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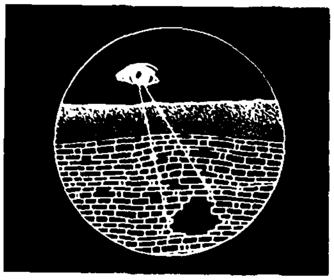

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MISCELLANEOUS PAPER GL-91-6

GEOPHYSICAL SURVEYS FOR LOCATION OF A SUSPECTED ABANDONED MINE OPENING: GRAYS LANDING SITE

by

Dwain K. Butler, Thomas B. Kean II

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March 1991

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13. ABSTRACT *(Maximum 200 words)*

The results of magnetic and electromagnetic surveys at the Grays landing Lock and Dam site on the Monongahela River near Waynesburg, Pennsylvania, are presented. The purpose of the surveys was to locate suspected abandoned mine openings in an area of the left abutment. Extensive subsurface mining of the Pittsburgh Coal has been carried out in this area since the mid-to-late nineteenth century. Old mine maps and records indicate an 1882 drift opening into the Alicia No. 2 Mine in the right abutment area which could be under water during a 100-year flood event. Exploratory drilling in the left abutment has failed to encounter the opening.

The area surveyed in rugged topographically and contains considerable surface metallic debris which represents possible noise sources for the geophysical surveys. While the geophysical survey results are complicated, there are anomalies on both the magnetic and electromagnetic data profiles which are identifiable from one survey line to the next. An integrated geophysical anomaly map is presented. Three anomalous zones are identified which trend into a steep slope. One of these

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anomalous zones is consistent with the suspected location of the 1882 opening. Another anomalous zone may be associated with a concrete-lined drainage channel which is exposed on the riverward side of the slope and disappears into the slope; this anomaly trends toward a more recent, known, sealed mine opening.

Preface

A geophysical investigation of an area of the left abutment of Grays Landing Lock and Dam site was authorized by the US Army Engineer District, Pittsburgh (CEORP), under MIPR No. CEORP-ED-90-48, dated 31 July 1990. The work was performed during the period October-November 1990.

Mr. Thomas B. Kean II and Dr. Dwain K. Butler, Engineering Geophysics Branch (EGB), Earthquake Engineering and Geosciences Division (EEGD), Geotechnical Laboratory (GL), US Army Engineer Waterways Experiment Station (WES), conducted the field investigations with the assistance of Mr. Gary D'Urso, Pittsburgh District. Messrs. Brian Greene and James Brown were the District's points of contact for the work. This work was performed under the general supervision of Mr. Joseph R. Curro, Jr., Chief, EGB, Dr. Arley G. Franklin, Chief, EEGD, and Dr. William F. Marcuson III, Chief, GL. This report was prepared by Dr. Butler.

COL Larry B. Fulton, EN, was Commander and Director of WES during the publication of this report. Dr. Robert W. Whalin was Technical Director.

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Conversion Factors, Non-SI to SI (Metric) Units of Measurements

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	BY	To Obtain
feet	0.3048	metres

GEOPHYSICAL SURVEYS FOR LOCATION OF A SUSPECTED ABANDONED MINE OPENING: GRAYS LANDING SITE

Background

1. The Pittsburgh District, US Army Corps of Engineers, is constructing a lock and dam at a site known as Grays Landing on the Monongahela River. Old mine records indicate openings to access drift mining operations in the valley slope of the left abutment side of the project. There are some indications that an 1882 mine opening (Alicia No. 2 Mine) accessed the Pittsburgh coal seam (approximately 9 ft* thick) in the left abutment area, and, if it existed, may not have been sealed. Since the suspected mine opening might be below the 100 year frequency flood pool level, it is important to verify its existence. An extensive exploratory drilling program has failed to definitively locate the 1882 opening, although at least one boring encountered a void due to mined out coal. The present geophysical investigations were conducted by personnel from the US Army Engineer Waterways Experiment Station (WES), with the assistance of District personnel, to locate the suspected 1882 drift opening. This report gives guidance for location of exploratory borings or trenches to verify the suspected opening location.

Geophysical Survey Program

2. Geophysical survey lines established in the left abutment area specified by District personnel are shown in Figure 1a. Various site features are also indicated in Figure 1a, including approximate locations for the sealed mine opening and the suspected 1882 mine opening. MS-23 and MS-24 are existing exploratory borings. The survey line locations were determined

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*A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 3.

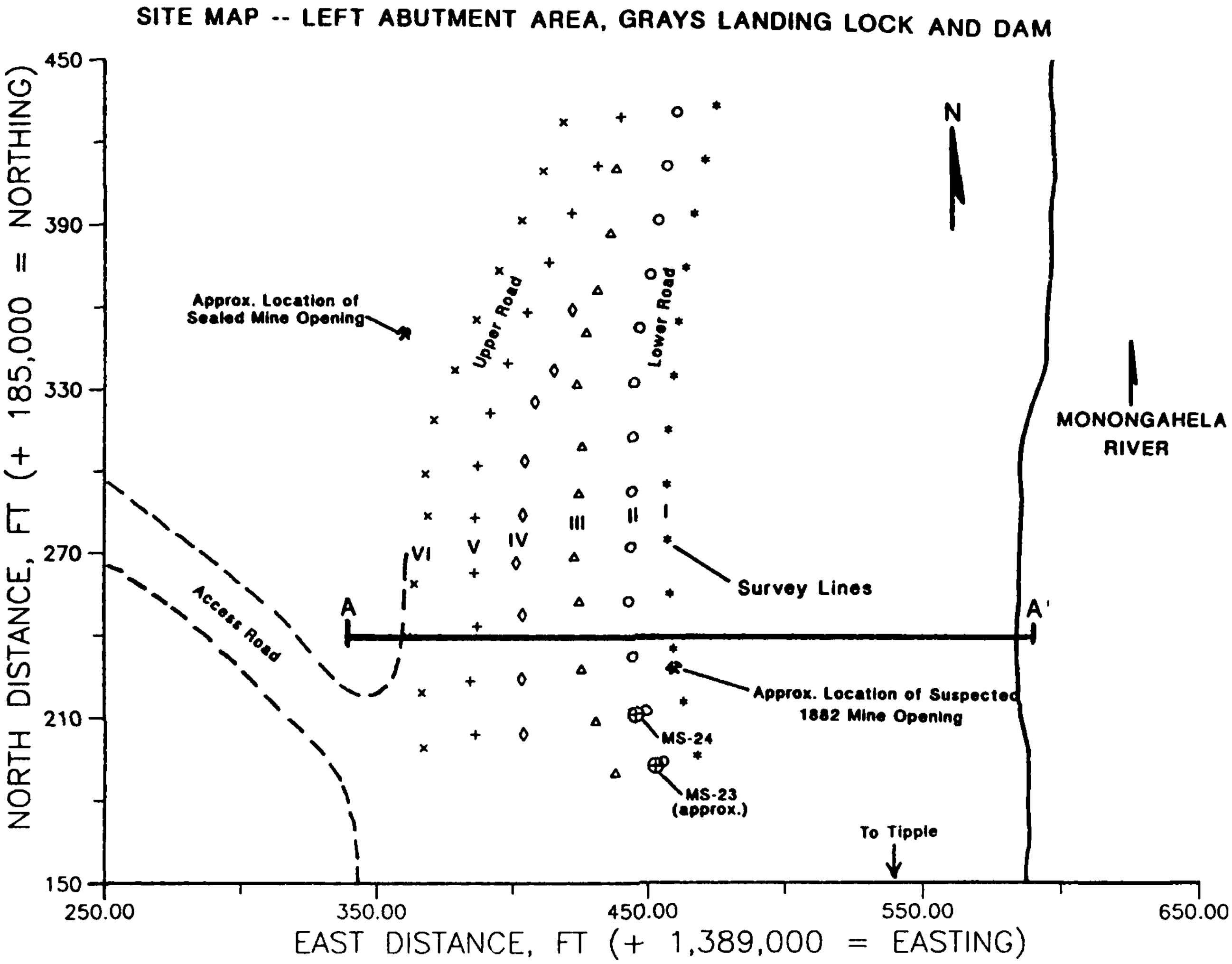


Figure 1a. Geophysical survey site map. Roman Numerals indicate geophysical survey lines. Symbols along survey lines indicate flagged locations.

