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Field Summary Report

Geophysical Investigations at FU-1, TA-73, SWMU 73-001 (a), Los Alamos Airport

Submitted to:

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Submitted by:

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Geophex Job Number 422
April 1995

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April 13, 1995

University of California
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Attn: Garry Allen
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P. O. Box 1663, MS E525
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Dear Mr. Allen:

Enclosed are three copies of our field summary report, "Geophysical Investigations at FU-1, TA-73, SWMU 73-001(a), Los Alamos Airport". This report summarizes the geophysical surveys conducted by Geophex from June to September 1994.

The airport landfill proved to be a challenging site. We put significant effort into mapping the landfill thickness with a variety of methods. Results from some methods were more successful than others. We feel that the interpretation provided in this report is the best that can be provided for the level of effort of these investigations.

We have enjoyed the opportunity of working on this project and look forward to providing you with assistance in the future.

Sincerely yours,

John W. Clough, Ph.D., PG.
Project Manager

Edward A. Hull, II
Project Geologist

Enclosure: Field Summary Report, "Geophysical Investigations at FU-1, TA-73, SWMU 73-001(a), Los Alamos Airport" (3 copies)

cc: Larry Brown, LANL MS P274 with Enclosure (3 copies)

Executive Summary

Geophex,Ltd. conducted investigations within Field Unit (FU)-1, at Technical Area (TA)-73, as part of the Los Alamos National Laboratory (LANL) Environmental Restoration Program. We acquired geophysical data, covering over 21 acres at the former landfill area, Solid Waste Management Unit (SWMU) 73-001(a). The purpose of the surveys was to map the lateral and vertical extents of the landfill.

We conducted geophysical surveys with the following methods: magnetic total field, gravity field profiling and mapping, seismic refraction, ground penetrating radar (GPR), and Schlumberger vertical electric sounding (VES) resistivity measurement. All methods, with the exception of gravity, provided useful data for portions of the surveyed area.

We integrated data from the geophysical surveys with historical records, geological information and borehole results to produce an isopach map of landfill thickness. The landfill extends from the hangar area 1,100 feet east to the mesa edge and from the hot pad road 400 feet north to the mesa edge. The maximum thickness of the fill is approximately 75 feet, at the east edge of the site, where a natural, hanging valley was used to receive materials.

To further detail the boundaries of the landfill would require a much greater level of effort. Geophex Ltd. recommends no further geophysical investigations at this site.

Table of Contents

Executive Summary i
List of Tables ii
List of Figures ii

1.0 Project Introduction 1
1.1 Project Description 1
1.2 Scope of Work 1
1.3 Preliminary Evaluation 1
2.0 Geophysical Methods and Instruments 2
2.1 Magnetic Total Field Measurement 2
2.2 Gravity Field Measurement 3
2.3 Seismic Refraction 3
2.4 Ground-penetrating Radar 3
2.5 Schlumberger VES 5
3.0 Geophysical Survey Results 5
3.1 Magnetic Results 5
3.1.1 Magnetic Total Field Mapping 6
3.1.2 Magnetic Profiling 6
3.2 Gravity Mapping and Profiling 7
3.3 Seismic Refraction Results 7
3.4 GPR Survey 8
3.5 VES Results 8
4.0 Integration and Discussion 9
5.0 Conclusions 9

List of Tables

Table 1. Dielectric constants of some typical materials 4

List of Figures

Figure 1. Location map showing FU-1, TA-73, Los Alamos Airport and SWMU constituents. 11
Figure 2. Location map showing Los Alamos Airport structures, survey grid, former trench locations and other features. 12
Figure 3. Map of residual magnetic field data 13
Figure 4. Color plot of residual magnetic field data collected from main portion of survey area 14
Figure 5. Magnetic total field profile collected along 1550E 15
Figure 6. Index map showing gravity survey locations 16

List of Figures (continued)

Figure 7. Gravity profile along A-A' 17
Figure 8. Index map showing seismic refraction survey locations 18
Figure 9. Seismic profile and travel time plot from 700E 19
Figure 10. Seismic profile and travel time plot from 1000E 20
Figure 11. Index map showing GPR survey location 21
Figure 12. Uninterpreted and interpreted versions of GPR profile 700E 22
Figure 13. Comparison of GPR and seismic profiles along 700E 23
Figure 14. Index map showing VES survey locations 24
Figure 15. VES plot from 1400E-300N 25
Figure 16. Isopach map of landfill thickness and cross section locations 26
Figure 17. Four cross sections of the landfill structure 27

1.0 Project Introduction

1.1 Project Description

Geophex Ltd. conducted geophysical investigations at SWMU 73-001(a), the former landfill at the Los Alamos Airport (Figure 1). The main body of the landfill is comprised of a natural hanging valley located north of the runway and east of the aircraft hangars. The valley was approximately 70 feet deep and 300 feet wide at it's east end where it opened to the edge of the mesa. The 1,000 feet long valley narrowed into a steep shallow canyon towards the west. Landfill operations also included trenching on the mesa tops west of the canyon. The landfill covers 21 acres. Most of the fill material is within a ten acre area at the location of the former hanging valley.

Los Alamos National Laboratory (LANL) operated the landfill from the early 1940's until the middle 1960's. Los Alamos County operated the site from the mid 1960's until 1973. The presence of radioactive materials and other hazardous wastes in the landfill have been documented (RFI Work Plan for OU 1079, May 1992). The work plan refers to a LANL document that describes "a yet to be identified radioactive disposal area in the vicinity of the airport that was active in 1943-1944...." On high oblique aerial photographs taken in 1946, two trenches are visible on the mesa top north of the current runway.

1.2 Scope of Work

The purpose of these investigations is to map the lateral and vertical extent of the landfill. The statement of work emphasizes the importance of delineating two trenches (observed on the 1946 aerial photographs) located beneath the landfill.

We conducted geophysical surveys at a number of locations over the landfill area, using several methods and covered approximately 21 acres. The area is bounded to the south by the runway, to the north by Pueblo Canyon, and to the west by four airplane hangars. The eastern boundary is 500 feet east of the hot pad area (Figure 2).

1.3 Preliminary Evaluation

We examined the aerial photographs of the airport area to accurately locate the position of the trenches described in the statement of work. We designed portions of the geophysical surveys based on these trench locations.

Geophex compared modern photographs and maps with the 1946 and 1958 images. We located the positions of two trenches and several other former facilities (Figure 2). A large east-west trench is observed on 1946 aerial photographs of the airport. The trench was approximately 950 feet long and 100 feet wide and extended from the present terminal building to a location 200 feet east of the hangar area. A smaller trench, identified in early photographs, was located at the present position of the hot pad. This trench was approximately 200 feet long and 50 feet wide.

We have also located a sand and gravel operation, that we attribute to a reported asphalt batch plant.

The contents of material placed in the trenches is unknown. In 1984, the western end of the landfill area was excavated, by the Department of Energy (DOE) during an airport improvement project, for the construction of the hangars and an airplane tie-down area. The excavated debris was transferred to two newly excavated 60-foot pits near the east end of the current runway. The landfill material removed was replaced with clean Bandelier Tuff and tuff-derived soil material excavated from the new pits. If a trench still exists at the hangar location it is probably filled with clean Bandelier Tuff. It is likely that any hazardous materials have been moved from the hangar area to the east end of the runway. The eastern pit area was not included in the current surveys, and has not yet been surveyed.

Surv-tek, Inc, of Albuquerque, established a 100 foot orthogonal grid network of surveyed stobs over the project area. This grid provided location control for our geophysical surveys (Figure 2).

2.0 Geophysical Methods and Instruments

We conducted several surveys at the site. Methods used include: 1) magnetic total field, 2) gravity profiling, 3) seismic refraction profiling, 4) digital ground-penetrating radar (GPR), and 5) Schlumberger vertical electric sounding (VES).

2.1 Magnetic Total Field Measurement

The earth's magnetic field would be spatially smooth and slowly varying were it not for the presence of ferrous materials (i.e., containing iron) within and on the surface of the earth. Ferrous materials cause deviations of the earth's magnetic field. Identification of these deviations, or anomalies, can be used to detect and locate the causative ferrous object.

Two types of magnetic surveys are commonly conducted to locate buried ferrous objects: 1) measurement of the total field, or 2) measurement of the vertical gradient of the magnetic field. Total field surveys are the most common. A hand-held magnetometer is used to measure the strength of the prevailing magnetic field at equal spatial increments. Total field surveys are best used when searching for large or deeply buried ferrous objects. The total field instrument used for this project is a proton precession magnetometer (EG&G, Geometrics G846).

In addition to locating anomaly-producing bodies, the magnetic total field anomaly can be used to determine the depth to the top of a body, based upon the anomaly shape. Depth estimates can be quite accurate, particularly when the anomaly is spatially separated from other anomalies.

In a landfill, with many anomaly-producing bodies, the total field measurement can be used to map the areal distribution of ferrous objects and to some extent their depth. The total magnetic field survey method allows for rapid data collection and is inexpensive.

2.2 Gravity Field Measurement

The gravity method measures small changes in the gravitational attraction of the earth due to changes in underground structure or density. Changes in density between soil and bedrock, geological formations or buried objects will cause a perturbation in the measured gravitational attraction. The unit of gravitational acceleration is the gal. One gal is equal to an acceleration of one cm/sec^2. The acceleration of gravity is roughly 980,000 milligals. The change in acceleration due to geologic formations and buried objects encountered in environmental work are often in the range of a few tenths of milligals. Therefore, measurements must be made to one part in 10^7 or better. This is accomplished by use of the gravimeter, a sensitive spring balance instrument designed for geophysical prospecting.

In addition to the changes in the gravitational acceleration due to density variations at depth, changes result from variation in elevation and latitude. Temporal changes result from tidal effects and aging of the instrument itself. The Bouguer gravity value is obtained by making corrections for measurable changes in elevation and latitude. Temporal changes are determined by frequent repeat measurements at a fixed location. The resulting Bouguer gravity values are plotted or mapped to identify anomalies which can be related to subsurface geology or buried objects.

The gravimeter used for this survey was a Lacoste Romberg, model G-724. LANL loaned the meter to Geophex for this survey.

2.3 Seismic Refraction

The seismic refraction method is based on the fact that rock layers within the earth generally have increasing density and elastic wave velocity as depth increases. Elastic (seismic) waves, propagated into the earth at an oblique angle, are refracted toward the horizontal until they eventually emerge back at the surface. By measuring the travel time of the wave energy refracted along different paths, the depth and geometry of the rock layers is determined.

