Final Report

on

Geophysical Investigation of Material Disposal Areas A and T (TA-21-016[a-c] and TA-21-011[c]) Los Alamos, New Mexico

submitted to

Los Alamos National Laboratory
Los Alamos, New Mexico 87545

by

Geophex, Ltd.
605 Mercury Street
Raleigh, North Carolina 27603

Geophex Job No. 636

September 1996

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Executive Summary

This report presents the results of a geophysical investigation of Materials Disposal Area (MDA) 71, (TA-21-016[a-c] and TA-21-011[c]); Operable Unit 1106 at the Los Alamos National Laboratory (LANL), Los Alamos, New Mexico.

This geophysical investigation concentrated on two MDAs located within TA-21; MDA-A and MDA-T. The primary objective was to use electromagnetic (EM) methods to identify and delineate the presence of paleochannels that may, if present, be partly responsible for transporting the contaminants off-site.

We established two grids, one at each site. The total survey area encompasses 60,000 square feet (1.5 acre). Geophex acquired EM data in June 1996, along transect lines spaced five feet apart. The in-line data sampling is approximately two feet. At each sampling location, we acquired in-phase and quadrature component data for two frequencies; 9,210 and 15,210 Hz. The two EM surveys recorded over 27,400 raw data measurements.

The EM data were recorded and logged internally by the GEM-2 instrument. Data processing included assigning spatial registry information, converting the measured signal from part-per-million response to conductivity (in milli-Seimen per meter, mS/m), and contouring (krigging).

A broad EM anomaly is present within the MDA-T site that may represent the anticipated paleochannel. The broad anomaly may, however, identify a recent but currently abandoned, compacted roadway. Aerial photographs taken in 1975 and 1982 show non-paved roads and a trench in the same vicinity as the EM anomaly. We recommend shallow excavation or borings within the anomalous area to confirm the nature of the causative source.

The EM surveys have identified several isolated anomalies within MDA-T and MDA-A that, we believe, represent distinct separate buried objects or debris. Although we do not know the source of the anomalies, or if they contribute contaminants, we do not anticipate that these isolated anomalies are significant to the current project.

We do not observe EM signatures indicative of a meandering paleochannel at the MDA-A site.

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1.0 Introduction

This report presents the results of a geophysical investigation of Materials Disposal Area (MDA) 71, (TA-21-016[a-c] and TA-21-011[c]); Operable Unit 1106 at the Los Alamos National Laboratory (LANL), Los Alamos, New Mexico.

TA-21 is centrally located on the Pajarito Plateau and bordered by two canyons; DP Canyon to the north, and Los Alamos Canyon to the south (Figure 1). TA-21 was used primarily for plutonium research and metal production from 1945 to 1978 (Broxton and Eller, 1995). The major waste-disposal activities involve byproducts of the chemical processing. The anticipated disposal mechanisms include (Broxton and Eller, 1995):

- deep liquid releases into absorption beds and seepage pits,
- near-surface liquid releases (surface discharges),
- subsurface solid-waste disposal areas, and
- surface contamination areas (surface spills).

This geophysical investigation concentrated on two MDAs located within TA-21; MDA-A and MDA-T (Figure 1 and 2). Both MDAs are located on DP Mesa and drain north into DP Canyon. Radioactive contamination has been documented in DP Canyon (Purtymun, 1971; Purtymun et al., 1990). The primary objective of this project was to use electromagnetic (EM) methods to identify and delineate the presence of paleochannels that may, if present, be partly responsible for transporting the contaminants into DP Canyon.

Geophex established two survey areas, one located within the fenced borders of MDA-A and one within the fenced border of MDA-T (Figure 2). The surface vegetation consisted of native grass (Figure 3). The two sites collectively occupy approximately 60,000 square feet (1.5 acres). Although the sites do not currently contain surface features or obstacles, aerial photographs of the site taken in 1975 and 1982 (Broxton and Eller, 1995) reveal substantial landscaping, heavy-equipment traffic, and even a possible trench and associated surface mound.

2.0 Geophysical Instruments and Methods

We acquired EM data using a man-portable EM instrument known as the GEM-2, designed and fabricated by Geophex. The GEM-2 is a unique, hand-held, digital, broad-band EM sensor. The sensor exploits the relationship between electric fields, magnetic fields, and electrical current to detect changes in subsurface conductivity. Electrical conductivity is an inherent property of a material to conduct electrical current and can be used to rapidly and economically characterize near-surface materials.

The GEM-2 simultaneously acquires data from multiple transmitter frequencies. This capability is important because the electromagnetic response of a buried object is frequency dependent (Won, 1980). The EM response is also a function of the coil separation and ground conductivity. For a fixed coil separation (such as the GEM-2) and site-specific background conductivity, low frequencies propagate further into the earth than high frequencies. Consequently, lower frequencies generally respond to deeper targets, and higher frequencies respond to shallower

targets. Acquiring data at multiple frequencies (known as frequency sounding) is, therefore, equivalent to measuring the earth response at multiple depths. Appendix A presents additional background information on the EM method.

3.0 EM Data

We acquired EM data along survey lines spaced five feet apart at each site. Both EM surveys employed a horizontal coil configuration (viz., vertical magnetic dipole [hmd]). The in-line sampling interval was approximately two feet. At each sampling location, we obtained in-phase and quadrature data at two frequencies, 9,210 and 15,210 Hz. The EM surveys generated over 27,400 raw measurements.

The EM data were recorded and logged internally by the GEM-2 instrument. After completing the EM survey, we downloaded the raw data into a laptop computer for processing and display. Data processing included assigning spatial registry information, converting the measured signal from part-per-million response to conductivity (in milli-Seimen per meter, mS/m), and contouring (krigging). We used a commercially available software package called Surfer, manufactured by Golden Software, to contour and display the EM data.

The processed EM data for MDA-T and MDA-A are shown in Figures 4 and 5, and Figures 7 and 8, respectively.