Figure 1. Geophysical survey site map and cross-section. (Continued)

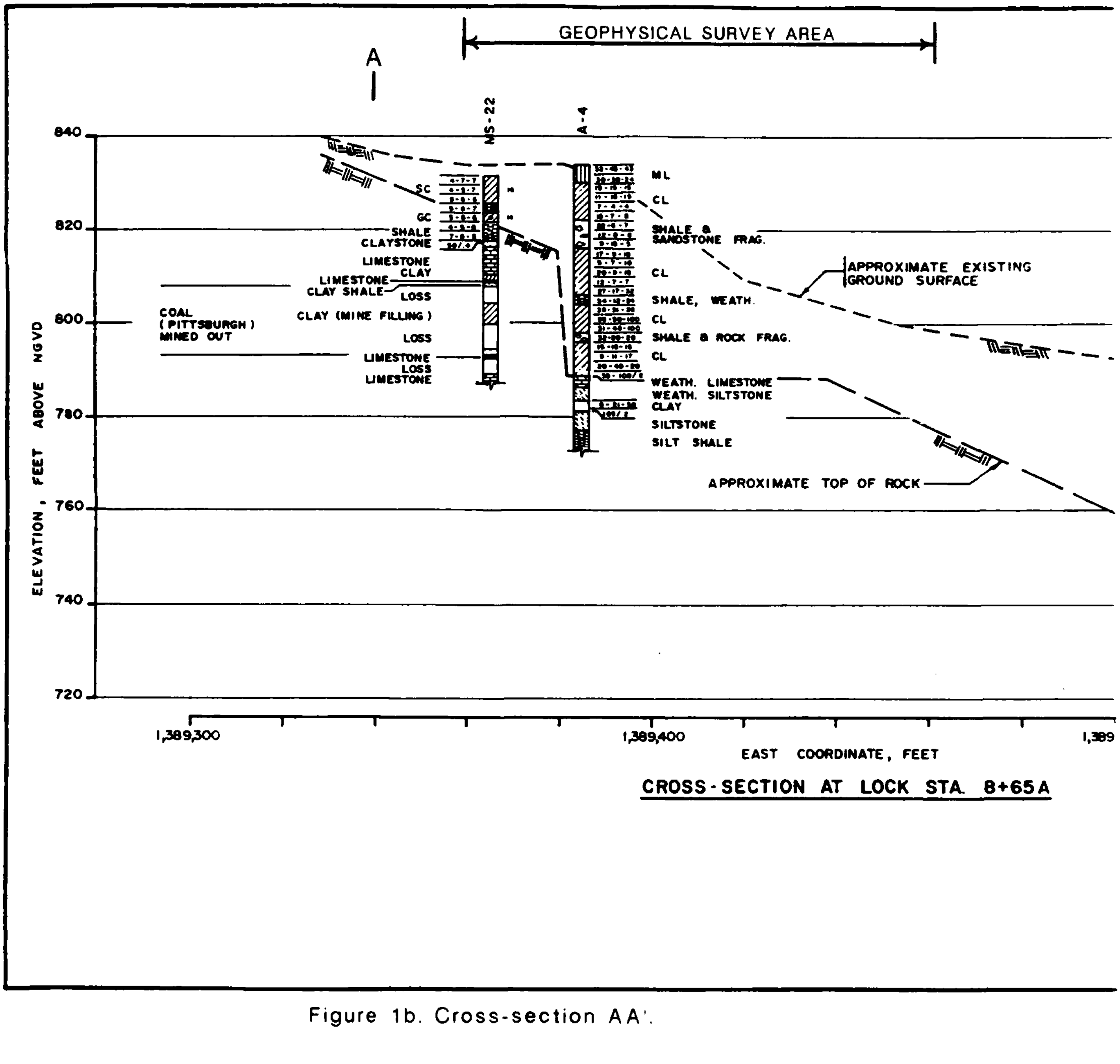
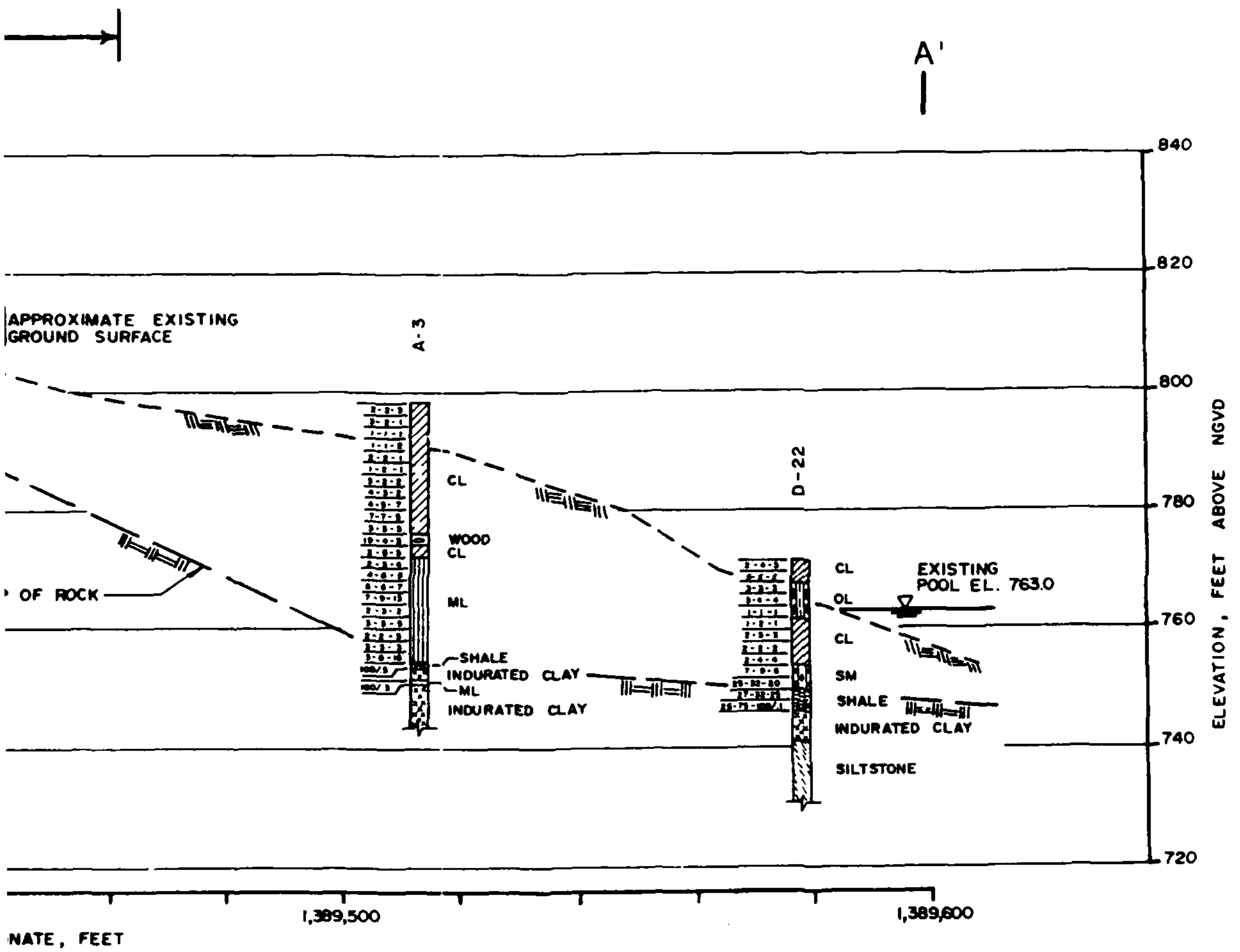


Figure 1b. Cross-section AA'.

Figure 1. Geophysical survey site map and cross-section. (Concluded)



LOCK STA. 8+65A

LEGEND

ORBITAL ENGINEERING, INC. PITTSBURGH • CHICAGO • CLEVELAND • PHILADELPHIA	
MONONGAHELA RIVER, PA. GRAYS LANDING LOCK AND DAM EVALUATION OF LEFT BANK (ABUTMENT SIDE) MINE SEAL AND CUT SLOPE REQUIREMENTS CROSS SECTION AT LOCK STA. 8+65A	
PROJ. NO.: E-3318	FIGURE 7

ed)

by a Pittsburgh District survey team, the approximate mine opening locations were obtained from "Evaluation of Left Bank (Abutment Side) Mine Seal and Cut Slope Requirements," Appendix D of Design Memorandum No.4, Feature Design Memorandum, Grays Landing Lock and Dam*, and other site features were obtained from a Borings Plan/Topographic Map provided by District personnel. Figure 1b is a cross-section from the above reference along cross-section AA' in Figure 1a. The individual survey lines are identified in Figures 1a and 2 by Roman Numerals.

3. The survey lines were located by the geophysical survey team and flagged at 20 ft intervals; flagged locations are indicated in Figures 1 and 2 by different symbols for each line. Geophysical measurements along lines I, II, V, and VI were obtained at 10 ft intervals, where points between flags were located by pacing. Lines I and II and lines V and VI are located along the sides of the Lower Road and the Upper Road, respectively, as indicated in Figure 1a. Measurements along lines III and IV, located on a steep slope, were obtained at 20 ft intervals. The following tabulation summarizes the geophysical surveys conducted at the site and gives approximate or "rule of thumb" depths of investigation:

Line	Survey Method/Equipment	Approximate Depth of Investigation
I-VI	Magnetic	< 100 ft**
I-VI	Electromagnetic (EM-31)	< 18 ft
I/II V/VI	Electromagnetic (EM-34) (Horizontal Dipole)	< 25 ft
I/II V/VI	Electromagnetic (EM-34) (Vertical Dipole)	< 50 ft

*Orbital Engineering, Inc., October 1987, Prepared for US Army Corps of Engineers, Pittsburgh District.

**This is a practical limit on depth of investigation due to the length of the survey lines and not a physical limitation of the magnetic method itself.