For this survey, we used a 24-channel digital recording system. Geophones are spaced along a straight line and the ground motions associated with the traveling waves are recorded for later analysis. For this survey, the source of energy is a 16-pound sledge hammer striking an eight-inch diameter metal plate placed on the ground. Multiple strikes can be added together to increase the total energy and improve the signal-to-noise ratio.

We conducted this survey using the StrataView™ Exploration Seismograph by Geometrics, Inc coupled to 60 Hz geophones. The data were processed using Rimrock Geophysics SIPT2 software.

2.4 Ground-Penetrating Radar (GPR)

This method employs an extremely short electromagnetic pulse that penetrates into the earth. A small portion of the pulse energy is reflected to the surface. The return signal is continuously recorded on a strip-chart or, in some cases, into a digital recording device. Amplitude of the

reflected pulse depends primarily on the medium's dielectric constant. GPR anomalies result when there is a contrast in bulk dielectric property between materials. Dielectric constants of some typical materials are listed in Table 1.

Table 1. Dielectric constants of some typical materials.

Material	Dielectric Constant
Air	1
Ice	3 - 4
Dry Sand	3 - 5
Granite	4 - 6
Limestone	4 - 8
Dry Salt	5 - 6
Shale	5 - 15
Silts	5 - 30
Clays	5 - 40
Saturated Sand	20 - 30
Water	80

[from Sensors and Software pulseEKKO IV, version 3.1, literature.]

For instance, there is a significant contrast in the dielectric property between clay and sandstone (or sand). Owing to this contrast, GPR can usually detect a shallow clay horizon below a sand formation. GPR anomalies arising from man-made structures exhibit the form of artificial geometric shapes created by buried targets. These targets may include both metallic and nonmetallic objects such as tanks, drums, pipes, concrete blocks, bulk chemicals, animal bones, etc. Under favorable geologic conditions, the method can also detect the disturbed soil of backfilled pits and trenches.

The primary GPR used at TA-73 was the Sensors & Software pulseEKKO IV. This GPR has pulse voltages of 400 and 1000. Antenna frequencies of 50, 100, and 200 MHz provide flexibility of depth penetration and resolution. During normal operation of the system, data are collected at discrete intervals along the surface with the antennas stationary during data collection. The number of pulses stacked and recorded at each antenna location is selectable. High stacking can be used to increase the signal-to-noise ratio in order to improve imaging of weak signals.

This radar system uses separate transmitting and receiving antennas, referred to as bistatic mode, thus allowing flexibility of antenna configuration and spacing. The configuration and spacing of the antennas can be adjusted to optimize imaging of a particular target.

2.5 Schlumberger Vertical Electric Sounding (VES)

The Schlumberger VES method is a specific type of earth resistivity measurement. In earth resistivity measurements, an electrical current is introduced into the ground through metal electrodes. Separate electrodes are used to measure the electrical potential, or voltage, produced by the induced current. The electrical resistivity of geologic materials and their included fluids are determined from the current and voltage measurements.

Vertical electrical sounding methods are obtained by increasing the separation of the current electrodes about a fixed central point on the ground surface. As the electrode spacing is increased, the method senses deeper into the ground. The measured resistivity, referred to as apparent resistivity, is equal to the true resistivity of the earth material for the case of a uniform homogeneous half-space. In the case of a layered earth, the true resistivity and thickness of the layers can be determined by mathematical modeling of the observed data.

Apparent resistivity is plotted as a function of electrode spacing. The apparent resistivity curve is used to calculate true resistivity versus depth. The end-product of the survey produces a vertical profile of resistivity beneath the survey point. The profile resembles, and is interpreted similarly to a down-hole resistivity log. The method is useful for mapping changes, with depth, of lithology, moisture content, salinity or any other factor which will cause changes in the conductivity of the sampled material.

Data acquisition is relatively rapid and data processing and interpretation is very quick and inexpensive. The method normally provides good depth penetration. The depth is generally limited only by the array length, which is usually hundreds of feet. VES has the poorest resolution of the methods described here; therefore the resulting interpretation has the least detail.

We used the ABEM Terrameter 300B instrument to conduct this survey. Geophex uses a proprietary cable system, which increases the speed and accuracy of data collection.

3.0 Geophysical Survey Results

The results of each of the geophysical methods used to characterize the landfill are summarized in this section. We include a description of the data collected and an interpretation of the results for each of the methods. An integration and discussion of all the results is described in Section 4.0 of this report.

3.1 Magnetic Results

We acquired magnetic total field data over 18 acres within the survey area. We collected data from the centerline of the runway, north to the fence line and from the hangar area east to a line 500 feet beyond the hot pad. We recorded approximately 4,400 points on a 10 x 20 foot grid. We used this data to produce a contour map of magnetic anomalies. We did not obtain useable

data in the area near the hangars due to the presence of parked aircraft and the metal hangars themselves.

3.1.1 Magnetic Total Field Mapping

We produced a residual anomaly map by subtracting a background value of 52,400 nT from all measured values before contouring. The residual map, now with a background near zero, enhances the interpretation of highs and lows. The residual map in Figure 3 shows the area covered by the survey. Anomalous highs and lows are more easily discerned on a colored contour map of the main fill area (Figure 4).

Several distinct features are visible on the magnetic maps (Figures 3 and 4). There are very few anomalies visible east of 1900E. We interpret this area as containing very few ferrous objects and is probably composed of clean earth material. There is no indication of ferrous debris at the location of the small trench under the hot pad. There is one distinct, shallow anomaly east of the hot pad at grid location 2780E and 100N. We observed a cleared area at this location on a 1958 aerial photograph (Figure 2). This area clearly does not correspond with the small trench under the hot pad, seen on the 1946 photographs.

South of the 0 N line the field strength drops rapidly to background levels. We interpret these changes in anomaly pattern to mark the edges of the landfill area. Between 800E and 1900E, and paralleling the hot pad taxiway, there is a striking, linear anomaly rising to values of 4,000 nT from a background level near zero. We interpret this anomaly to represent the south edge of the landfill. This southern edge coincides with the southern edge of the hanging valley beneath the landfill. The amplitude of this anomaly, particularly when compared with many smaller anomalies scattered throughout the central part of the landfill, suggests a concentration of buried ferrous metal. Historical records indicate that no filled drums or other segregated metal debris was placed along this edge. Metal may have been concentrated by the practice of burning debris along this edge of the landfill. Combustible materials were reduced to ashes leaving behind a concentration of metal materials.

Just to the north of this area of high amplitude anomalies, a zone of high frequency anomalies is observed, striking ENE between 700E-150N and 1500N-300N. These anomalies are interpreted as a scattering of ferrous objects within the landfill, representing unsegregated household refuse.

Another large amplitude anomaly is observed between 750E-1050E and 200N-350N. This anomaly with amplitudes similar to the large east-west anomaly, is interpreted as an area of segregated ferrous material.

3.1.2 Magnetic Profiling

The depth of magnetic sources can be estimated from the shape of anomaly profiles across the causitive body. For several simple geometries, the depth is approximately equal to the width of the anomaly measured at one half its maximum amplitude. Complex geometries or multiple sources with overlapping anomaly patterns make interpretation more difficult. This difficulty can

be overcome by analyzing a large number of profiles or by carefully selecting the profiles to be interpreted.

We recorded a south-north profile along line 1550E with a station spacing of two feet and a sensor height of six feet (Figure 5). A gap in the profile from 44-56 feet is attributable to the high gradient of the magnetic field at these locations. This profile is never-the-less used to estimate the depth of the source, assuming a single causitive body. The width of the anomaly, at one half the maximum amplitude, is approximately 25 feet. Subtracting the sensor height of six feet, we interpret the depth to the top of the causative body to be no greater than 20 feet. Although a complex geometry or multiple sources at a shallower depth could, in principle, produce this anomaly shape; any source geometry at a greater depth would produce a wider anomaly.

3.2 Gravity Mapping and Profiling

We conducted gravimetric mapping and profiling at several locations within the landfill area (Figure 6). We carried out geodetic leveling at all gravity observation points in order to produce accurate Bouguer corrections. Base station readings were recorded at approximately one hour intervals to make corrections for instrument drift and earth tides.

When a sufficient contrast between low density fill and high density bedrock exists, the Bouguer gravity profile mimicks the bedrock topography. Low gravity values would be observed in the central area where the fill is thick and higher values observed on the edges where the bedrock is close to the surface.

The gravimetric method was unsuccessful at this site. Changes in the landfill thickness do not provide significant changes in the gravity field. This is due to the low density contrast between the Bandelier Tuff, and the contents of the landfill. Furthermore, density variations within the fill material add "noise" to the measured gravity values.

One example of the data is shown for profile A-A', which crosses the landfill from the edge of the hot pad taxiway on the south, across the original hanging valley, to a Bandelier outcrop on the north (Figure 7). The figure shows both the Bouguer profile, with a large decreasing regional trend towards the edge of the mesa top to the north, and a residual profile that has the large regional effect removed. The residual profile appears noisy and shows no obvious correlation with the expected bedrock topography.

3.3 Seismic Refraction Results

We conducted seismic refraction profiling at several locations within the landfill (Figure 8). We collected profile data directly on Bandelier outcrop at one location within the landfill (800E-200N) and on the exposed outcrop along the north edge of the mesa, just outside the fence at 1300E. The measured velocities were 2,600 feet per second and 2,400 feet per second respectively. These values represent a relatively low bedrock velocity. The velocity of the unconsolidated fill is approximately 1,100-1,300 feet per second. High absorption of the seismic

energy within the fill, together with the relatively low velocity contrast between the fill and bedrock, makes it difficult to obtain successful refraction data.

Five refraction profiles produced depth estimates (Figure 8). A travel time plot and cross-sectional interpretation of the reversed profiles from line 700E is shown in Figure 9. Following the profile from south to north one can see an abrupt thickening into a trench and then thinning to just a few feet at 200N, corresponding to the location of a former road and landfill office. An interpreted profile for the 1000E line shows a similar abrupt drop off toward the north (Figure 10). Depth estimates from three additional locations, along the inferred southern rim, are used in the integrated interpretation discussed in Section 4.0. Toward the eastern end of the fill the seismic profiles indicate a more uniform slope down into the canyon rather than an abrupt drop off. This is consistent with the natural shape of the valley prior to landfill development, as interpreted from aerial photographs and contour maps.

3.4 GPR Survey

We conducted digital GPR profiling at a number of locations, using 50 and 100 Mhz antennas and stacking up to 2048 stacks per trace for maximum signal-to-noise ratio. We concentrated our efforts at the western end of the landfill (Figure 11). These investigations met with limited success.