4.0 Interpretation

4.1 MDA-T

In addition to isolated anomalies that probably represent isolated buried objects, a broad positive anomaly is clearly seen in the quadrature component of data (Figures 4 and 5). The quadrature component is believed to respond to poor conductors (viz., namely non-ferrous materials). This broad anomaly, roughly 20 feet wide and 160 feet long, may therefore represent the anticipated paleochannel. It is entirely possible, however, that this anomaly represents an abandoned, compacted road bed. In fact, a trench and associated surface mound can be observed in an aerial photograph taken in 1985 (Figure 1). We recommend a shallow boring be placed along this anomaly (preferably at (60,90)) to confirm the nature of the source.

The in-phase response shows six isolated anomalies. Because the in-phase signal is believed to indicate conductive materials, we anticipate that the source of these isolated anomalies is probably buried ferrous objects or metallic debris.

Figure 6 presents our interpretation of the EM data for MDA-T.

4.2 MDA-A

We do not observe EM anomalies that suggest the presence of paleochannels in the data acquired at the MDA-A site. The north-south trending streaks in Figures 7 and 8 parallel the survey path and are not interpreted to represent real geology. We have observed this streaking before and are working to define its source and, ultimately, to minimize its impact on the recorded data.

The positive isolated anomalies shown in Figures 7 and 8 are interpreted, based on the relative strength of the in-phase and quadrature responses, to represent buried ferrous objects or metallic debris.

Figure 9 presents our interpretation of the EM data for MDA-A.

5.0 Conclusions

A broad EM anomaly is present within the MDA-T site that may represent the anticipated paleochannel. The broad anomaly may, however, identify a recent but currently abandoned, compacted roadway. Aerial photographs taken in 1975 and 1982 show non-paved roads and a trench in the same vicinity as the EM anomaly. We recommend shallow excavation or borings within the anomalous area to confirm the nature of the causative source.

The EM surveys have identified several isolated anomalies within MDA-T and MDA-A that, we believe, represent distinct separate buried objects or debris. Although we do not know the source of the anomalies, or if they contribute contaminants, we do not anticipate that these isolated anomalies are significant to the current project.

We do not observe EM signatures indicative of a meandering paleochannel at the MDA-A site.

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Figures

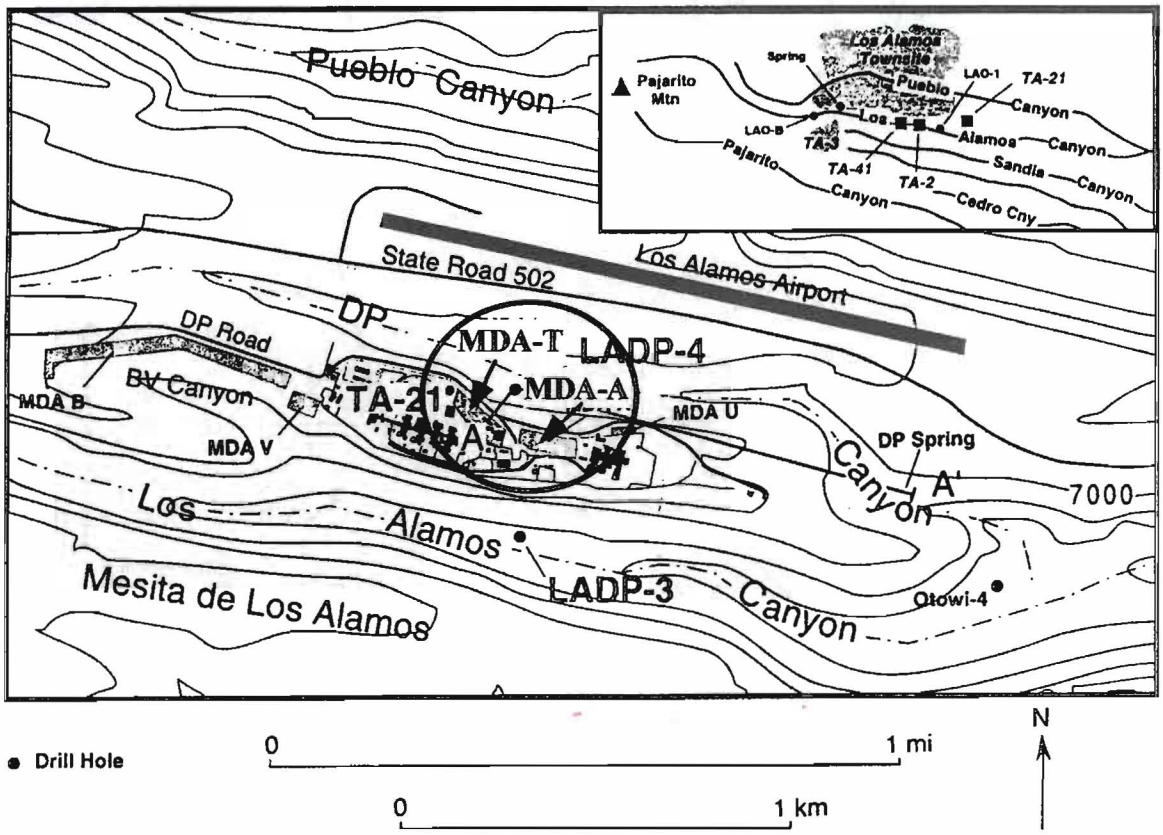

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Figure 1. Aerial view of TA-21 in 1982, looking west (top), and general site map (bottom). (Photograph from Broxton and Eller, 1995)