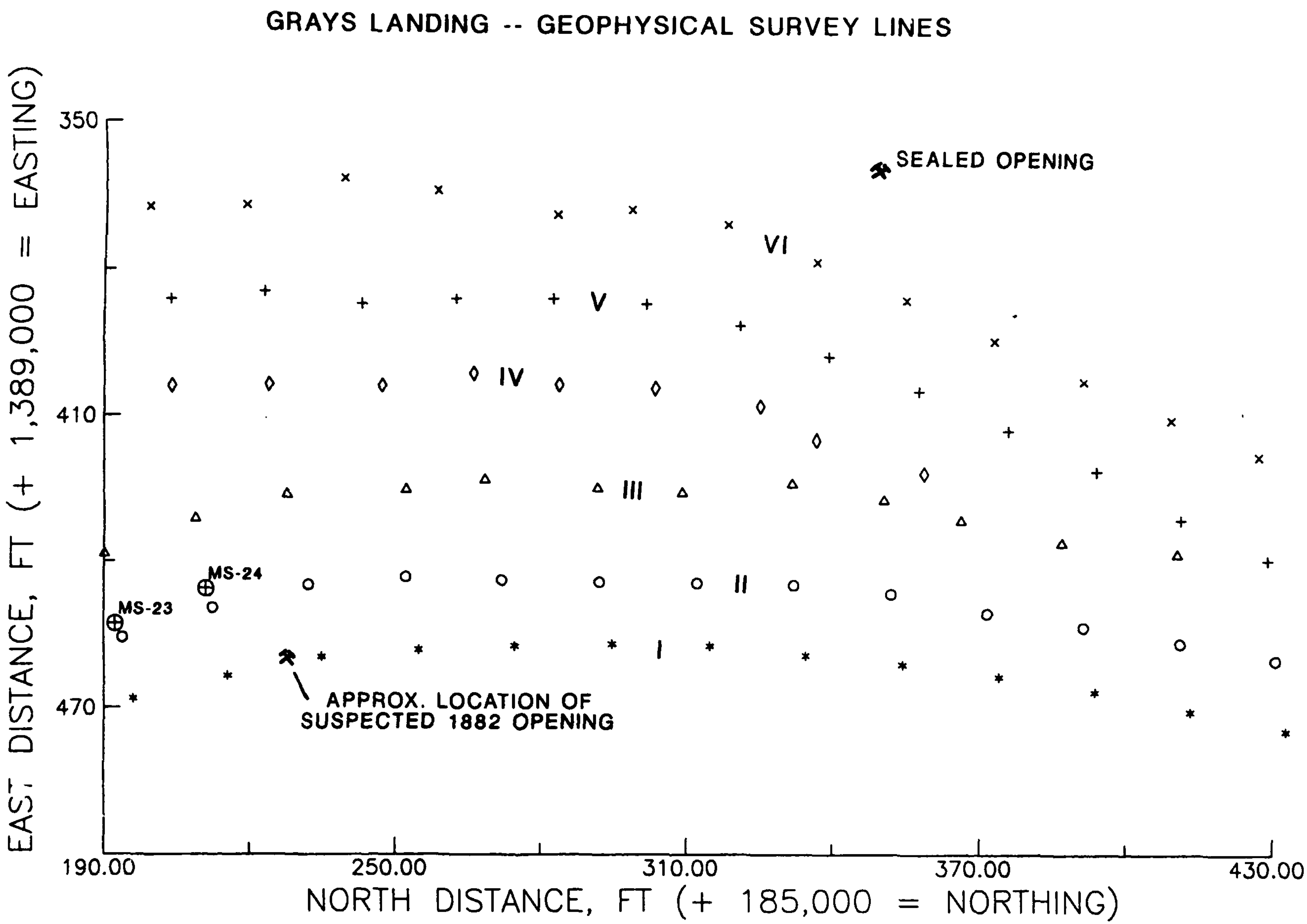


Figure 2. Geophysical survey lines, designated by Roman Numerals. Different symbols for each survey line designate flagged locations at 20 ft spacing

The designation I/II and V/VI for the EM-34 surveys indicates that the actual measurements were acquired along the Lower Road midway between lines I and II and along the Upper Road midway between lines V and VI, respectively.

4. Magnetic field measurements were made with an EDA Omni IV proton precession magnetometer. The magnetometer measures the total earth's magnetic field strength in nanoteslas (nt). For reference, the earth's total magnetic field strength at the site is approximately 55,000 nt. Electromagnetic surveys were conducted with the Geonics EM-31 and EM-34 instruments. The EM-31 is a one-man portable instrument with transmitter and receiver coils separated by 3.66 m (12 ft) in a fiber glass boom; the instrument operates at 9.8 Khz. The EM-34 is a two-man portable instrument with separable transmitter and receiver coils. Standard coil spacings for the EM-34 are 10, 20 and 40 m (approximately 33, 66 and 131 ft). Only the 10 m (33 ft) spacing was used for the present work; the operating frequency at 10 m coil spacing is 6.4 Khz. With the EM-34, measurements were made at each location with the coils horizontal, coplanar (called the vertical dipole mode), and with the coils vertical, coplanar (called the horizontal dipole mode). The EM instruments measure an apparent electrical conductivity (= 1/resistivity) of the subsurface in millisiemen/meter (mS/m).

Geophysical Anomalies

5. The strategy of the geophysical surveys is to detect anomalies relative to background which may indicate the presence of abandoned mine openings. The type of geophysical anomaly represented by the opening and access drift will vary depending on its present condition, i.e., the nature and extent of the filling material. It is likely that the access drift will contain metallic debris, perhaps even rails going into the old mine workings. It is unlikely that the access drift is completely filled. The filling material is likely soil, rock fragments, and assorted wood and metal debris, which may have

higher water content than surrounding rock. The combination of metallic debris and higher water content will result in high magnetic and high conductivity anomalies for the filled portion of the access drift relative to the surrounding undisturbed soil and rock. For the case of metallic debris in an otherwise unfilled access drift, there will still be a high magnetic anomaly; but, depending on the amount and depth of metal, there may or may not be a discernible conductivity anomaly. In any event, for the geological conditions at the site, magnetic anomalies can be considered to be due to buried or exposed metallic objects.

6. The site presents considerable complications to the application and interpretation of geophysical surveys. There is considerable topographic variation in the survey area. Magnetic surveys are not particularly affected by topography, but the electromagnetic methods can be significantly affected. The EM-34 in the horizontal dipole mode is particularly sensitive to topography and very near surface variations. Topographic sensitivity also depends on the coil orientation relative to the topographic variations. The EM-31 boom and the EM-34 coils are oriented along the survey lines, approximately parallel to topographic contours, for all measurements at this site. Another complication of the site is the presence of surface metallic debris that can affect both magnetic and electromagnetic measurements.

Survey Results

7. Data for survey lines I, II, V, and VI are presented in Figures 3-10. The data are plotted versus distance measured along the line during the geophysical surveys; layout of the lines in plan is shown in Figures 1 and 2. Data for lines III and IV are not shown as profile plots due to the larger measurement spacing and shorter line lengths; the data were utilized in plan maps used to construct geophysical anomaly maps discussed below. Note that the EM-34 data (10 m coil spacing) for lines I