We obtained our best image along the 700E line from 0N to 200N. Figure 12 shows the uninterpreted profile (top) together with our interpreted version (bottom). The interpreted profile shows an abrupt thickening into a trough and then thinning toward the north at the location of the former landfill office and road. Figure 13 compares the interpreted GPR profile and the seismic refraction profile at the same scale along this line. There is a good correlation between the two methods at this location.

We profiled at other locations, using the 50 Mhz antennas for maximum depth penetration, but were unsuccessful in imaging the base of the fill. We attribute this lack of success to poor contrast in the dielectric properties between the Bandelier and the fill and the greater thickness of the fill at most other locations.

3.5 VES Results

We collected 28 Schlumberger depth soundings at locations within the central portion of the landfill (Figure 14). A plot of the sounding results and interpretation for location 1400E - 300N is shown in Figure 15. The curved line through the data points is a plot of apparent resistivity versus electrode spacing. At an electrode spacing of four feet, the apparent resistivity, 600 ohm-meters, represents the true resistivity of the dry, near surface layer of the fill. As the electrode spacing is increased, the apparent resistivity decreases as the more conductive fill material is sensed. At even greater electrode spacing, the apparent resistivity increases as the resistive Bandelier Tuff, below the fill, influences the measured values.

The solid blocky line represents interpreted resistivity versus depth derived from the apparent resistivity curve. The resistivity in the lower part of the fill is less than 100 ohm-meters while the Bandelier Tuff has a resistivity of approximately 600 ohm-meters. We interpret the thickness of the landfill at this location to be 45 feet.

The depth interpretations of each VES were plotted on a map of the survey area and combined with data from other sources to produce a landfill thickness map. The VES data provide the basis for much of the interpretation, particularly in the thicker portions of the landfill where other methods failed to image the base of the fill.

4.0 Integration and Discussion

We collected data at TA-73 using several methods. The methods used involve different basic principles; wave propagation at different wavelengths (seismic and GPR), potential fields (gravity and magnetic) and electrical conduction current (VES). The results of the different surveys are combined to produce a consistent, integrated interpretation of all available data. We have integrated the results from the various methods into a contour map of the landfill thickness (isopach map, Figure 16).

A major portion of the map, where the landfill is thickest, is based on the VES data. The magnetic map together with a few seismic refraction profiles, help define the southern edge of the fill area. Outcrops of Bandelier Tuff, on the perimeter and within the landfill provide additional control for mapping.

The contour map shows that the fill at the western end of the site is approximately 20 feet thick and the base of the landfill is fairly flat. Trenching probably took place over most of this area. Toward the east, the thickness of the landfill increases. The deeper portions fill the natural contours of the hanging valley. At its eastern terminus the fill is greater than 70 feet thick.

We include four cross sectional profiles of the landfill thickness (Figure 17). These profiles include surface and bedrock structure across the landfill and are helpful in picturing the structure of the landfill, whereas the isopach map shows only fill thickness.

5.0 Conclusions

Integration of data obtained from a number of methods and sources is a key element of this interpretation. Each geophysical method, with the exception of gravity mapping and profiling, provides some input into the interpretation. The magnetic map provides good definition of the lateral boundaries of the landfill, minimum thickness of the landfill, and the distribution of ferrous materials within it. VES resistivity soundings provided thickness values for the central and eastern portions of the site where the fill reaches thicknesses up to 70 feet. The higher resolution seismic and GPR methods helped to define the edges and thinner portions of the fill, but were

unsuccessful in imaging the thicker portions of the fill. The geophysical data, when combined with geologic and topographic data, provides a consistent interpretation of the landfill geometry.

If further detailing of the landfill boundaries, both lateral and vertical, is required, we would recommend seismic refraction as the best method to use. However, a significantly larger energy source, such as a dynamite, would be required.

Geophex,Ltd. recommends no further geophysical investigations at this site.

Figures

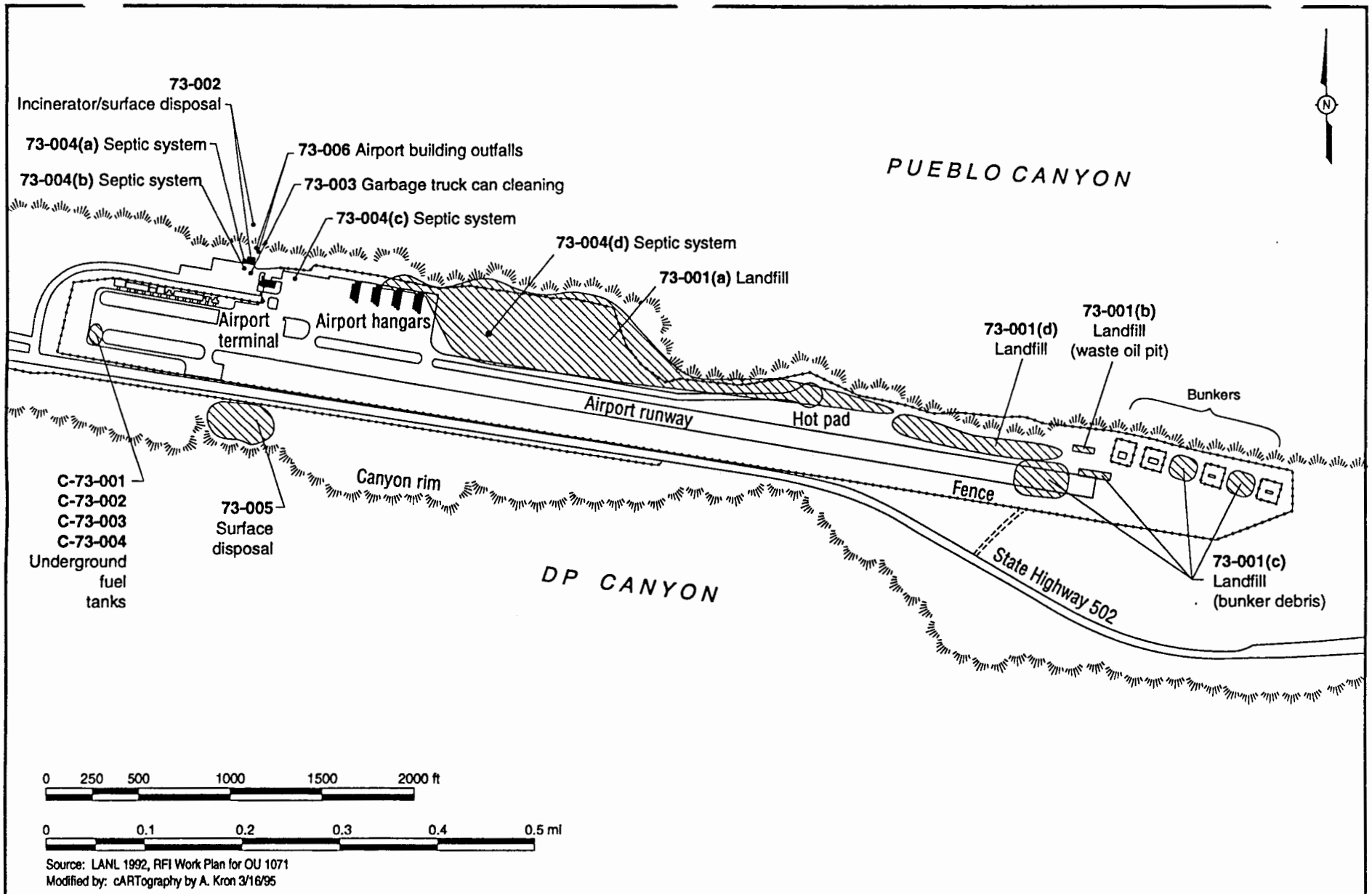

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Figure 1. Location map showing FU-1, TA-73, Los Alamos Airport and SWMU constituents.

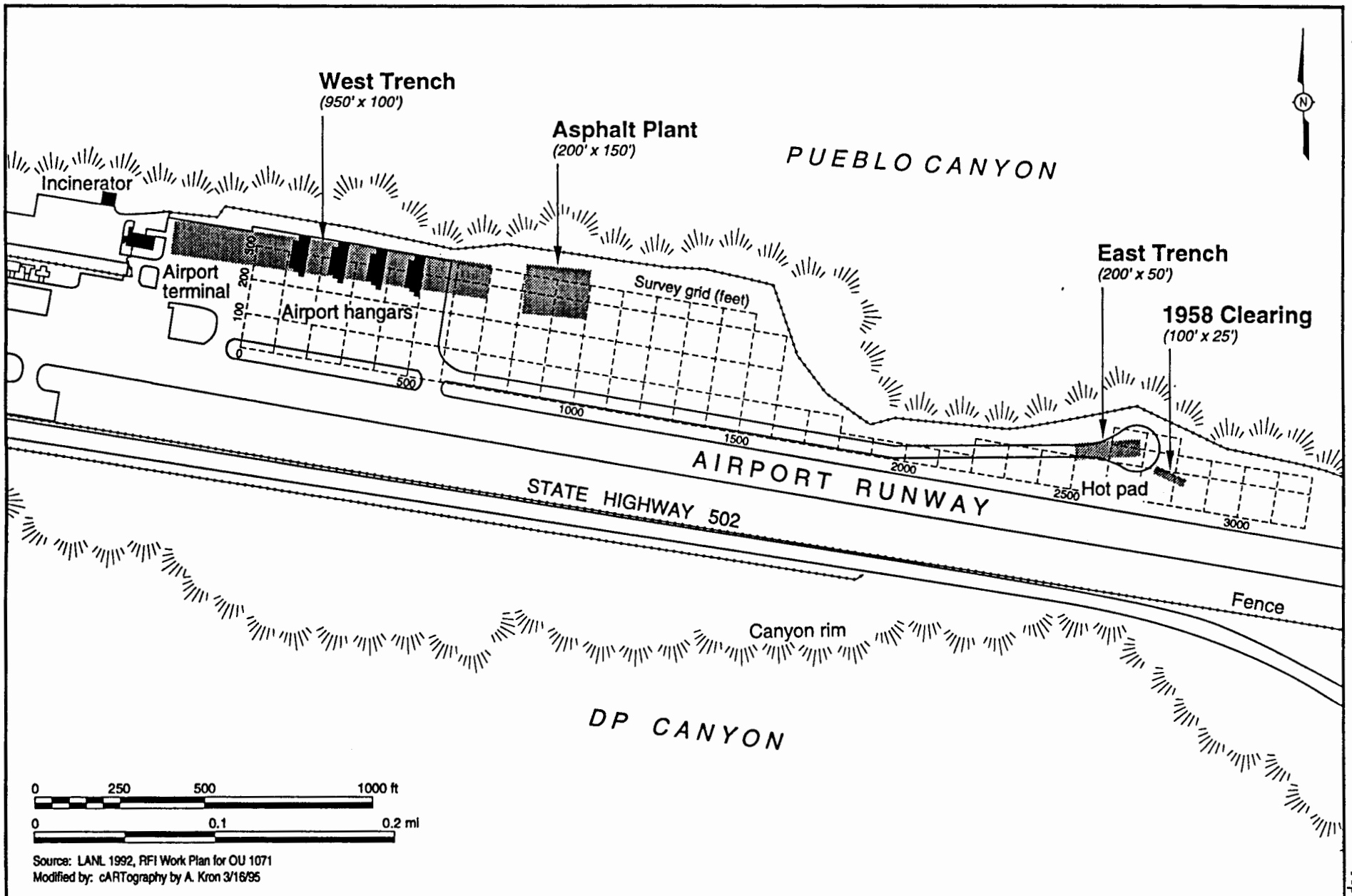

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Figure 2. Location map showing Los Alamos Airport structures, survey grid, former trench locations and other features.