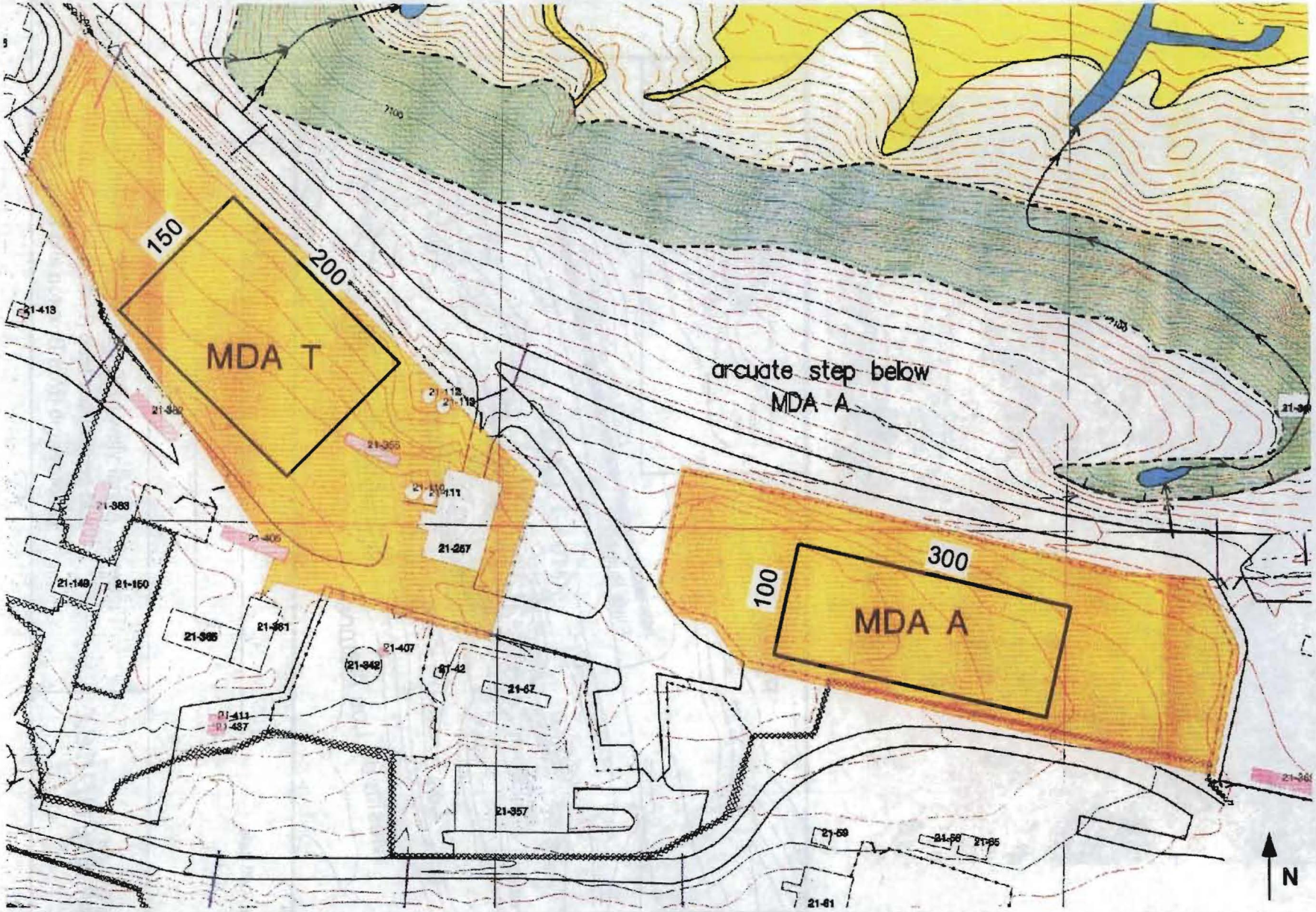

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Figure 2. Enlarged view of Material Disposal Area (MDA)-T and MDA-A.

MDA-A

MDA-T

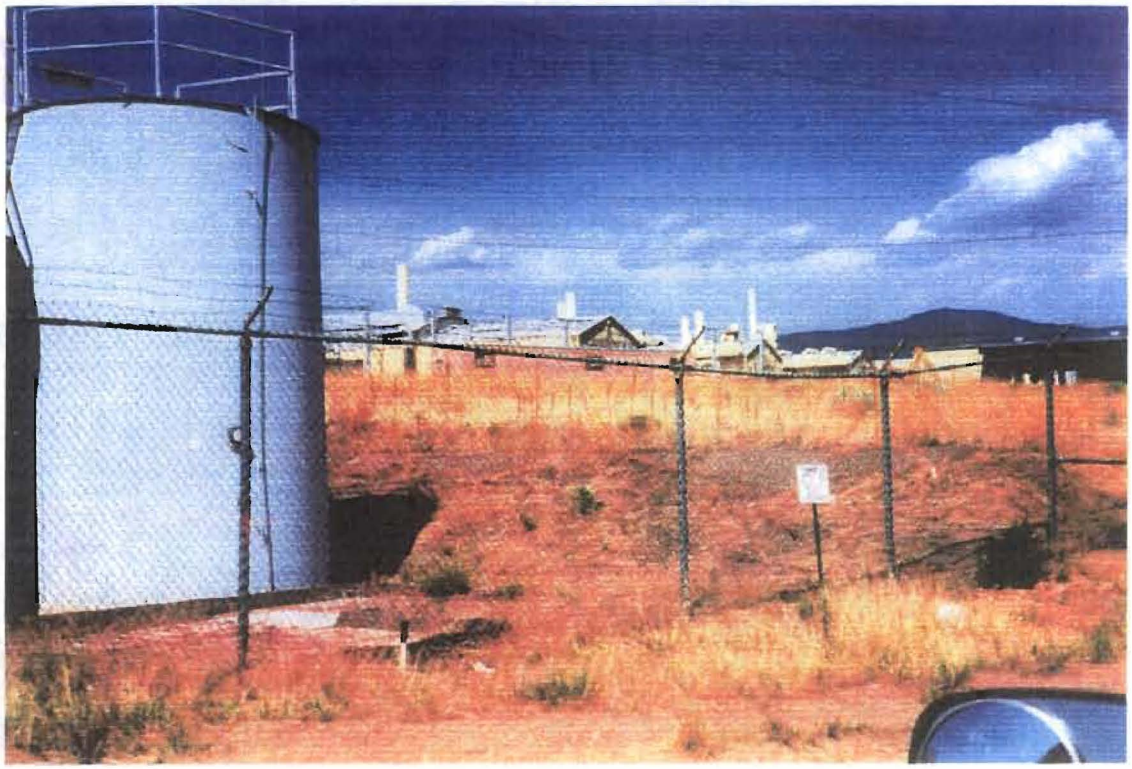

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Figure 3. Photograph of the MDA-A site (top) and MDA-T site (bottom) in 1996.