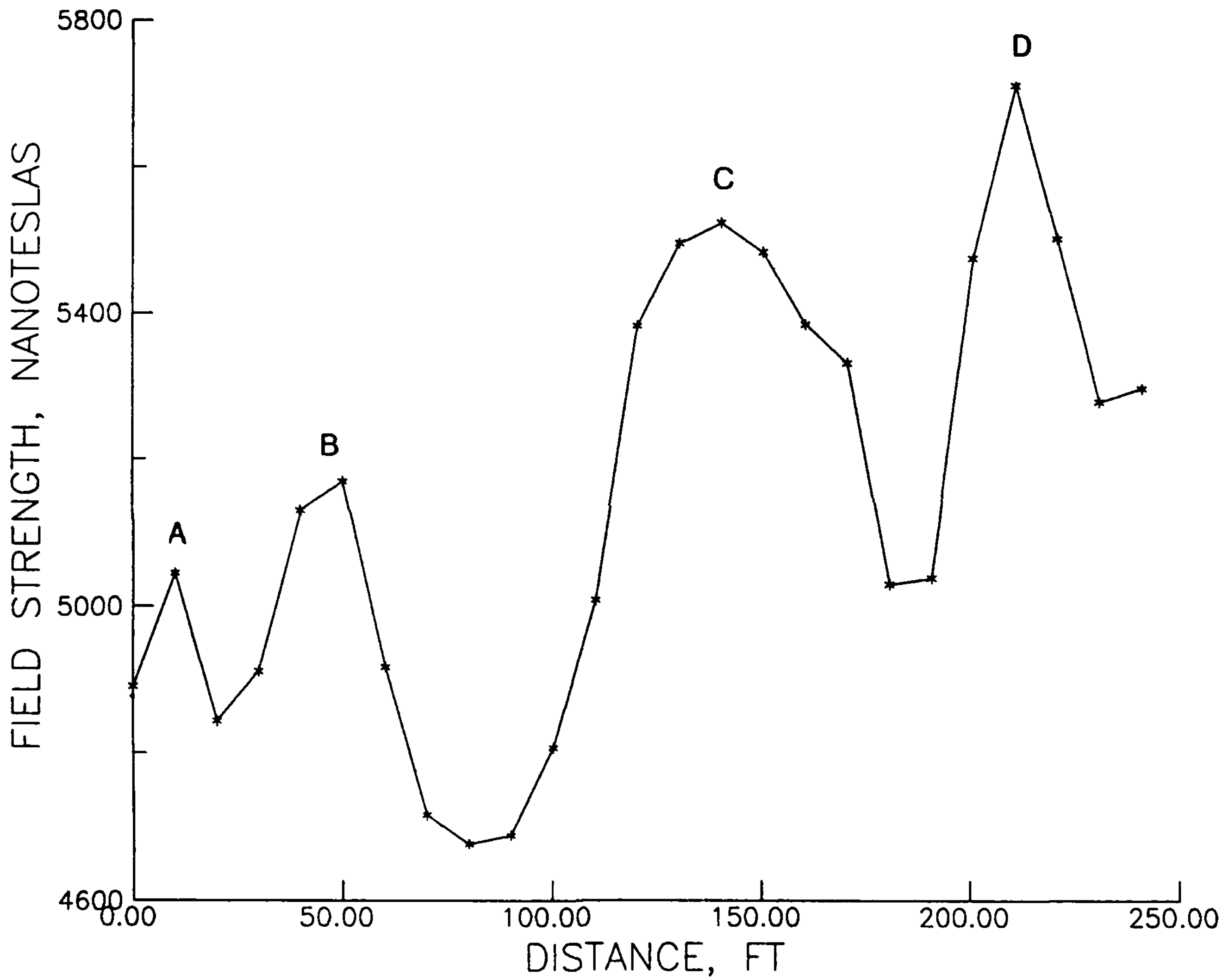


Figure 3. Magnetic survey data, line I

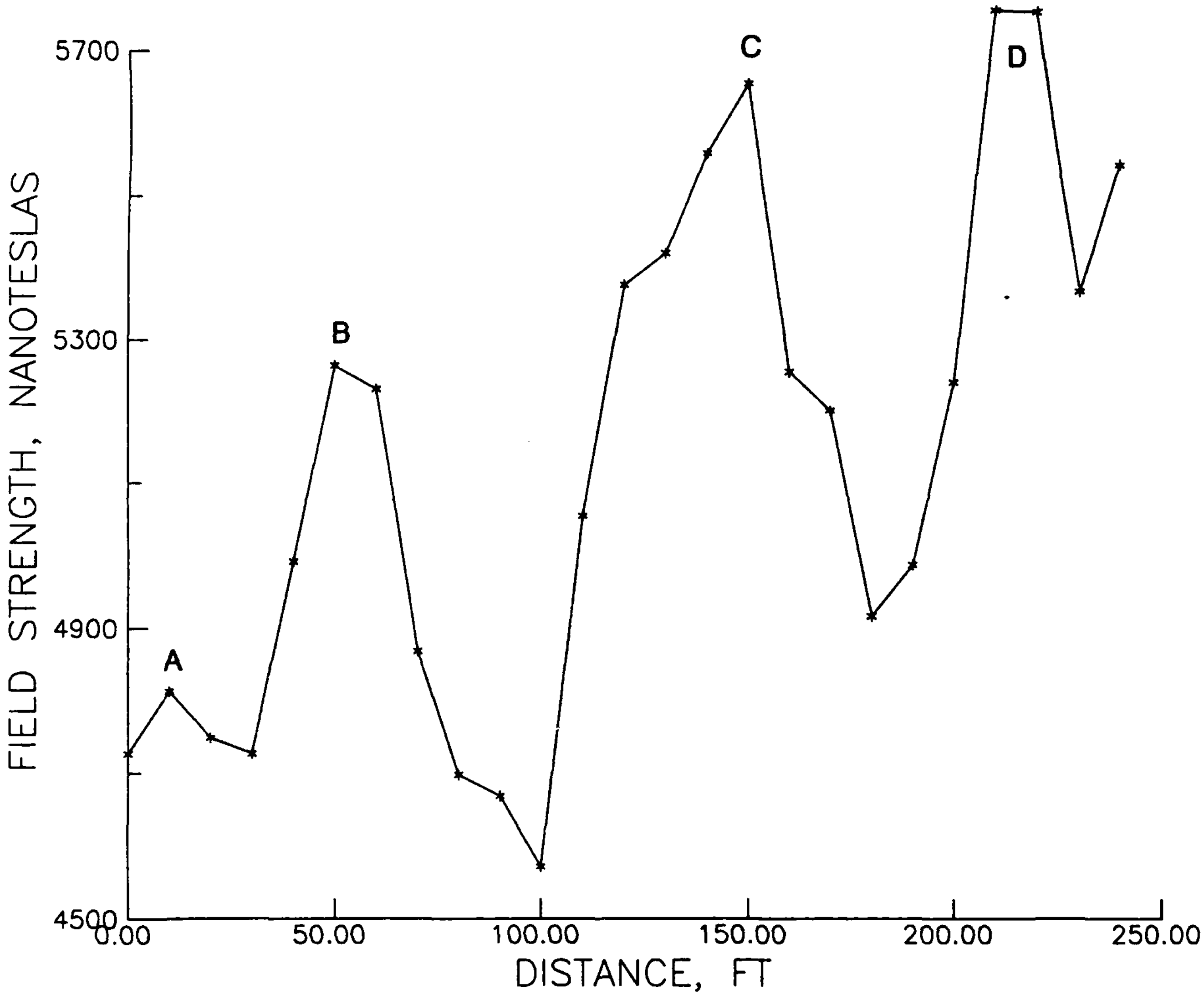


Figure 4. Magnetic survey data, line II

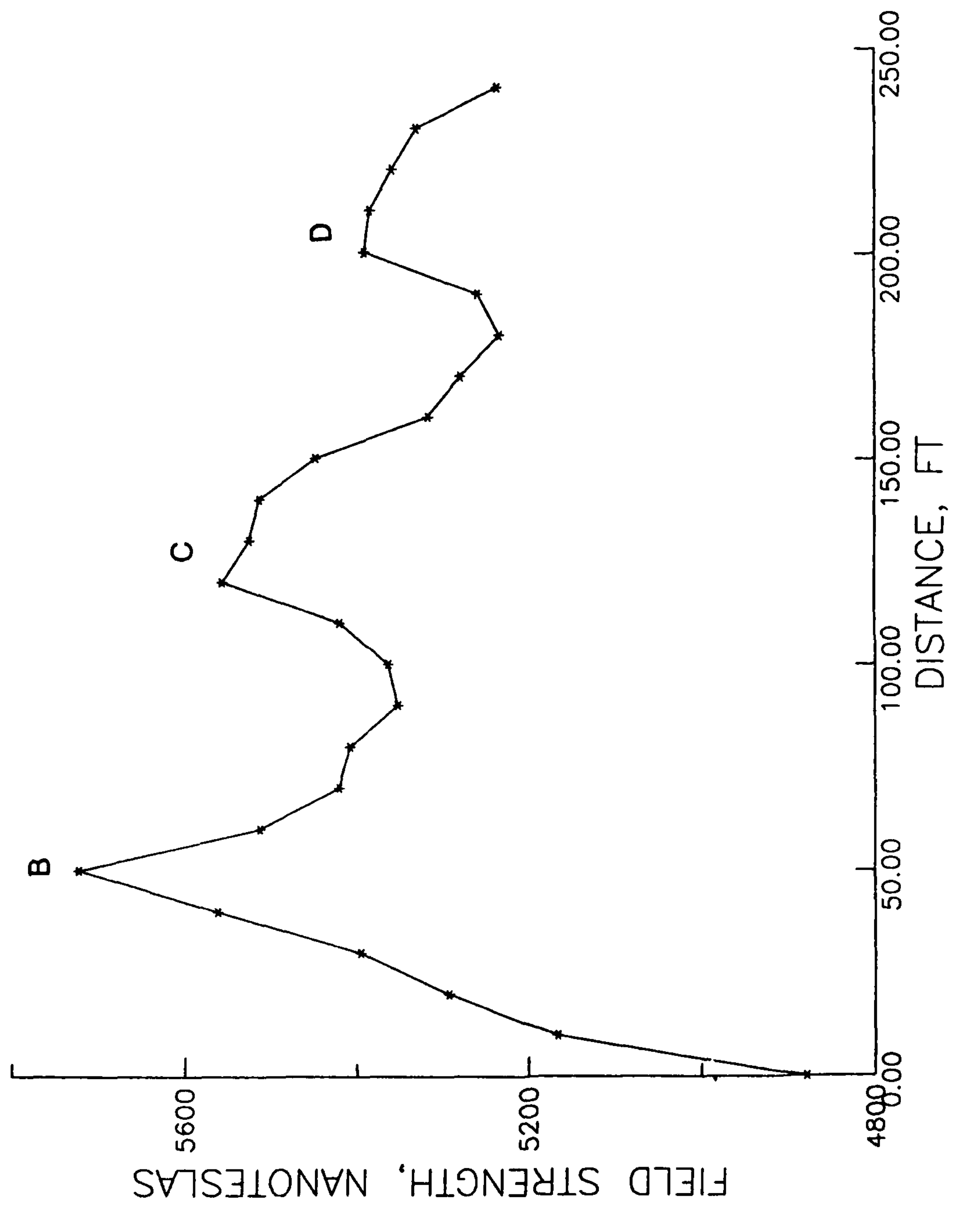


Figure 5. Magnetic survey data, line V

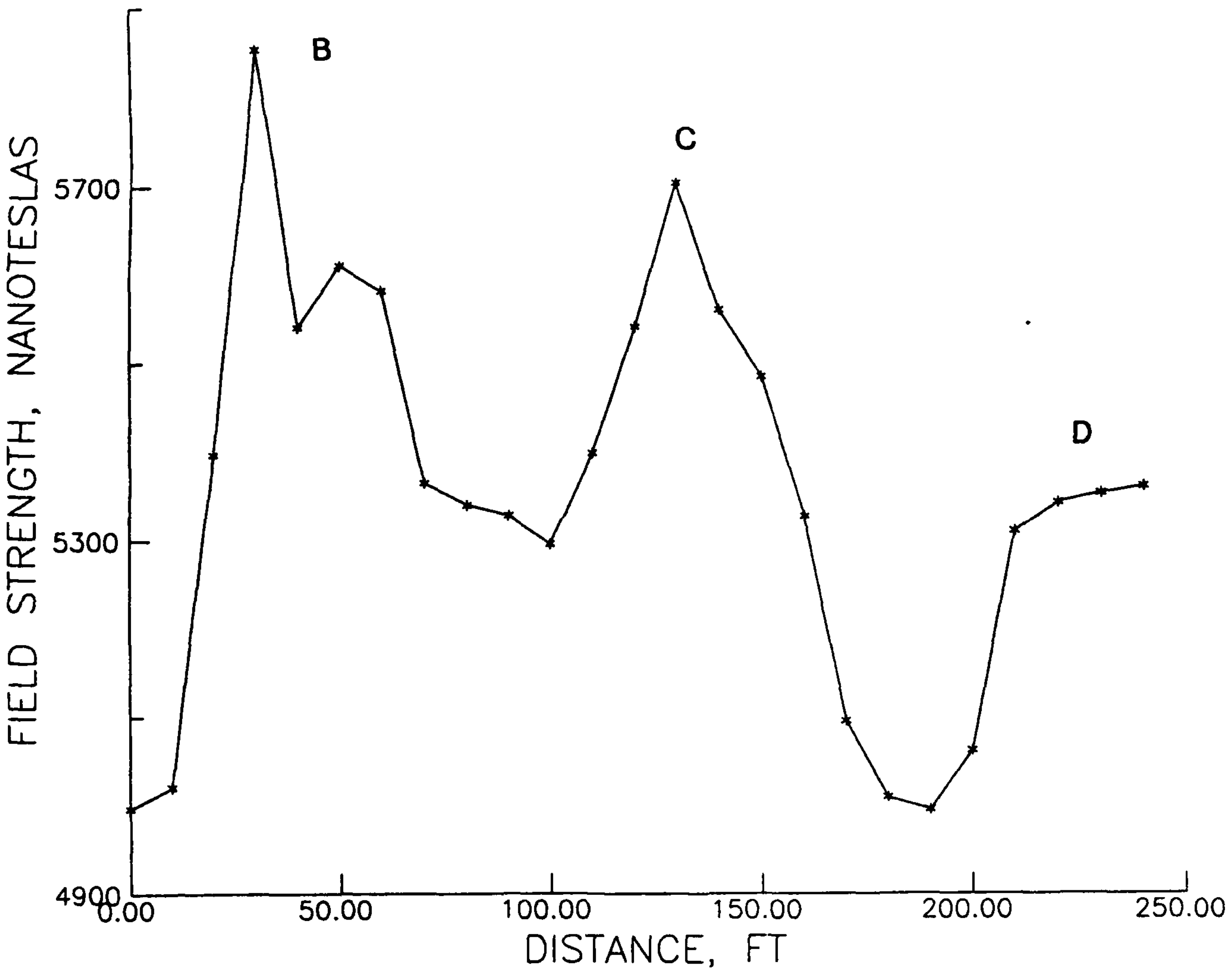


Figure 6. Magnetic survey data, line VI

