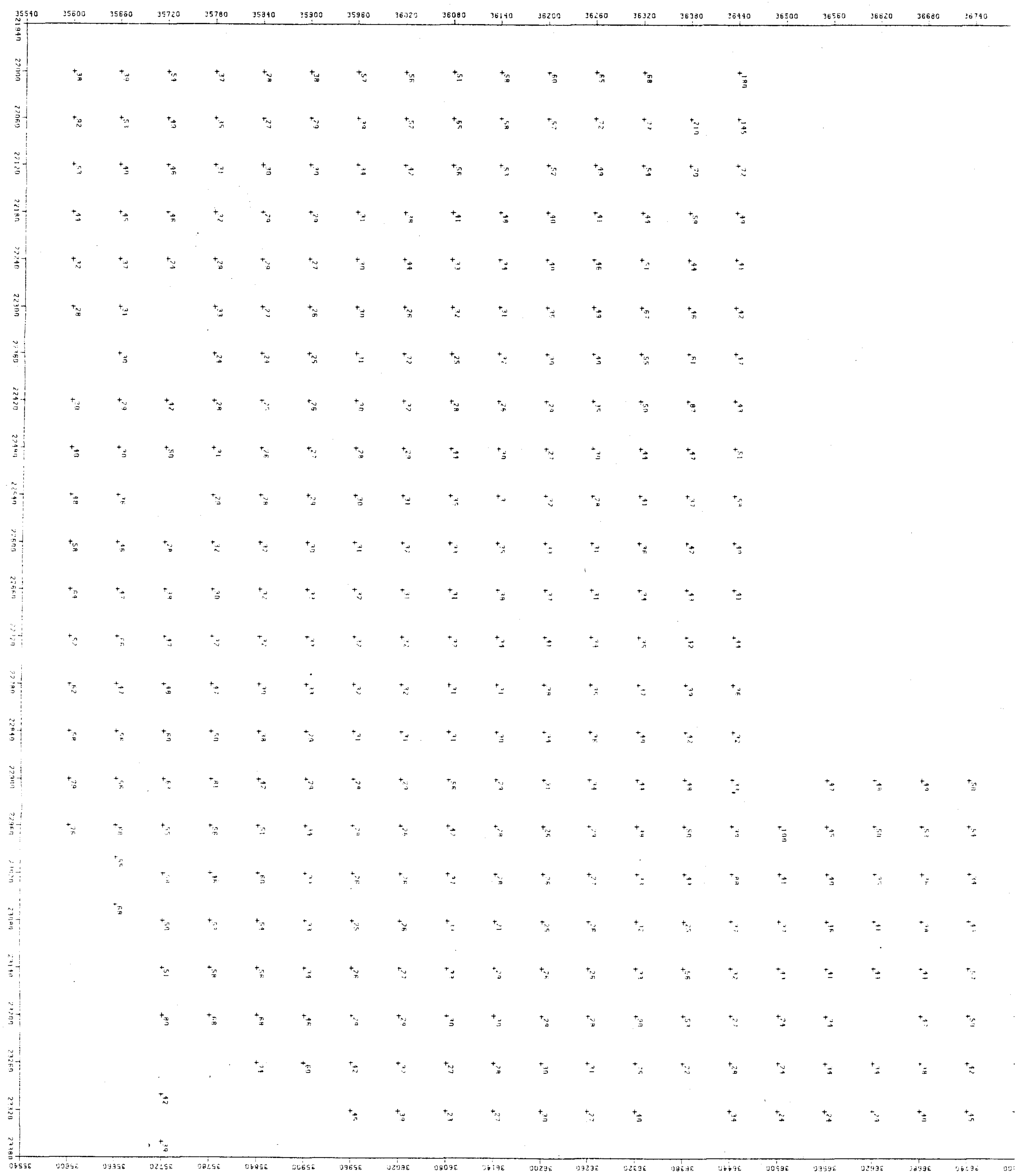


N

Scale: 1"=40'

Contour Intervals: 20 gammas

6 007 87	Chen & Associates		MAGNETIC CONTOUR MAP OF SWMU # 111.8	Fig. 2-6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36740

6.000:1 — ROCKY FLATS 903 PAD AND MOUND AREAS - EM38 VERTICAL DIPOLE POST (4/14/87)