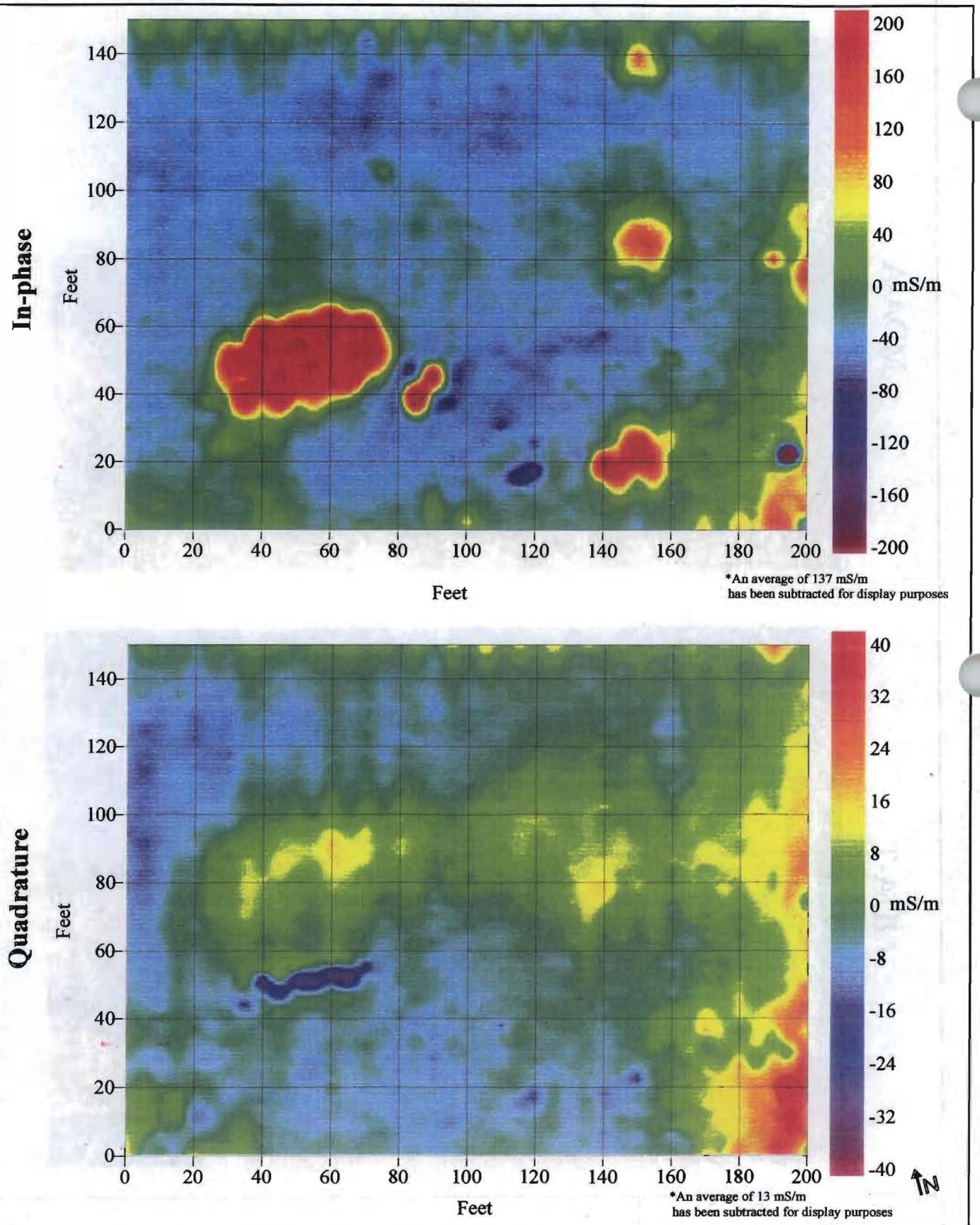

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Figure 4. Electromagentic (GEM) data for MDA-T; 9,210 Hz.