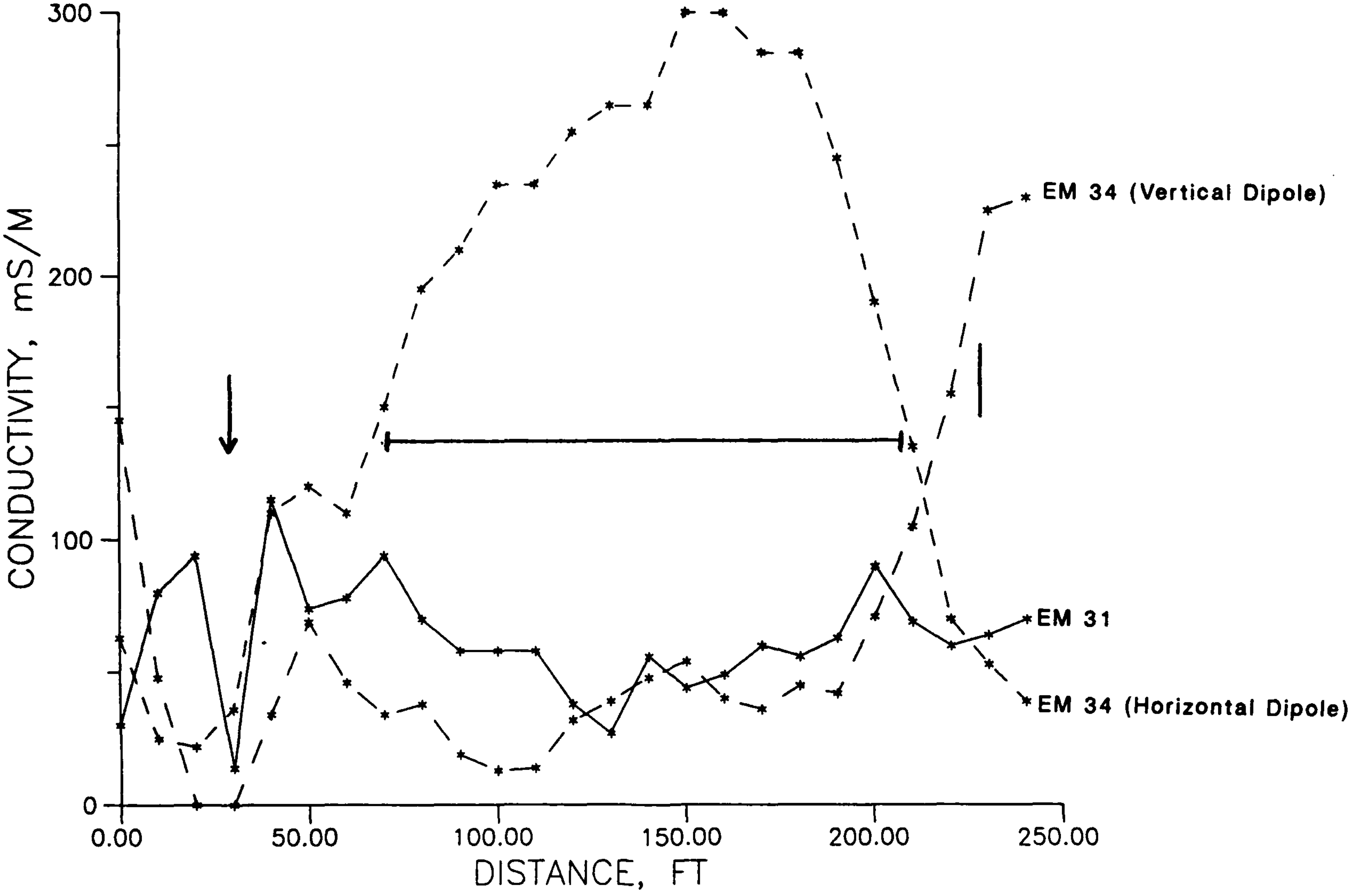


Figure 7. Electromagnetic survey data, line I

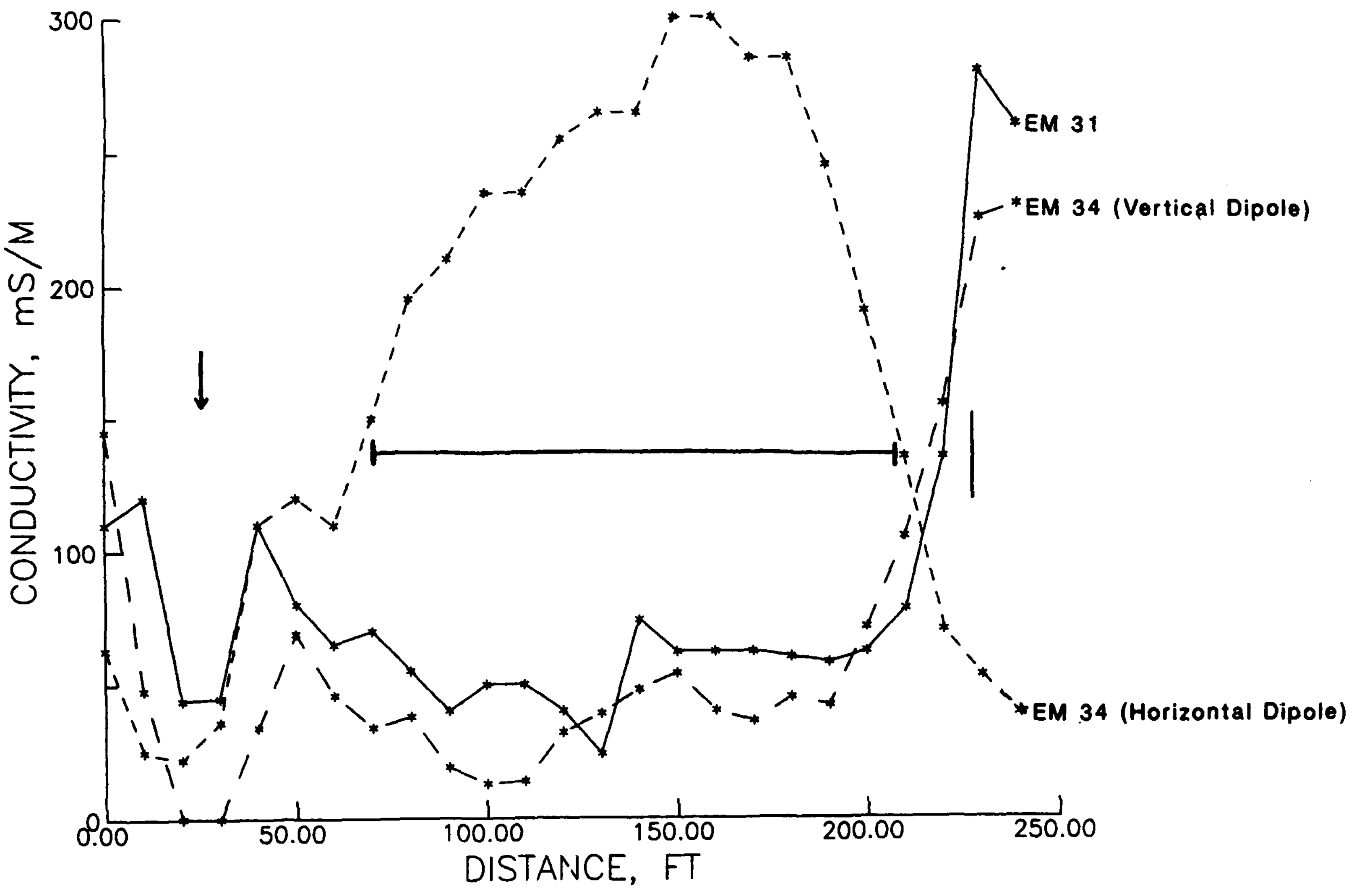


Figure 8. Electromagnetic survey data, line II

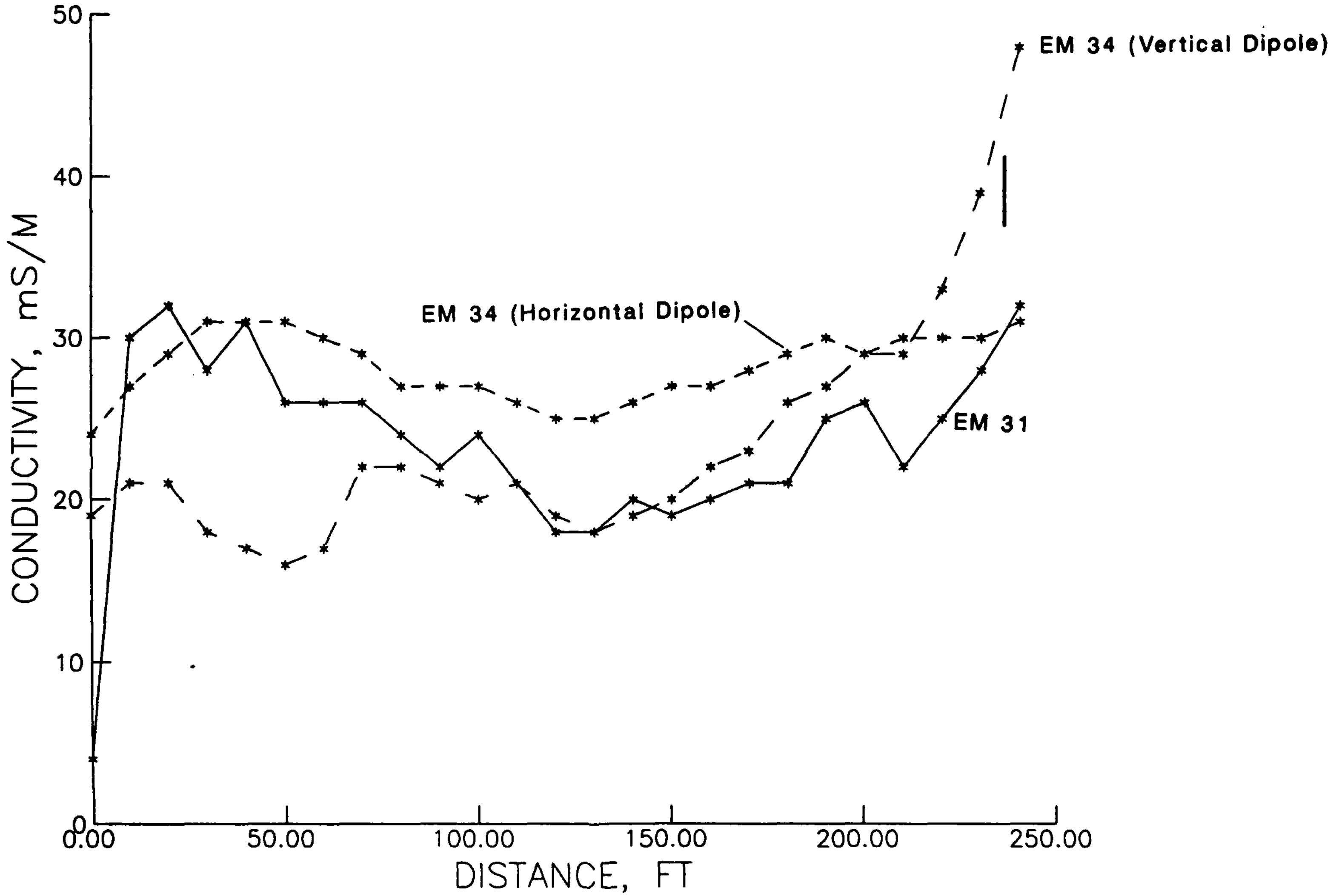


Figure 9. Electromagnetic survey data, line V

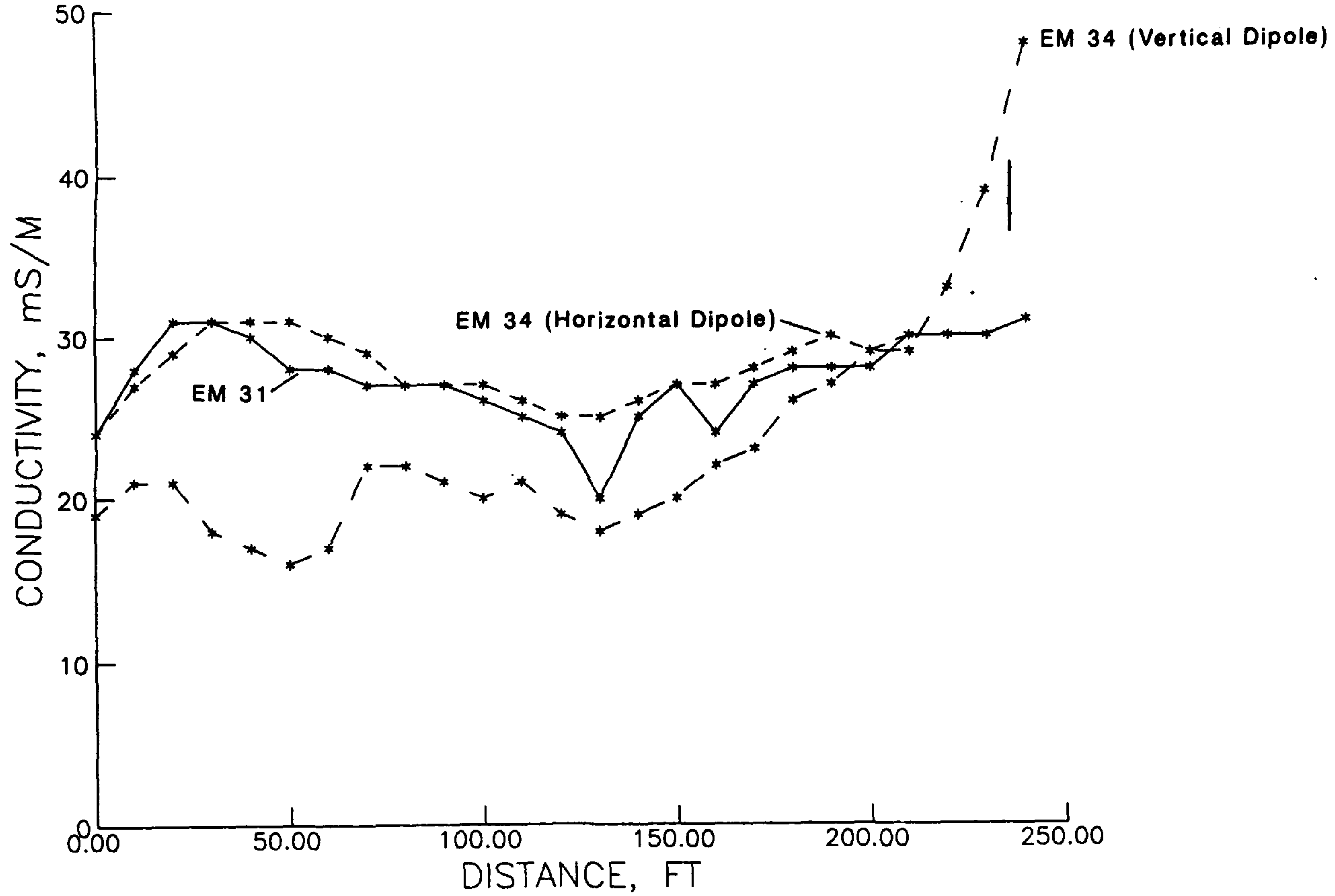


Figure 10. Electromagnetic survey data, line VI

and II and for lines V and VI are identical, since the EM-34 surveys were conducted midway between lines I and II and between lines V and VI. The magnetic and electromagnetic survey results will be discussed separately, and then an integrated anomaly map presented.