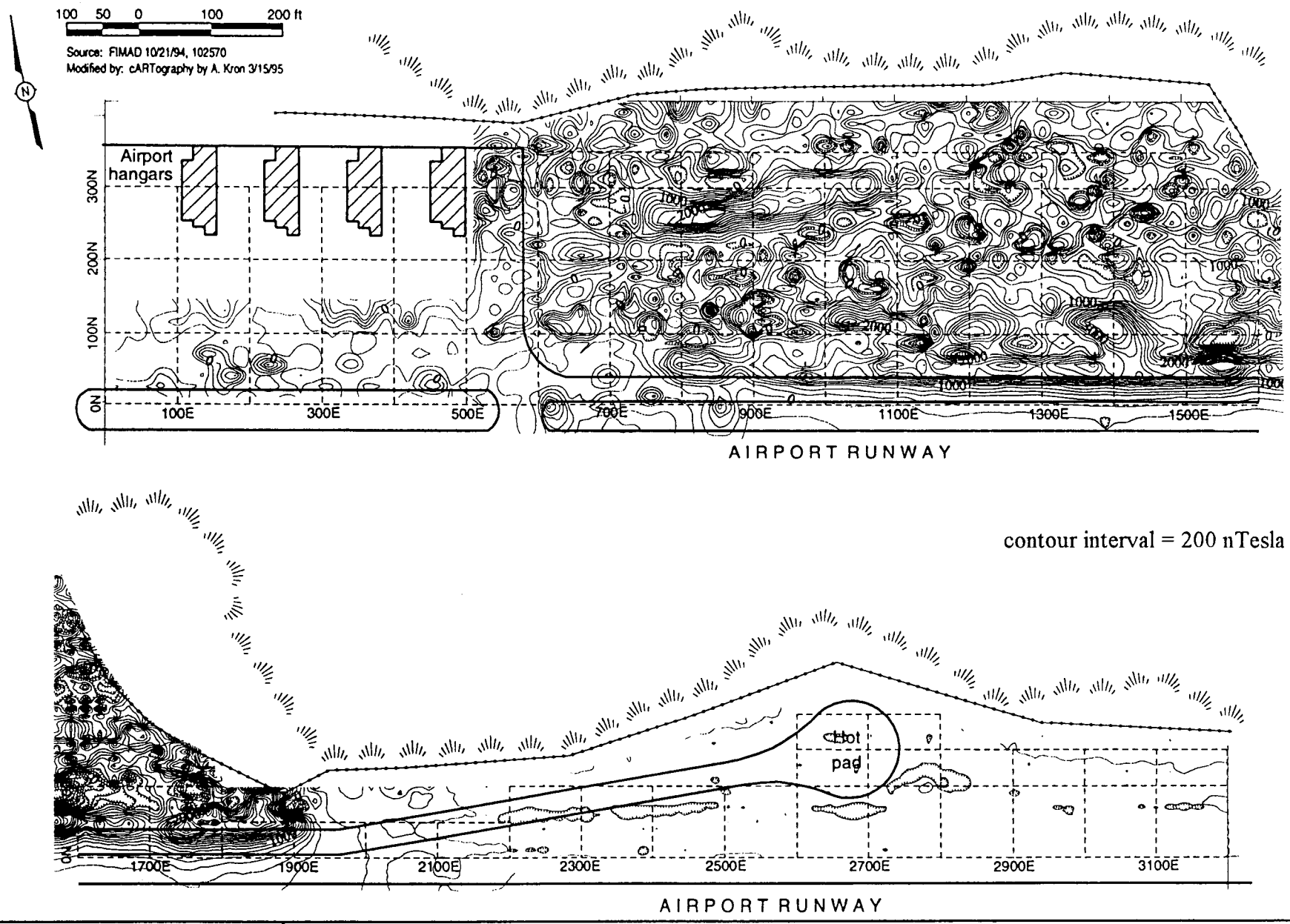

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Figure 3. Residual map of magnetic total field data.

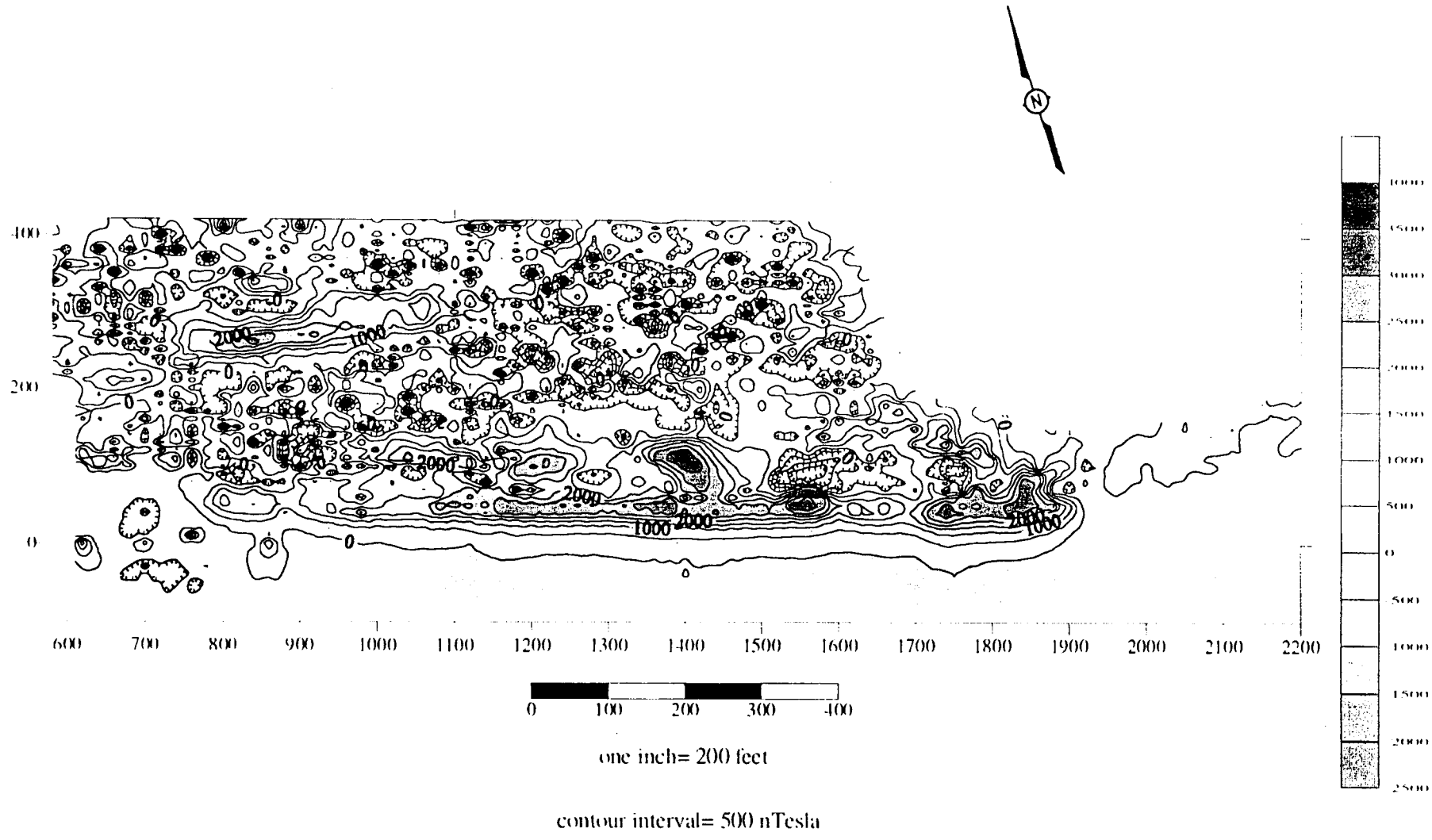

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Figure 4. Color plot of residual magnetic field data collected from main portion of survey area.