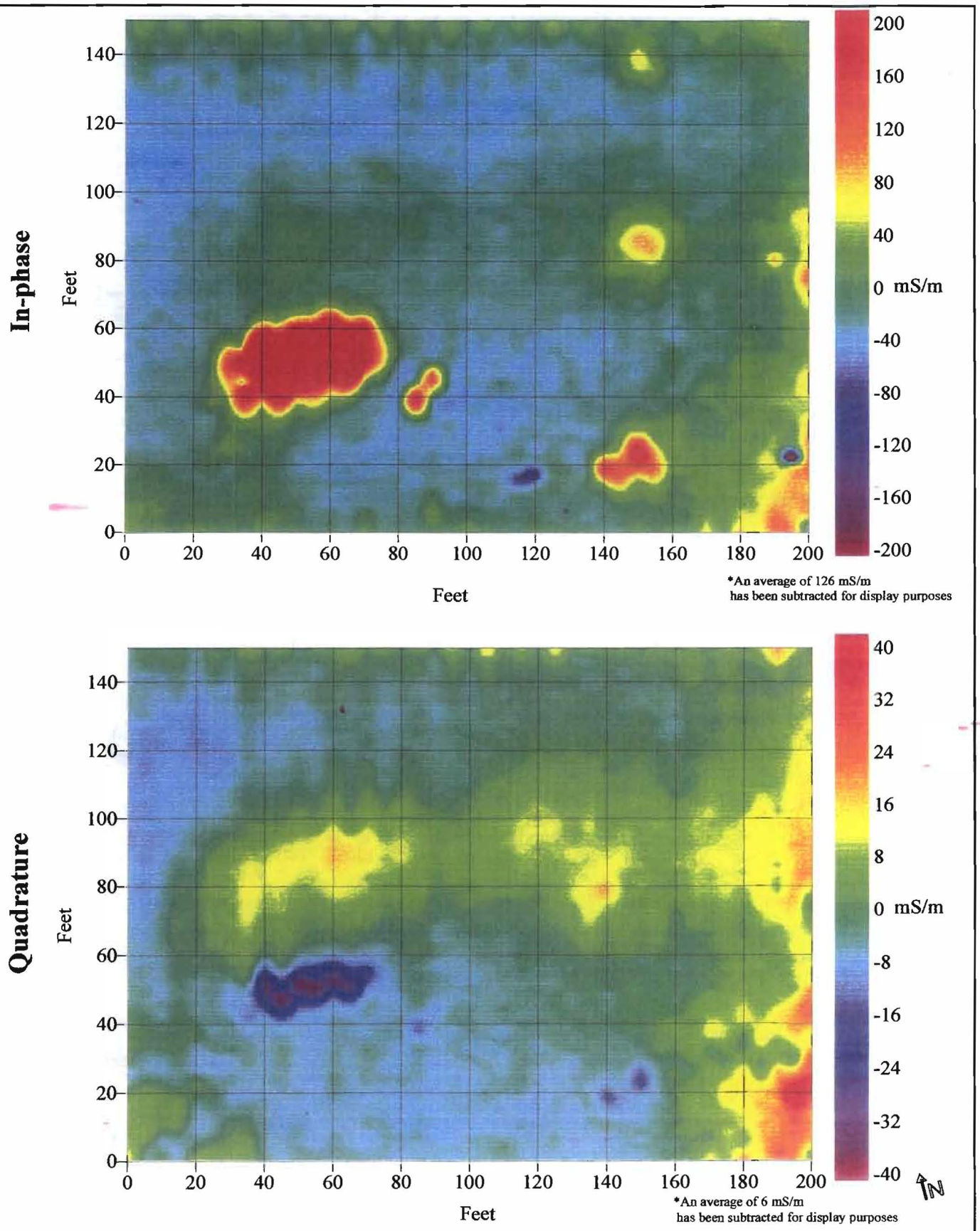

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Figure 5. Electromagnetic (GEM) data for MDA-T; 15,210 Hz.

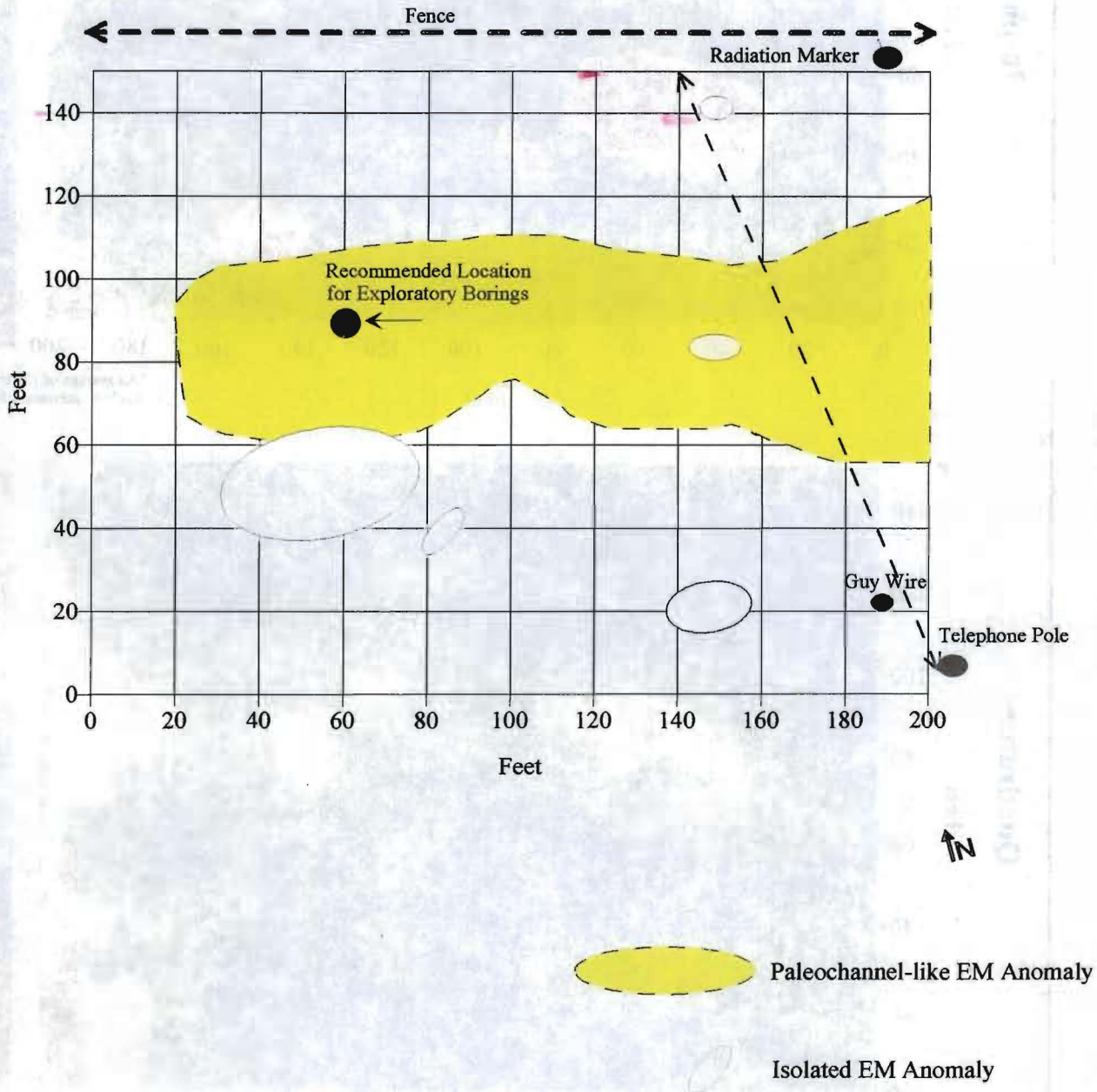

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Figure 6. Interpretation of EM anomalies for MDA-T.