Magnetic survey results

8. Variation of the magnetic field strength with time, during the survey, was negligible. The field strength values in Figures 3-6 are the measured total magnetic field strengths minus 50,000 nT. Results of the magnetic survey exhibit significant variation along each of the survey lines. Due to their close proximity, lines I and II are qualitatively similar with regard to number and location of maxima and minima. Likewise, lines V and VI are qualitatively similar. There is also some qualitative similarity between the two sets of survey lines; this similarity is indicated in Figures 3-6 by letter labels assigned to the major profile maxima. It appears that the features causing the magnetic anomalies are elongated and pass under the survey lines more or less perpendicular to the lines, consistent with the suspected drift access into the abandoned mine. The qualitative similarity of the anomalies on the four survey lines insures that the anomalies are caused by subsurface metallic features and not scattered surface metallic debris. One qualitative difference between the two sets of magnetic survey data is that overall the magnetic field strength for survey lines I and II increases with increasing distance along the profile line while the data for lines V and VI decrease with increasing distance. This qualitative difference may be due somehow to the fact that the surface elevation increases with distance along I and II but decreases with distance along V and VI.

9. The numerous maxima and minima along the relatively short survey lines present an interpretation problem, since the anomalies overlap. Depending on the depth, orientation and shape of the object causing the magnetic anomaly, the actual profile locations of object "centers" can vary from directly under the

anomaly maxima to a location under the point of maximum rate of change (slope) (approximately midway) between a maximum and the adjacent minimum located to the north. Closely spaced, subsurface metallic objects produce magnetic anomalies which overlap, and thus the individual magnetic anomalies cannot be observed completely. Anomaly locations are specified in such a way, i.e., in bands, that this range of possibilities is included; this fact must be remembered when locating boreholes or excavations. Figure 11 is the magnetic anomaly location map, where anomaly bands are indicated and labeled to correspond to anomalies identified in Figures 3-6. Within the bands, locations of the anomaly maxima and points of maximum slope are indicated.

Electromagnetic survey results

10. The electromagnetic survey results, Figures 7-10, do not have the large, nearly periodic sequences of maxima and minima exhibited by the magnetic field data. Figures 7 and 8 show a large, broad response for the horizontal dipole EM 34 response (indicated by the horizontal bar in the figures); this response, which is not as evident (if at all) in Figures 9 and 10, is considered to be due to topographic effects on the data (sharp dropoff on one side and steep slope on the other side of the survey line). There is no evidence to support such a large conductivity value, since both the EM 31 and the vertical dipole EM 34 data consistently show much lower conductivity in this region of the survey line. All of the data in Figures 7 and 8 are consistent in exhibiting the anomaly indicated by the arrow; the anomaly has the classic appearance (maximum, minimum, maximum) produced by crossing a very conductive object, even tending to become negative directly over the object. The object causing this anomaly (at the arrow) is shallow (less than 18 ft, since it produces such a prominent effect on the EM 31 response) and must be large in size and possess a high conductivity (since the effect on the EM 34 is significant and the conductivity measurements tend to go negative). A high conductivity anomaly is present near the 240 ft profile position (indicated by the

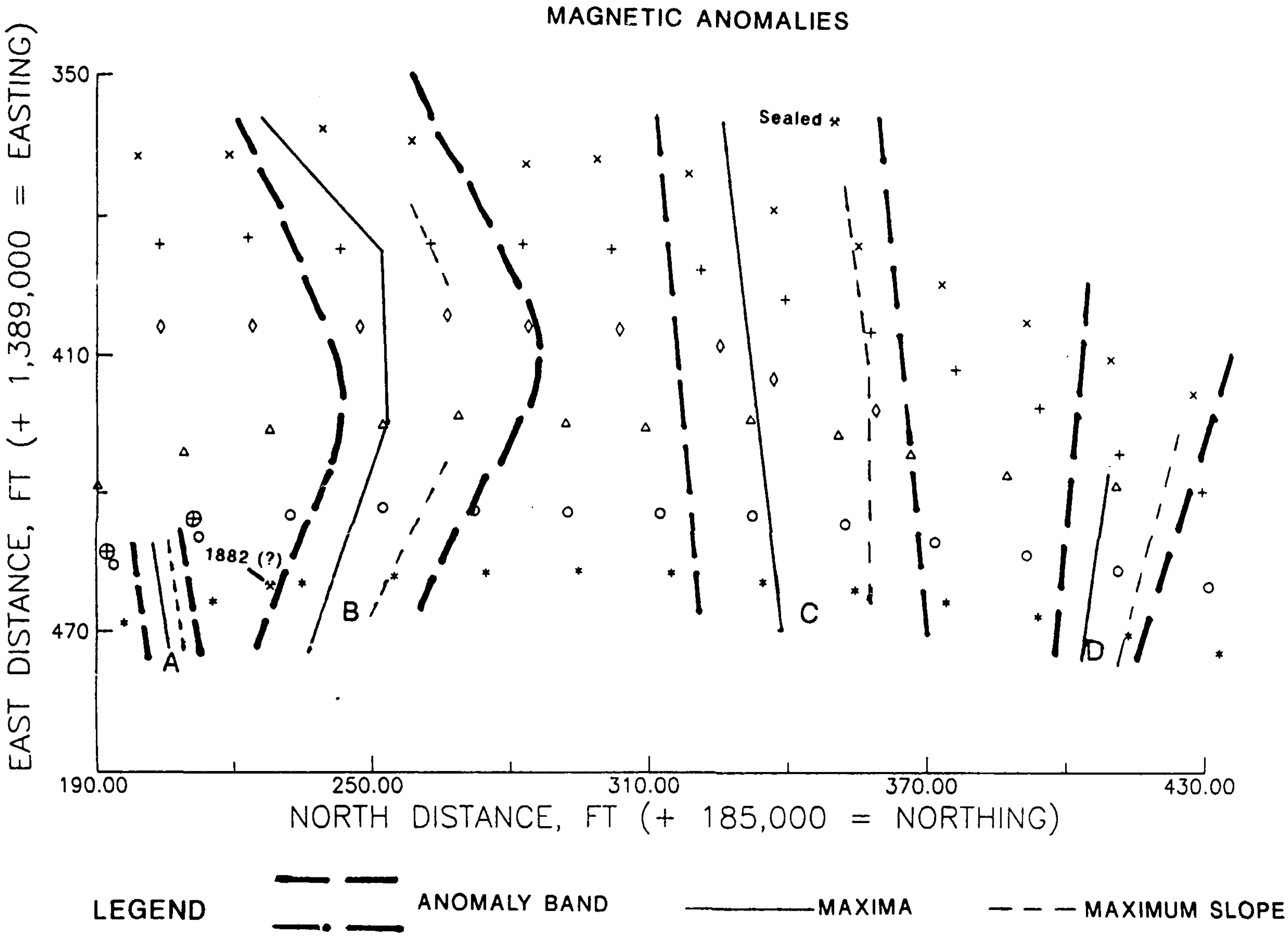


Figure 11. Magnetic anomaly map

vertical line) in Figures 7-10; in Figures 7 and 10, the anomaly is indicated by the vertical dipole EM 34 data but not obviously by the EM 31 data, while in Figures 8 and 9, the anomaly is indicated by both the EM 31 and the vertical dipole EM 34 data. Figure 12 indicates anomalous areas in plan from an analysis of the electromagnetic data.

Integrated Anomaly Map and Assessment

11. Figure 13 is an integrated anomaly map. The three anomaly areas indicated represent an integration of the results of the magnetic and electromagnetic results. The anomalies are defined by magnetic and electromagnetic highs; thus the anomalies are caused by subsurface features which contain metallic debris or structures and material that is otherwise electrically conductive. Anomaly area I is located appropriately to be associated with the suspected 1882 opening, which is indicated on the figure. Anomaly I has a complex structure but may just indicate a large, former opening into the slope which narrowed to a smaller adit accessing the interior of the mine. Anomaly I also correlates with a structure passing under the lower road, which can be observed exposed on the riverward side of the lower road. The structure could be the remnant of a conveyor or support system associated with a mine opening.

12. Anomaly II may be associated with structures passing through the slope and connecting with the sealed opening in some manner. There is a concrete-lined, steel grate-covered drainage tunnel emerging from the slope and passing under the lower road approximately at location 185,330 N. This drainage tunnel contributes to the overall anomaly and may have been associated with the sealed opening. The appearance of the slope face in the vicinity of and between anomalies I and II indicates the possibility that a substantial portion of the exposed Pittsburgh Coal seam may have been removed to form a large opening into the mine at one time.