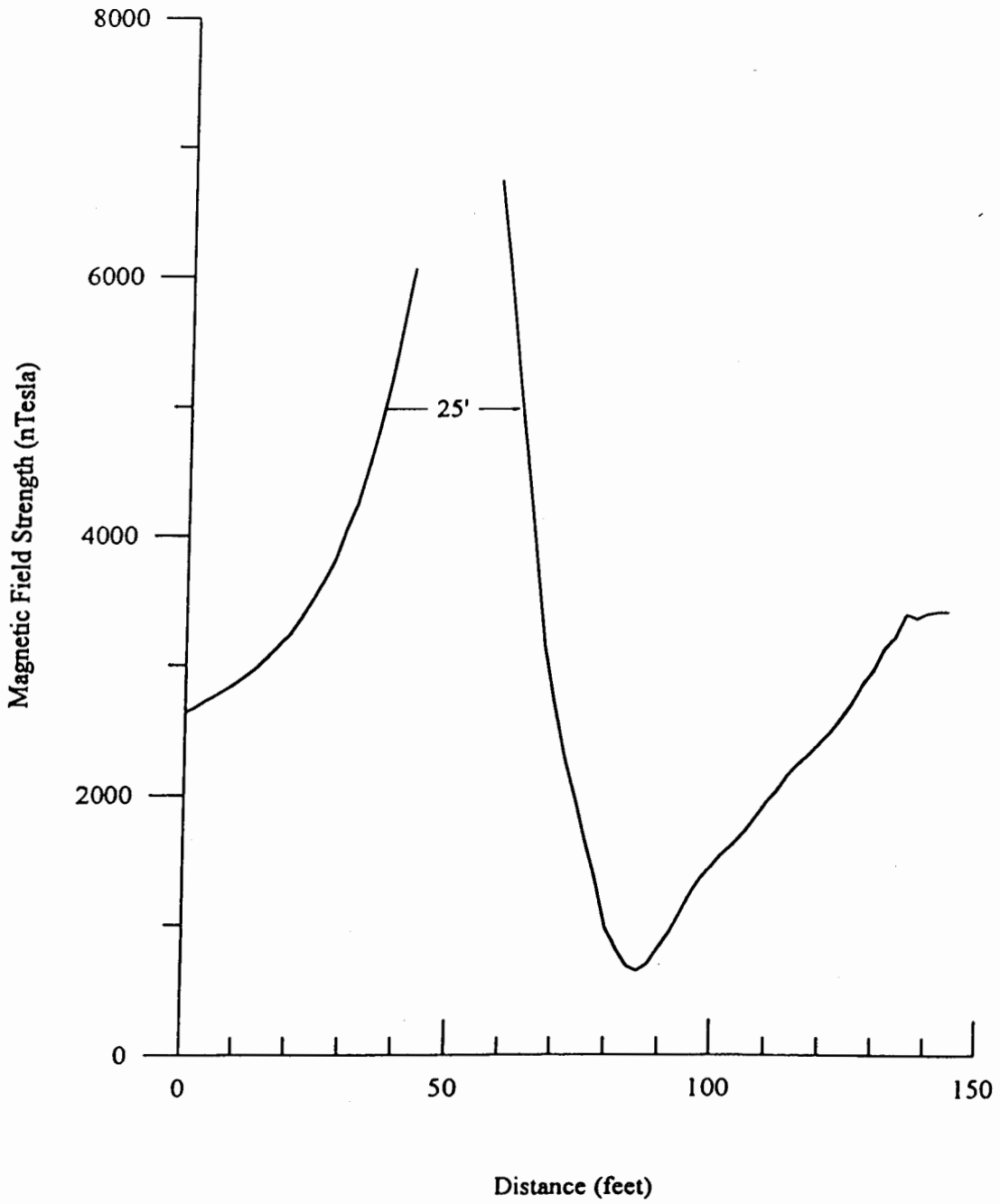

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Figure 5. Magnetic total field profile collected along 1550E.

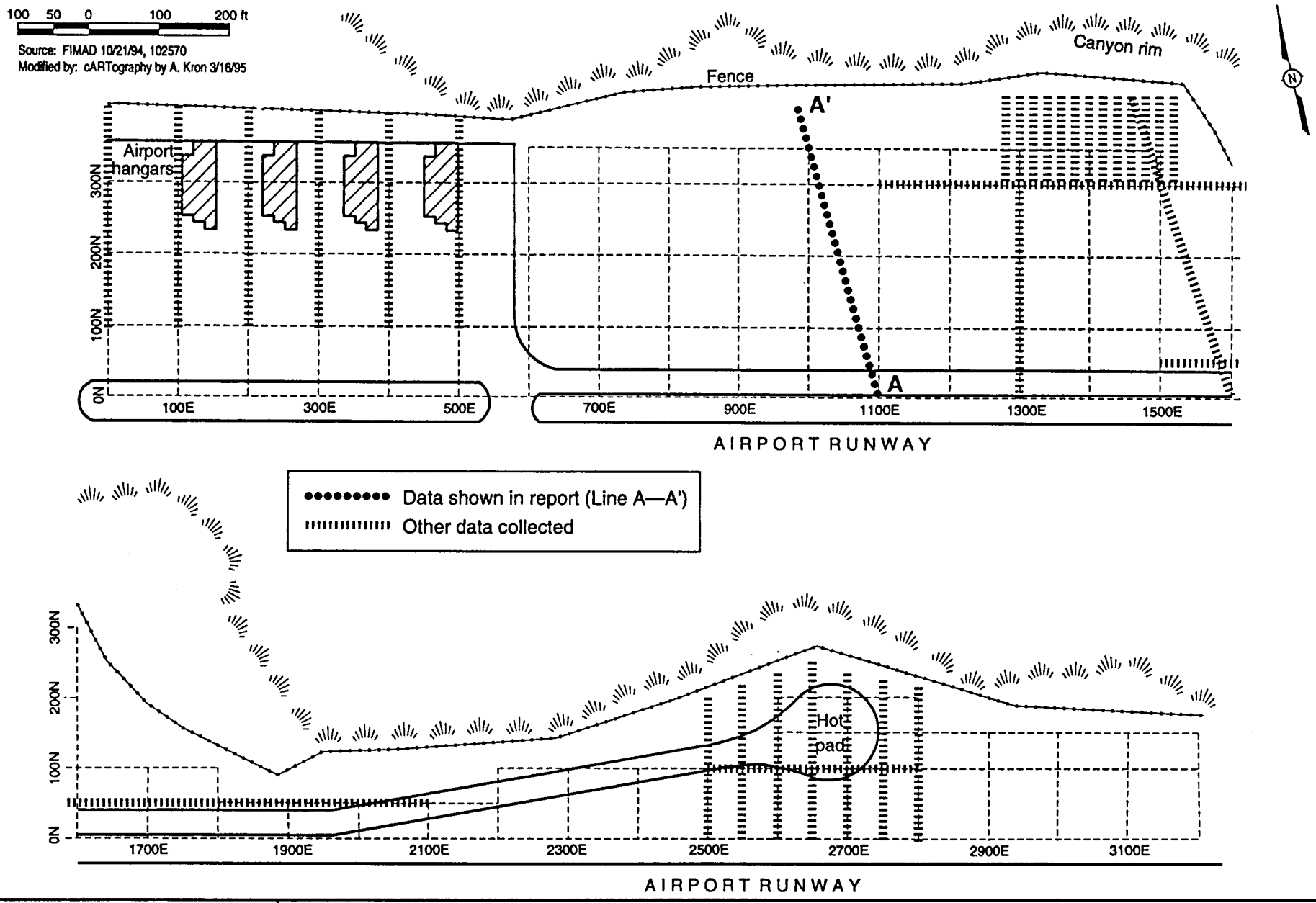

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Figure 6. Index map showing gravity survey locations.

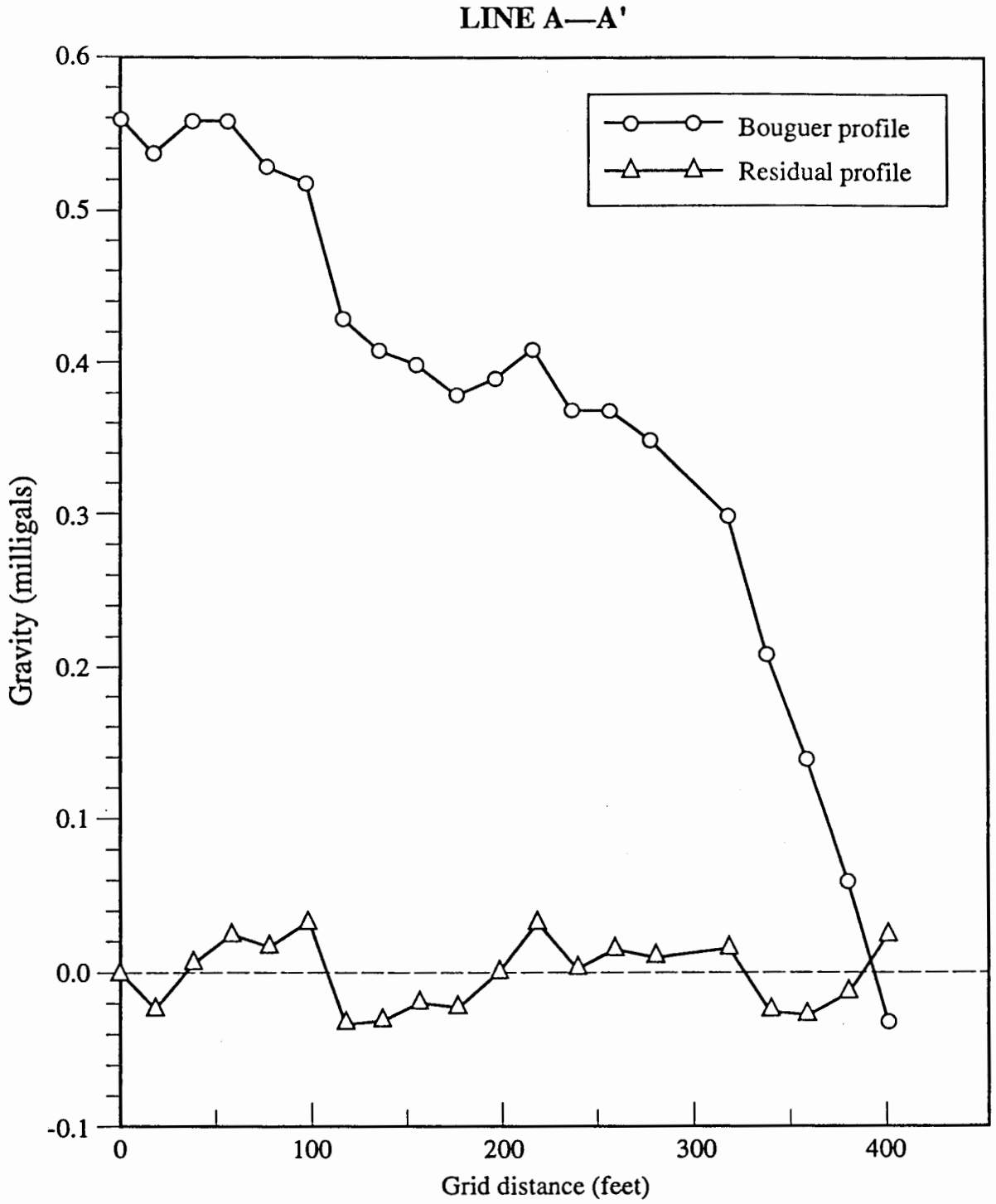

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Figure 7. Gravity profile along A–A'.