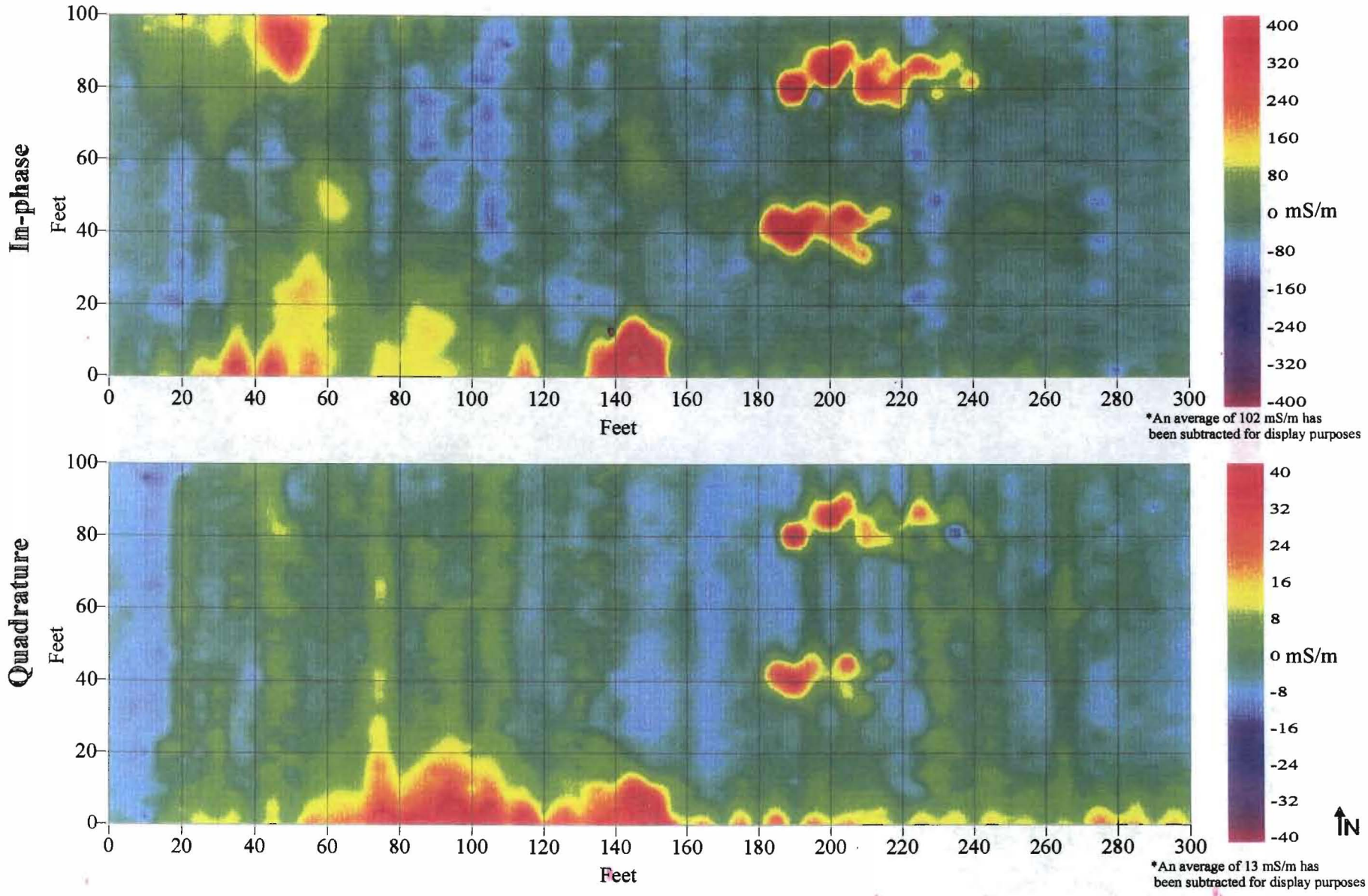

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Figure 7. Electromagnetic (GEM) data for MDA-A; 9,210 Hz.