13. Anomaly III reflects the fact that the northernmost

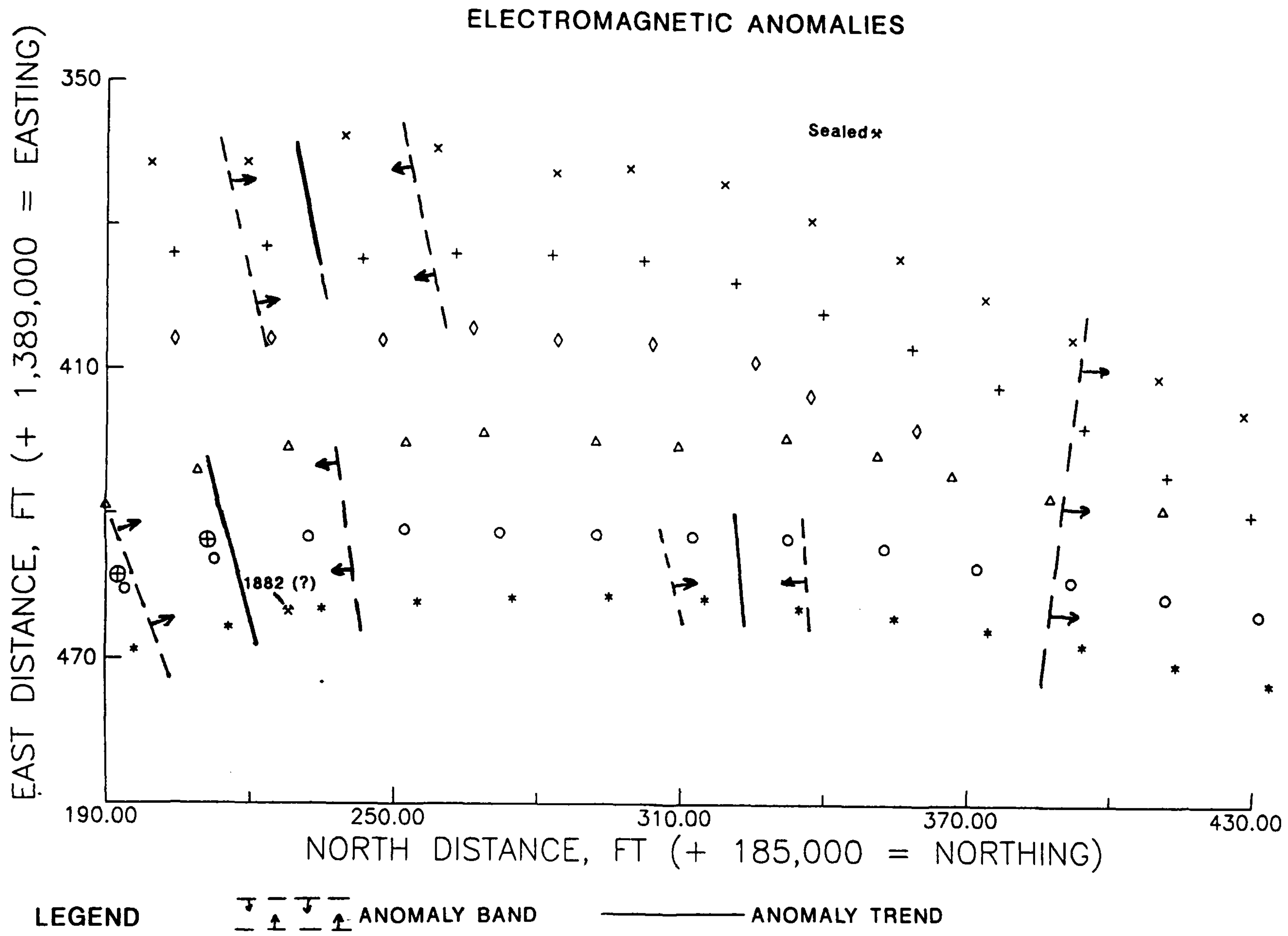


Figure 12. Electromagnetic anomaly map

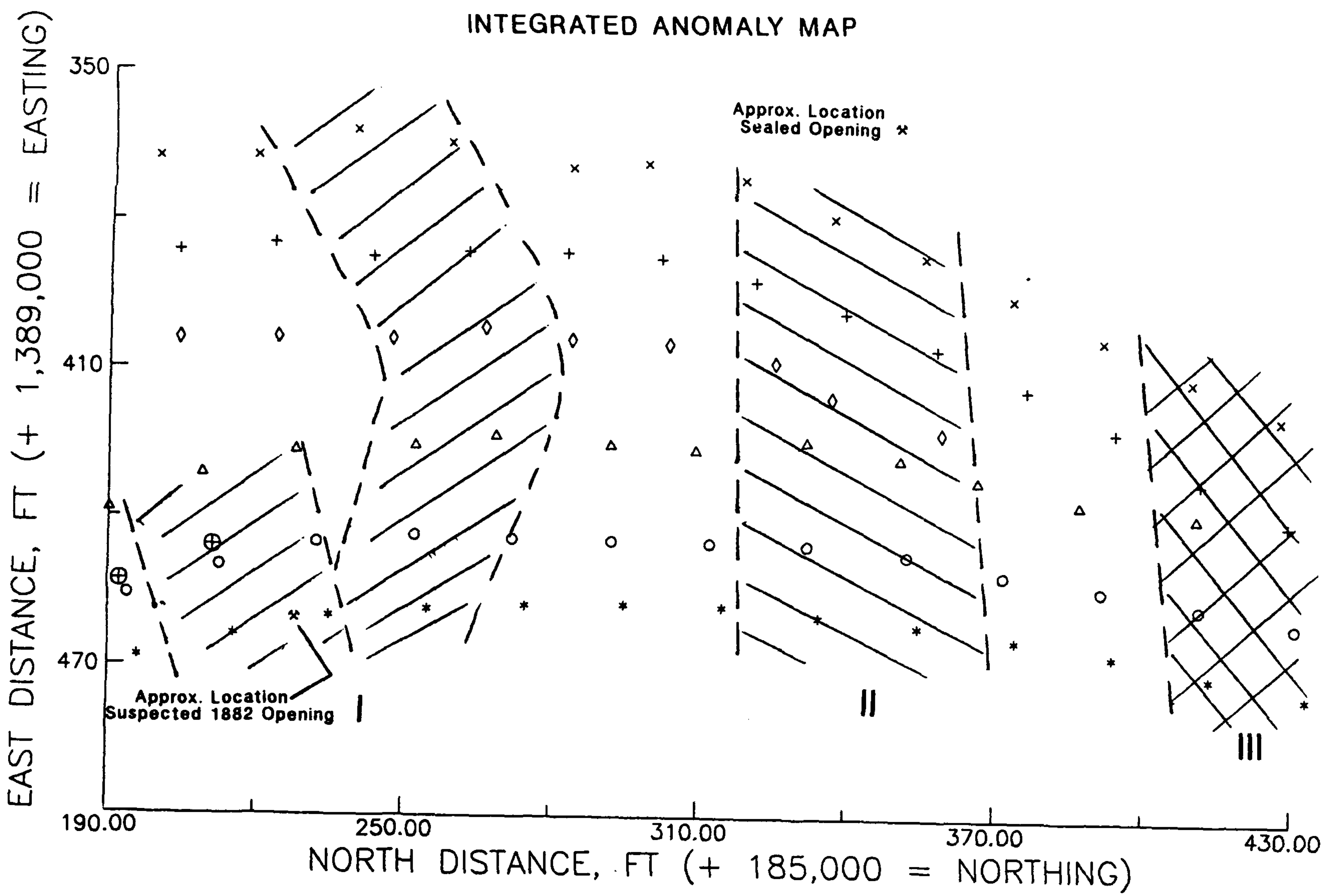


Figure 13. Integrated anomaly map for a portion of the left abutment area of Grays Landing Lock and Dam Site

end of all the geophysical survey lines was anomalous. There is a well-defined magnetic anomaly maximum on lines I, II, and V at profile location 200-210 ft, while the electromagnetic conductivity increases steadily from profile location 200 ft to the end of the survey lines. There is no known surface or subsurface feature to correlate with this anomalous area.

Conclusions

14. Results of the geophysical surveys in the left abutment area of Grays Landing Lock and Dam Site are less than completely satisfying due to the complexity of the site in terms of surface topography and surface metallic, cultural debris. The surveys succeed, however, in mapping anomalous areas (Figure 13) at the site. Two of the anomalous areas (I and II) trend westward from the lower road area into the slope. One of these anomalous areas (I) may be caused by the suspected 1882 mine opening and its debris fill. If the anomalous areas are investigated by exploratory drilling, the drilling should begin along the centerlines of the areas and then successively offset by approximately 10 ft to each side of the initial borehole, if the initial borehole fails to encounter an anomalous feature. The features causing the anomalies are likely less than 25 ft in depth. However, conservatively, boreholes should be extended to approximately 50 ft depth. Alternatively to drilling, trenching would be an effective technique for investigating anomalous area I for the suspected 1882 mine opening. The trench should be located approximately along survey line II (along the west side of the lower road), beginning about 10 ft north of MS-23 and continuing north for approximately 70 ft or until evidence of an opening is encountered.

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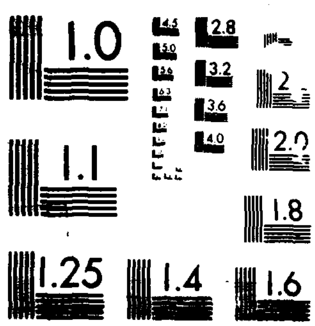
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OF A SUSPECTED ABANDONED MINE
OPENING: GRAYS LANDING SITE

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