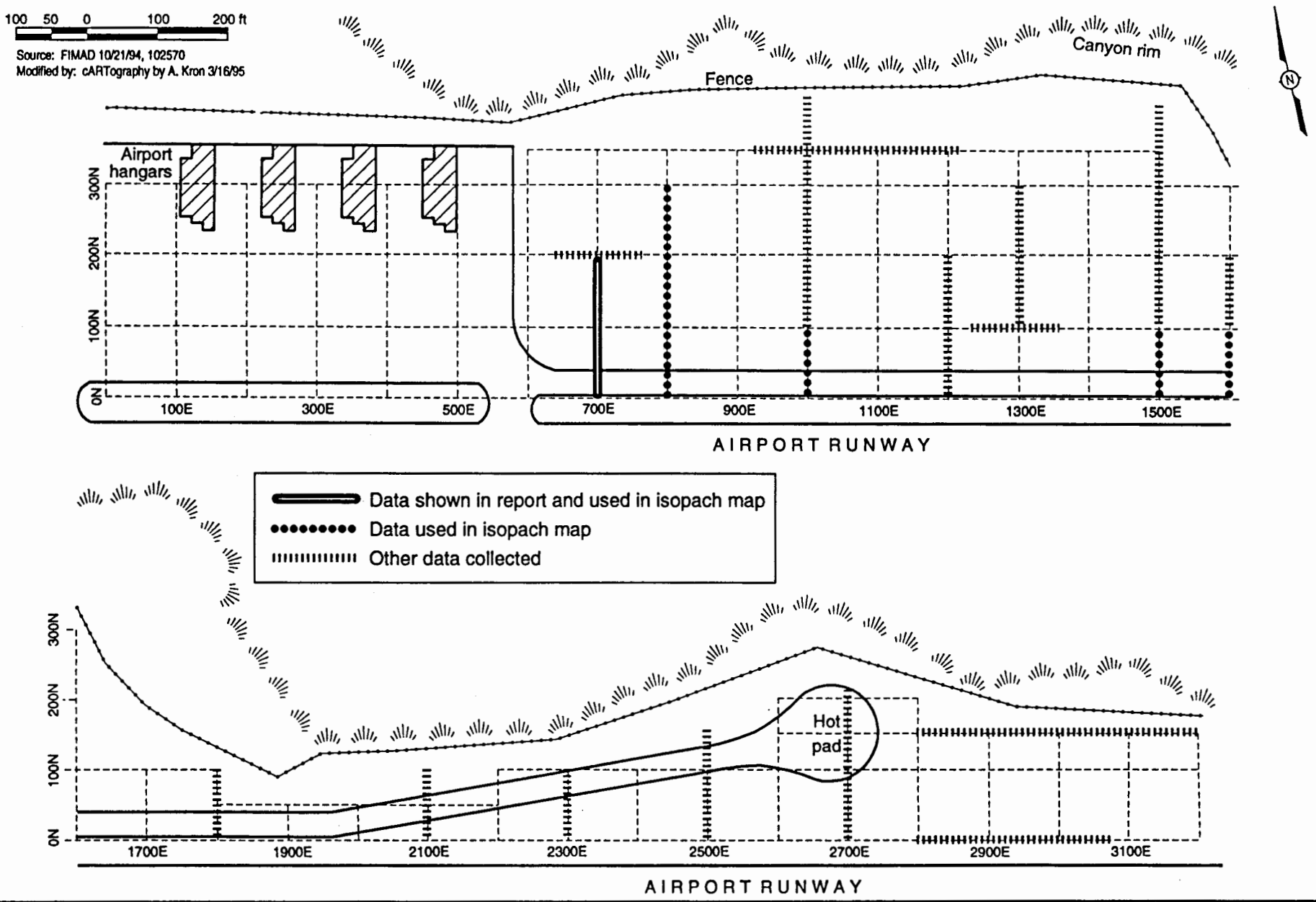

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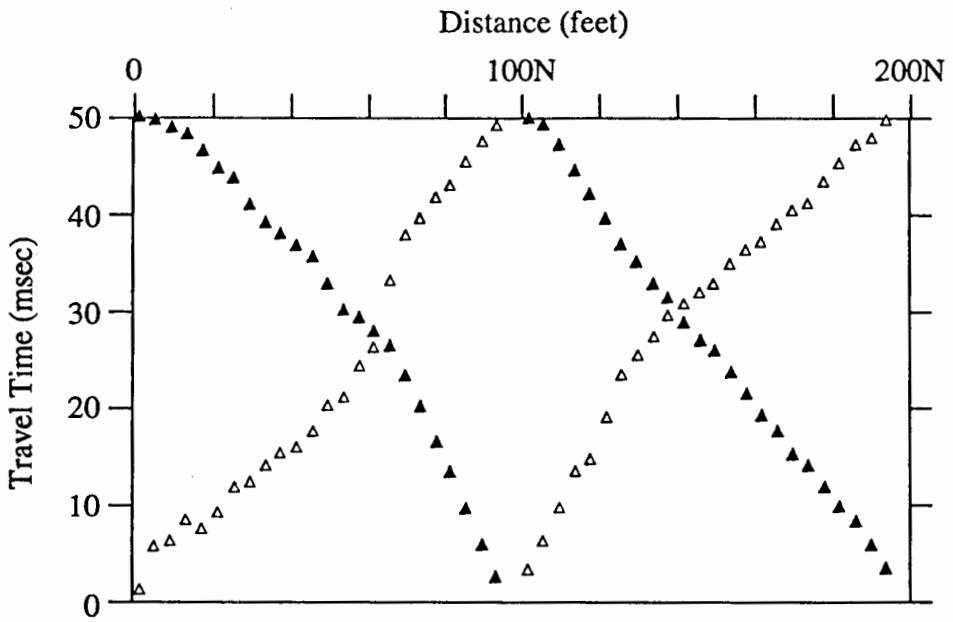
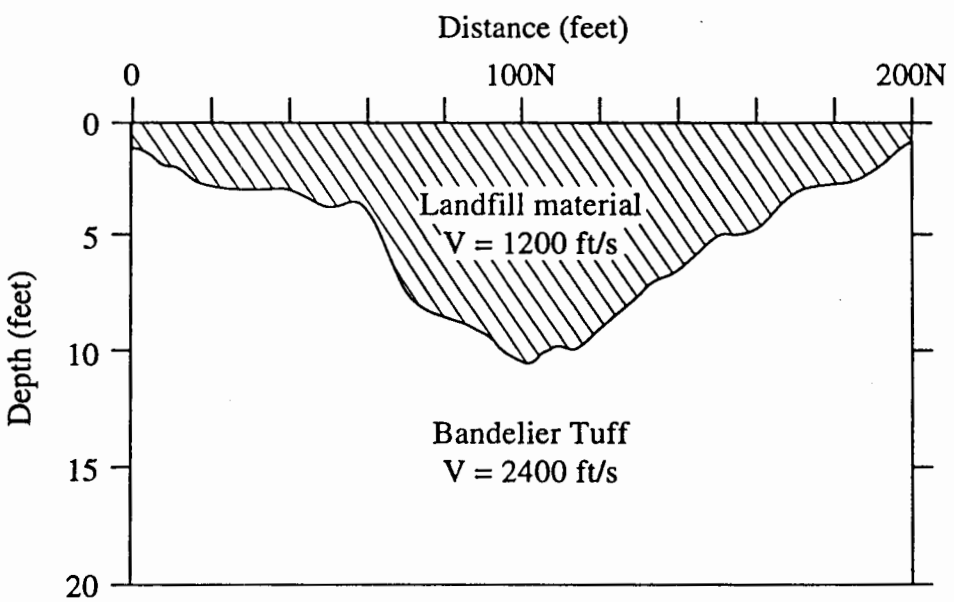
Figure 8. Index map showing seismic refraction survey locations.



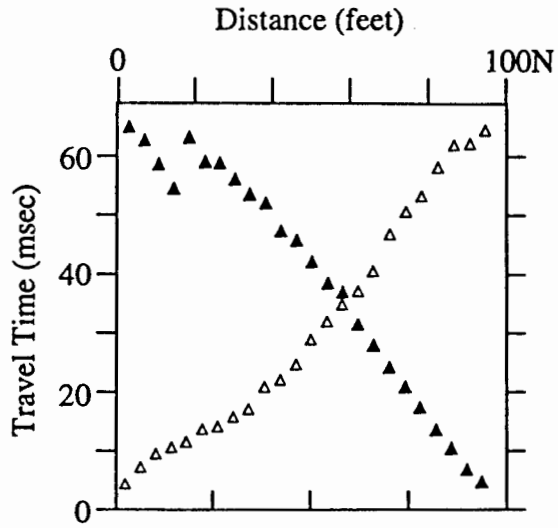
Travel Time Plot



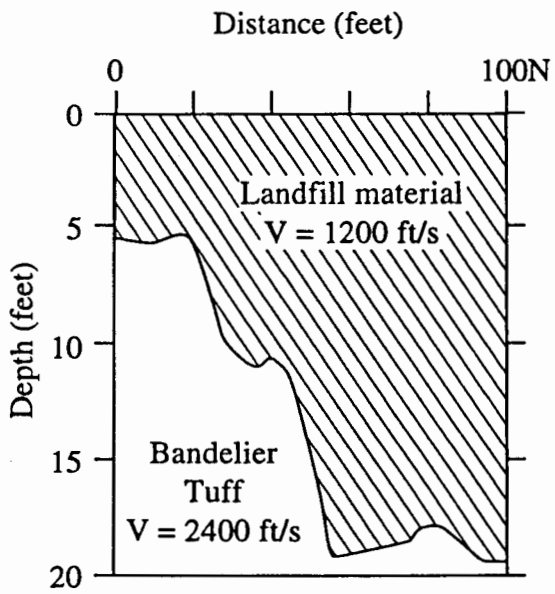
Seismic Profile

Geophex

Figure 9. Seismic profile and travel time plot from 700E.