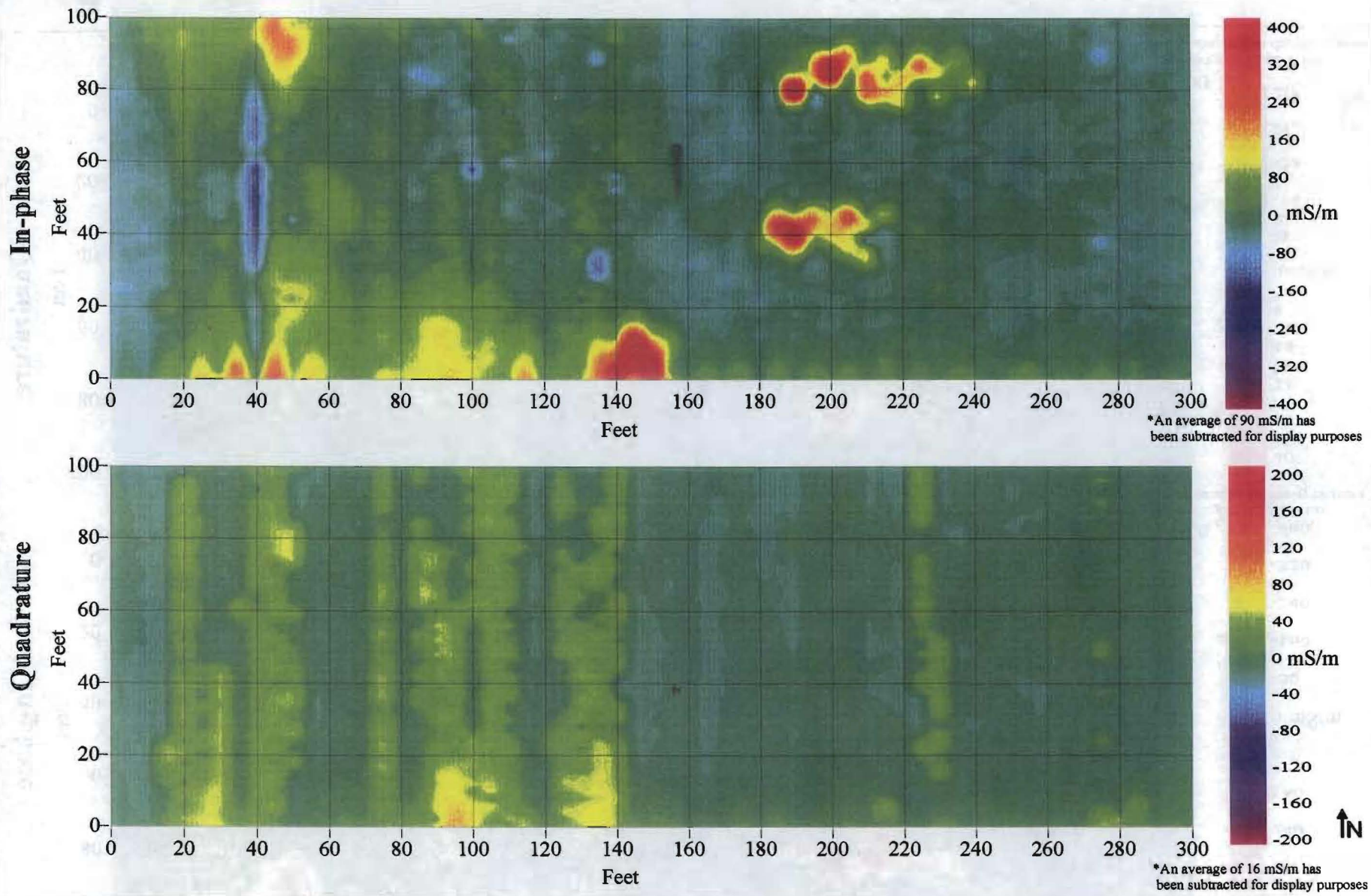

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Figure 8. Electromagnetic (GEM) data for MDA-A; 15,210 Hz.

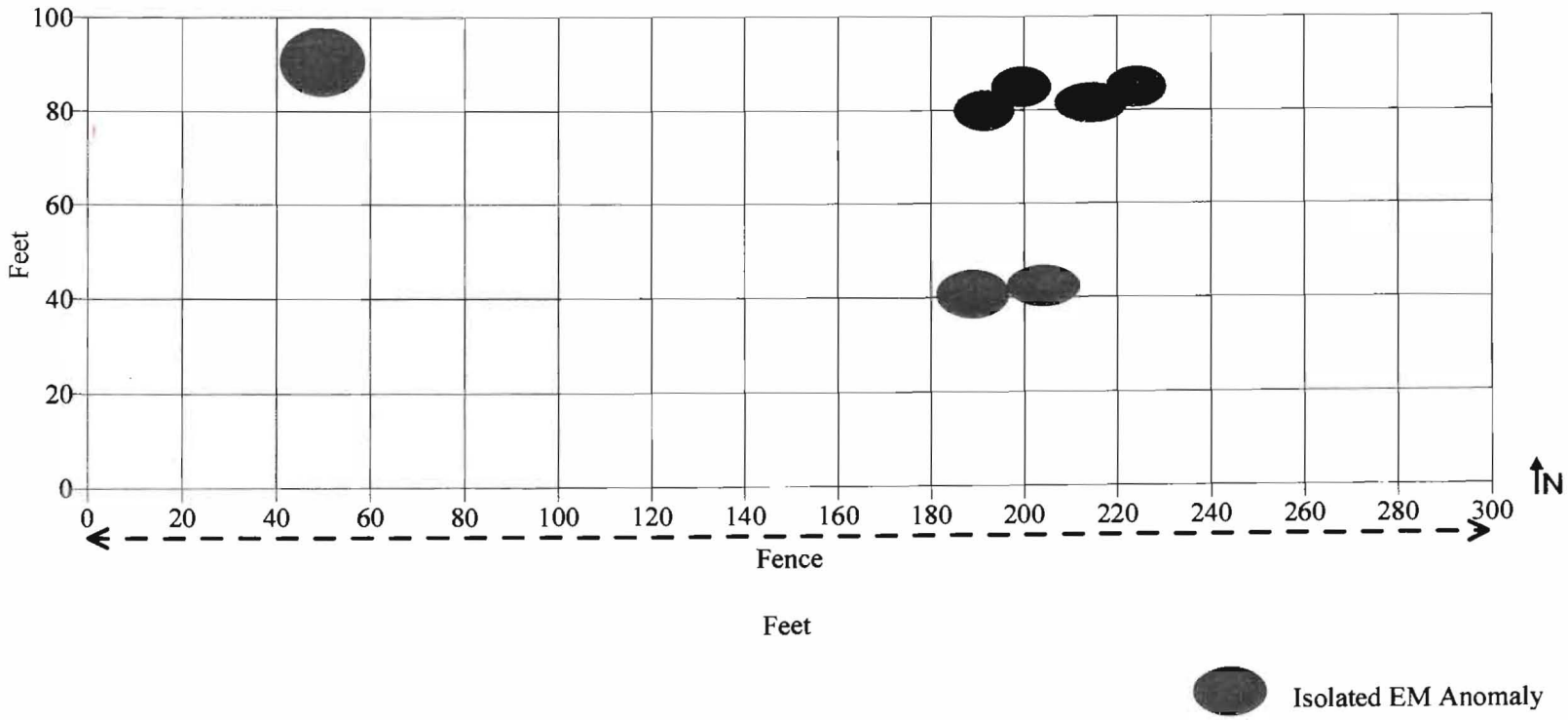

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Figure 9. Interpretation of EM anomalies for MDA-A.

Appendix A

Electromagnetic Method

Appendix A
Electromagnetic Method

The electromagnetic (EM) induction method, which is founded upon Maxwell's Equations (the relationship between electric fields, magnetic fields and electric current), characterizes the electrical conductivity of the subsurface and can be used to characterize shallow geological conditions. Electrical conductivity is an inherent property of a material to conduct electrical current. Variations in shallow earth conductivity can result from changes in soil moisture content, groundwater constituents (contamination), and lithological properties, as well as buried man-made materials. The primary application of EM surveys in site assessments are for:

- Searching for waste pits and trenches,
- Determining boundaries of landfills and other burial sites,
- Delineating leachate plumes,
- Locating buried drums, USTs, and other isolated metallic objects, and
- Detecting buried unexploded ordnance (UXO).

The EM method involves exciting the ground material with a primary, time-varying, electromagnetic field of one or more frequencies, and recording perturbations of the normal field that result from secondary eddy currents induced in conducting bodies at or beneath the surface. The primary field is typically established, in practice, by passing an alternating current through a small coil (i.e., the transmitter coils). The intensity of the induced eddy currents in the subsurface is a function of the ground conductivity and is measured by the receiver coil. The receiver generally consists of one or more coils, suitably arranged and connected to a data logger. Field efficient EM instruments, such as the Geophex Electromagnetic (GEM) sensor (Figure A-1), combine the transmitter, receiver, and processing electronics (data logger) into a single, lightweight, man-portable instrument.

Figure A-1. Photograph of the Geophex Electromagnetic (GEM-2) instrument during a site characterization study.

The primary advantage of electromagnetic induction sensors for detection of shallow man-made targets is that these sensors are sensitive to either ferrous or nonferrous (e.g., aluminum, copper, iron, steel) metals. The electromagnetic induction sensor can be used in conjunction with magnetic surveys for enhanced detection.

Figure A-2, adapted from Won (1980), shows ranges of conductivity for typical earth materials and the relationship between transmitter frequency and the skin depth (i.e., the maximum depth of exploration). In general, sediments and sedimentary rocks have higher conductivity than igneous or metamorphic rocks. Clay, owing to its electrolytic interaction with water, exhibits high conductivity, while typical sand shows relatively low conductivity.

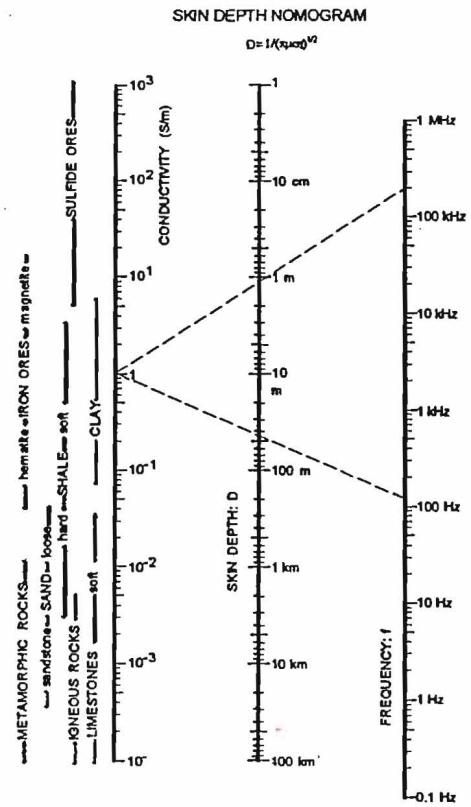

Figure A-2. Nomogram showing the relationship between transmitter frequency, ground conductivity, and depth of penetration. Magnetic permeability, μ, is assumed to be that of the free space. (From Won, 1980. Courtesy: Society of Exploration Geophysicists.)

The electromagnetic induction method can be used to target different depths of interest. The effective depth of exploration can be varied by changing either: 1) the spacing between transmitter and receiver coils, or 2) the frequency of the transmitted field (Patra and Mallick, 1980). The first method is known as *geometrical sounding* and involves recording data using several transmitter-receiver coil spacings at a fixed location; the depth of exploration increases with the coil spacing. The two coils systems (e.g., EM-24 by Geonics), although typically connected by an umbilical cord, are physically separate and thus require two field operators.

The second method is known as *frequency sounding* and involves changing the transmitter frequency, but keeping the transmitter-receiver coil constant (Figure A-3). The depth of exploration is inversely proportional to the square root of the frequency: a low frequency signal travels far through a conductive earth and, thus, sees deep structures, while a high frequency signal can travel only a short distance and, thus, sees only shallow structures. Therefore, broadband parametric sounding is analogous to depth sounding and can be used to create a pseudo 3-D subsurface image (Won, 1983).

Frequency sounding possesses inherent advantages over geometric sounding for depth imaging because: 1) signal attenuation does not allow a signal of fixed frequency to penetrate much deeper than several skin depths, and 2) geometrical sounding averages laterally and thus decreases the resolution. Theoretical and practical discussions on these methods may be found in Grant and West (1965), Keller and Frischkneckt (1966), Kaufman and Keller (1983), and Nabighian (1988).

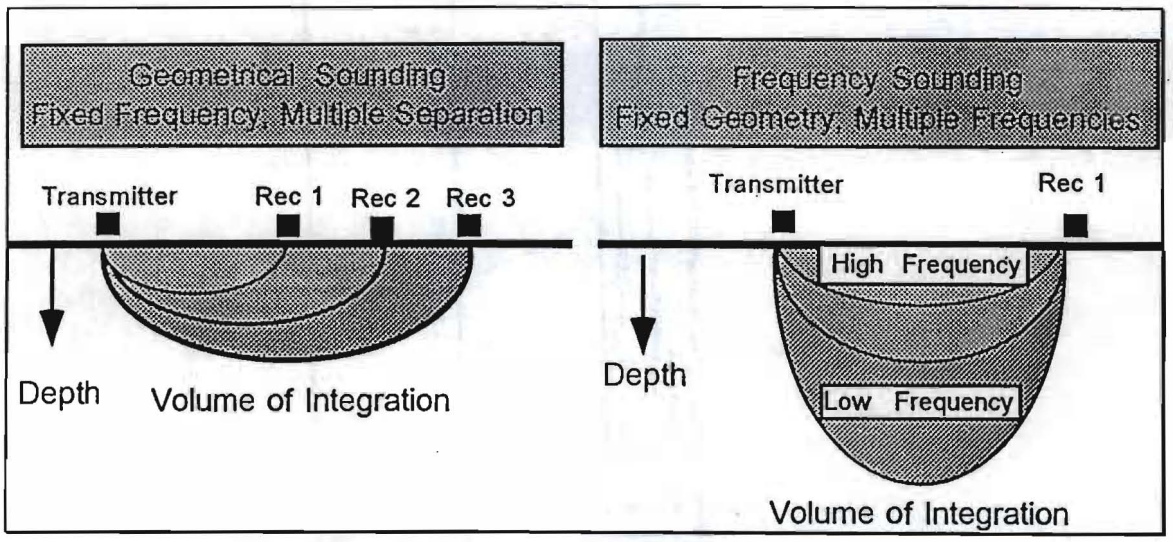

Figure A-3. Electromagnetic methods for depth sounding.

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