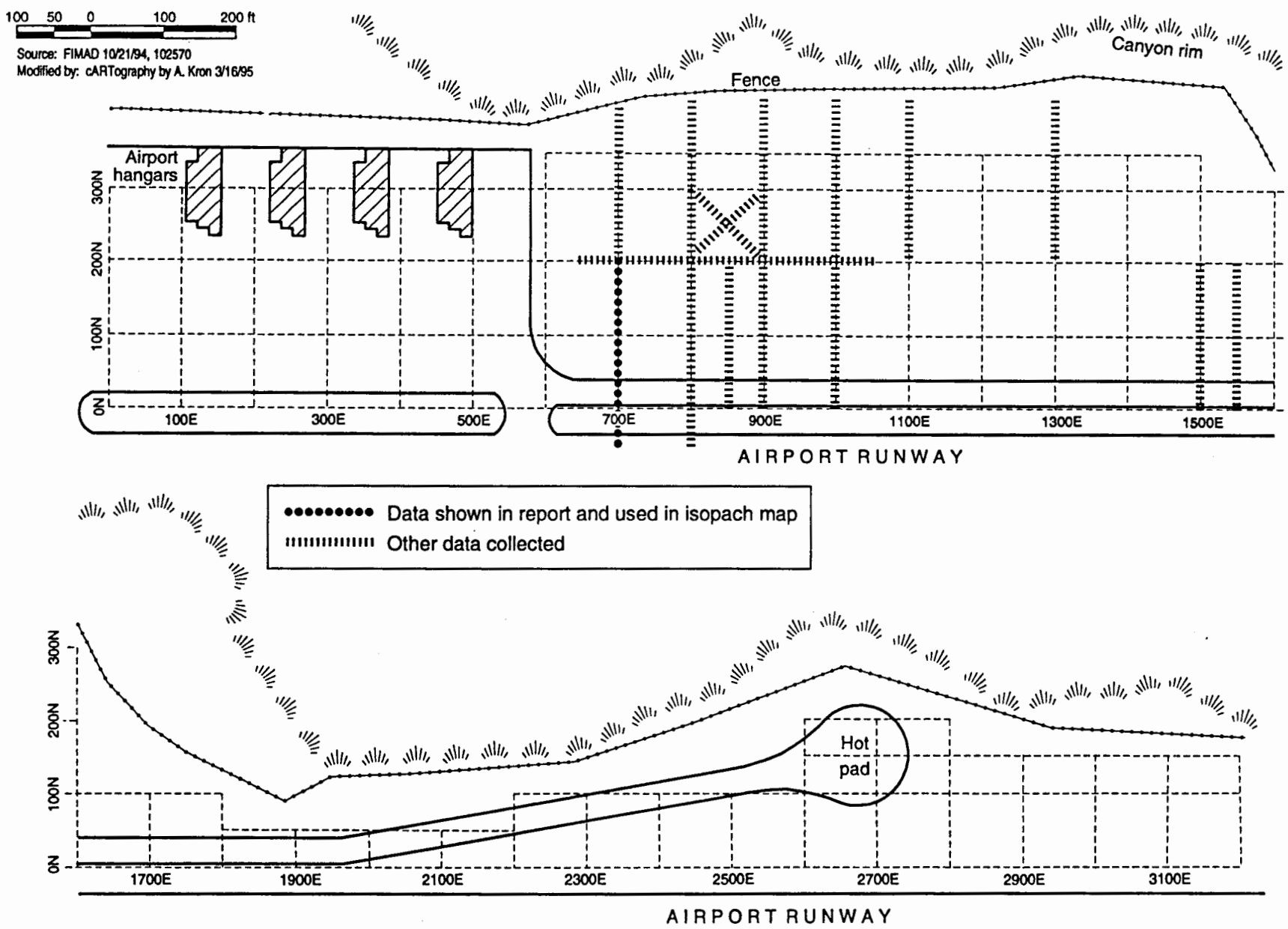
Travel Time Plot



Seismic Profile

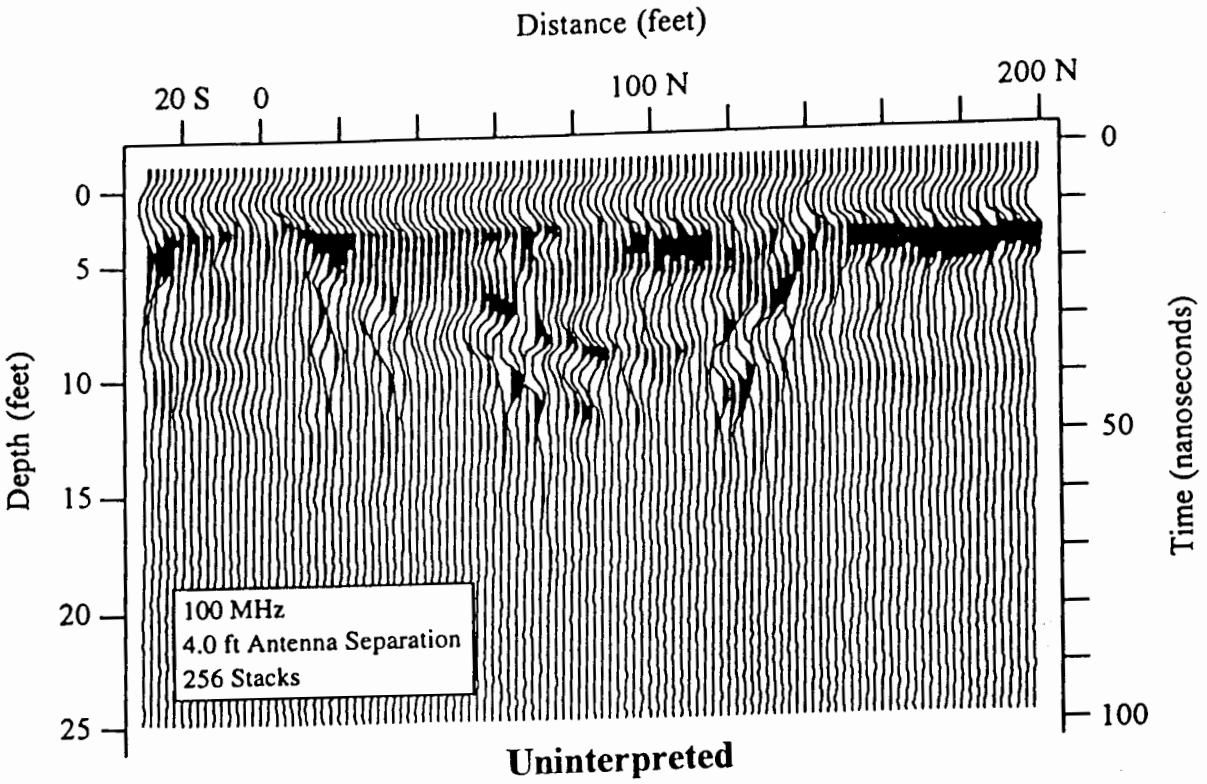
Geophex

Figure 10. Seismic profile and travel time plot from 1000E.

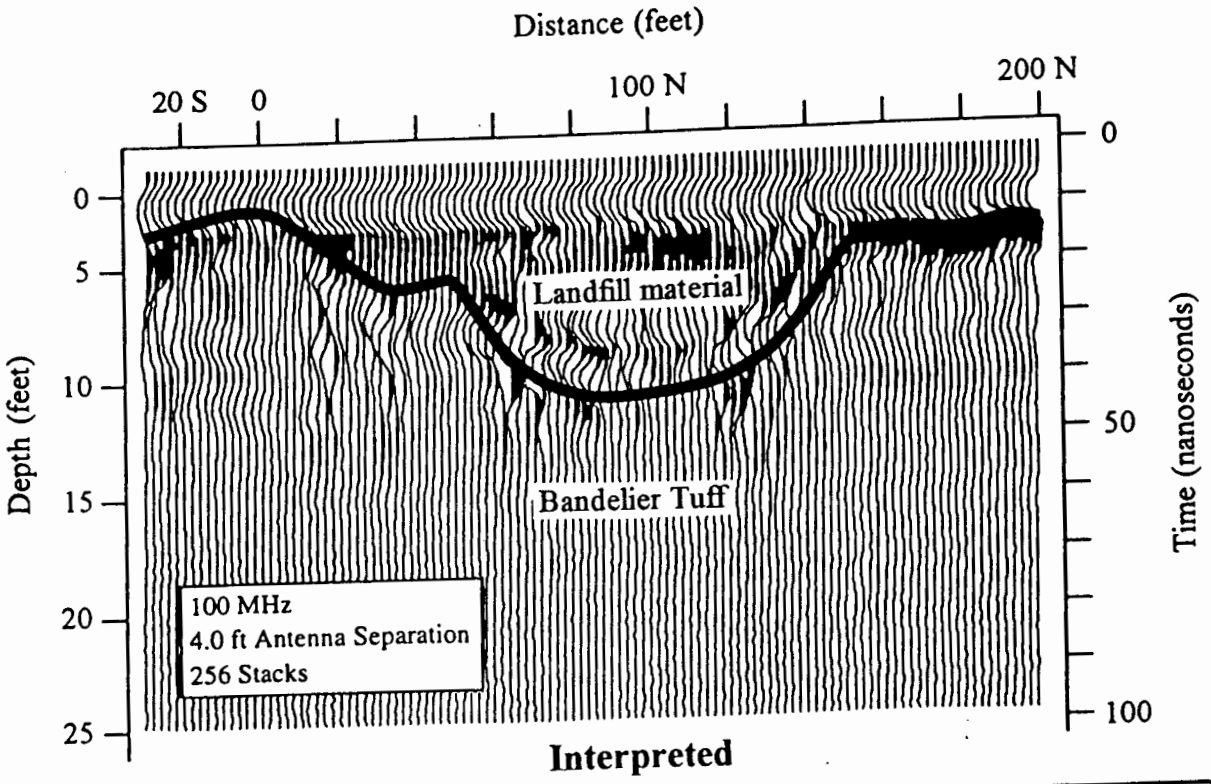


Geophex

Figure 11. Index map showing GPR survey locations.



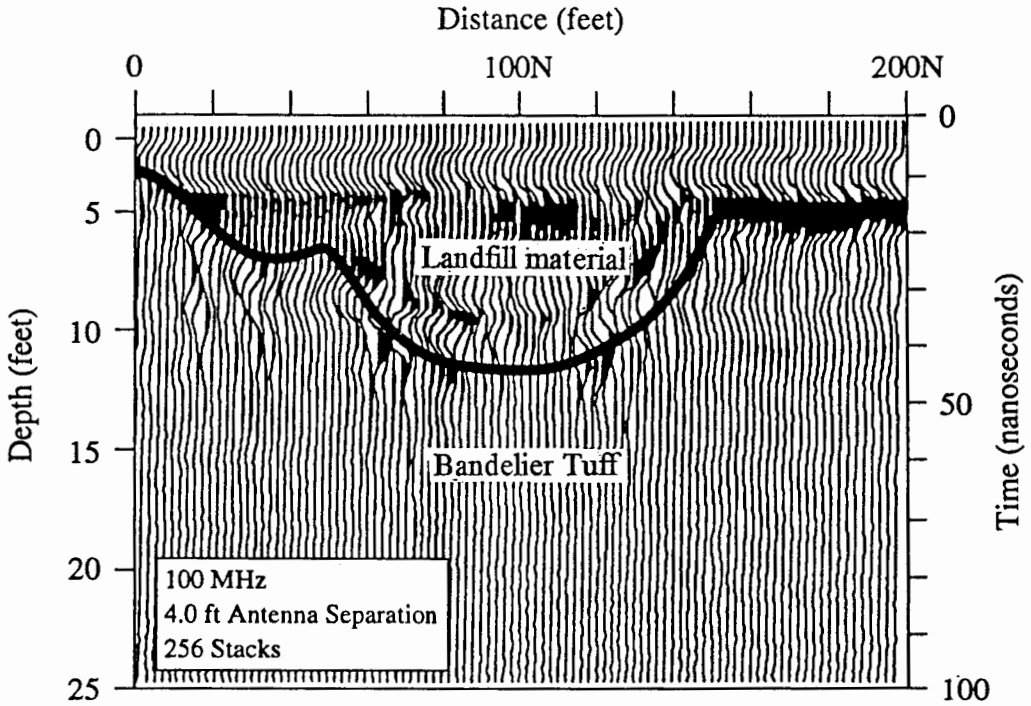
Uninterpreted



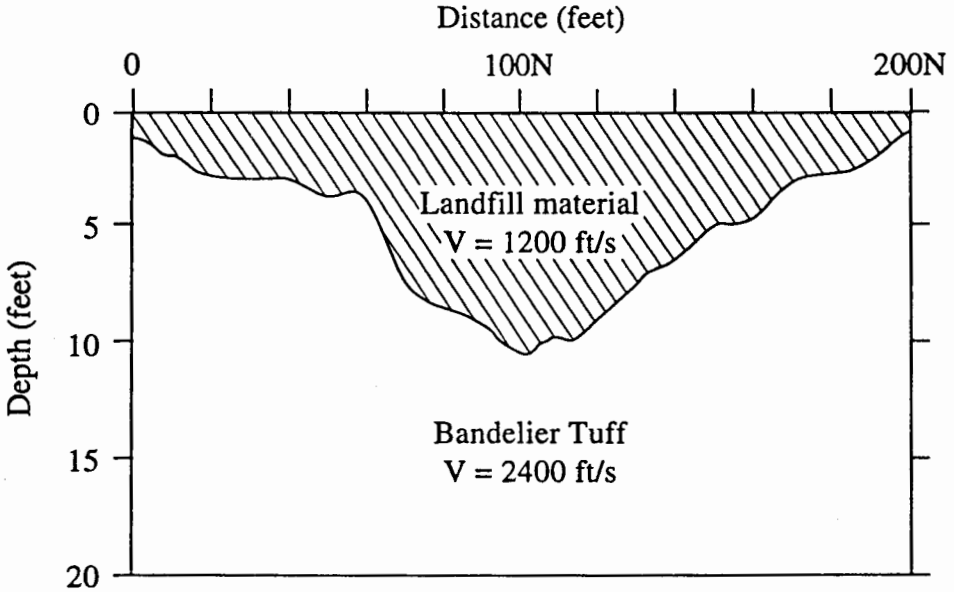
Interpreted

Geophex

Figure 12. Uninterpreted and interpreted versions of GPR profile 700E.



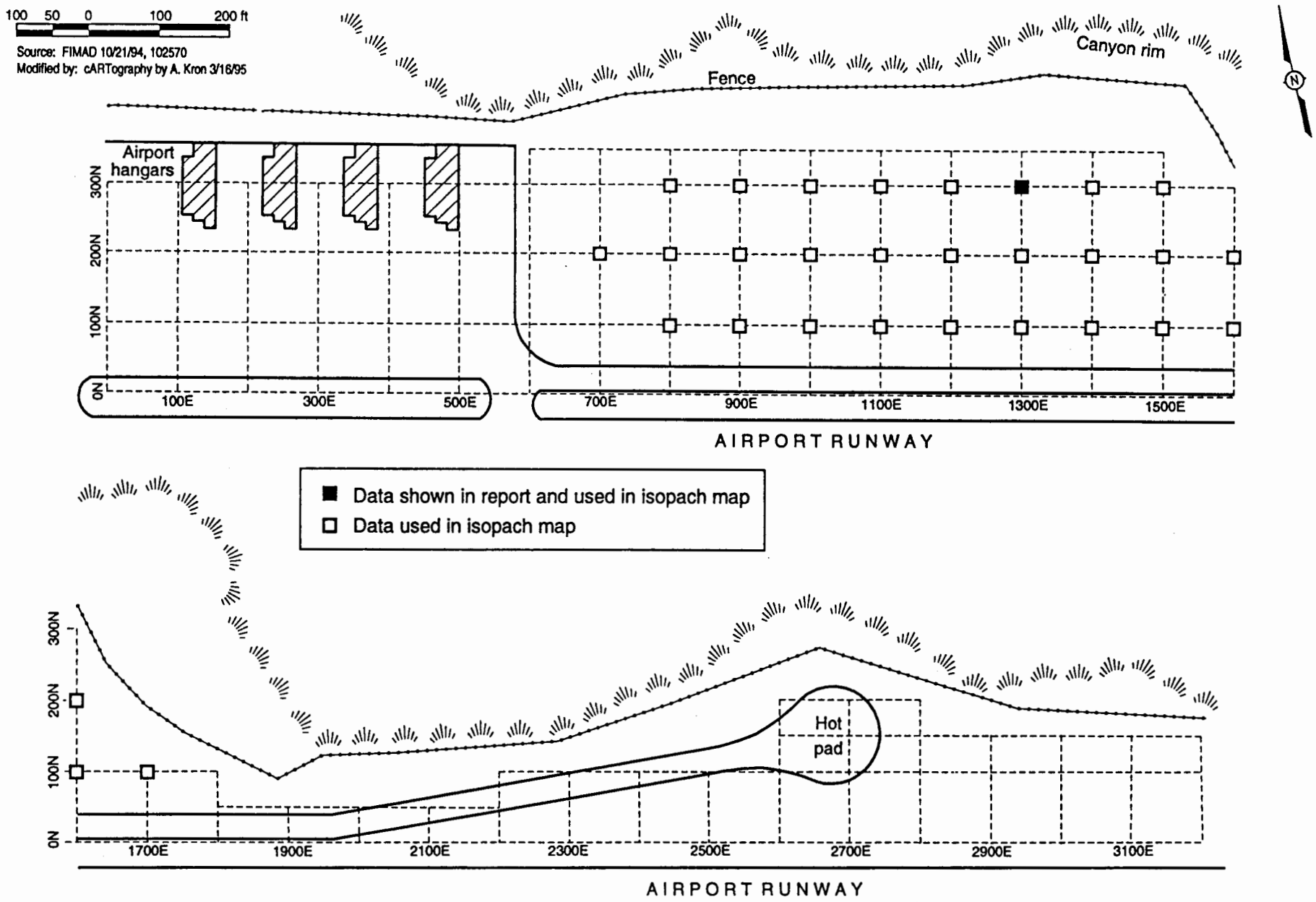
GPR Profile



Seismic Profile

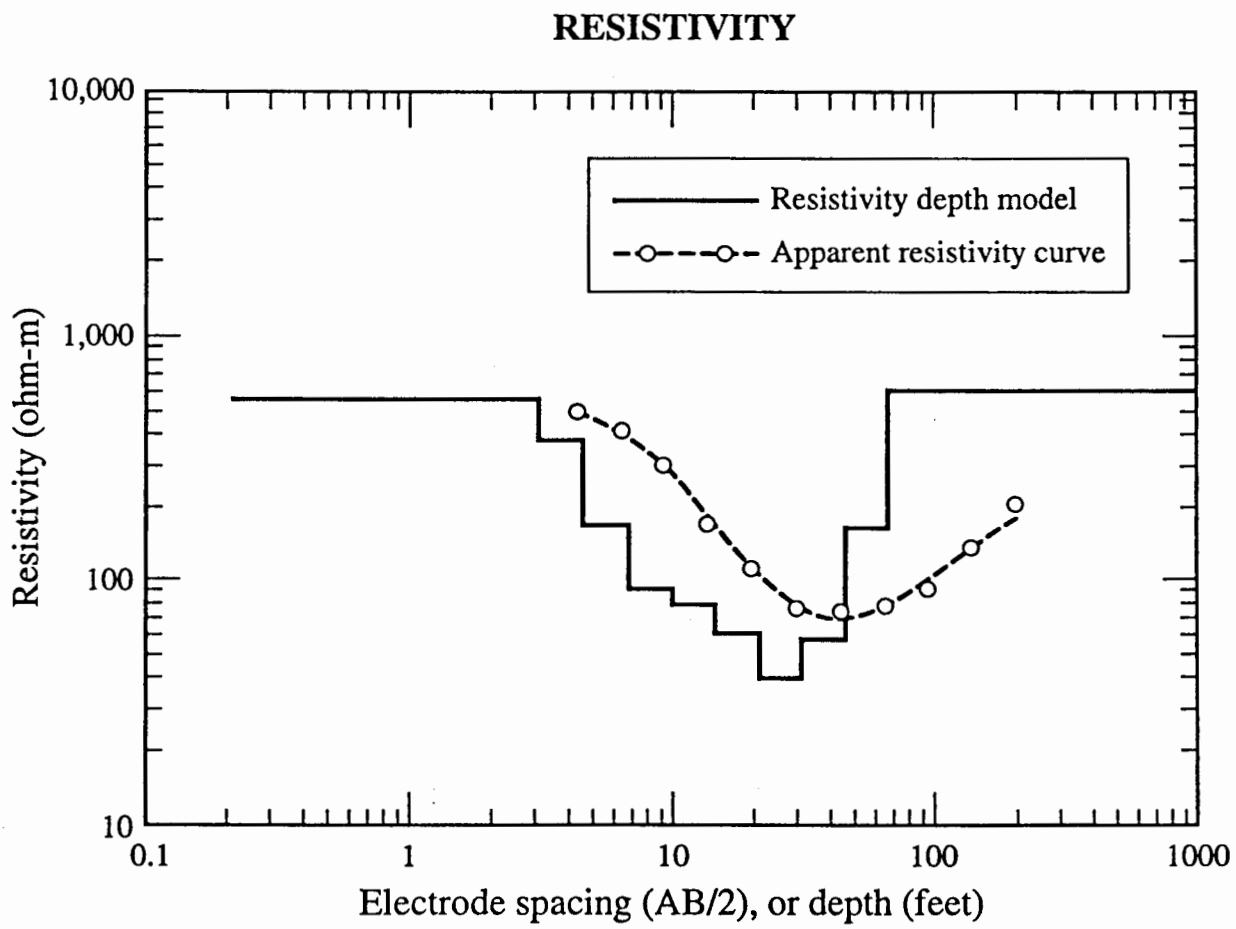
Geophex

Figure 13. Comparison of GPR and seismic profiles along 700E.



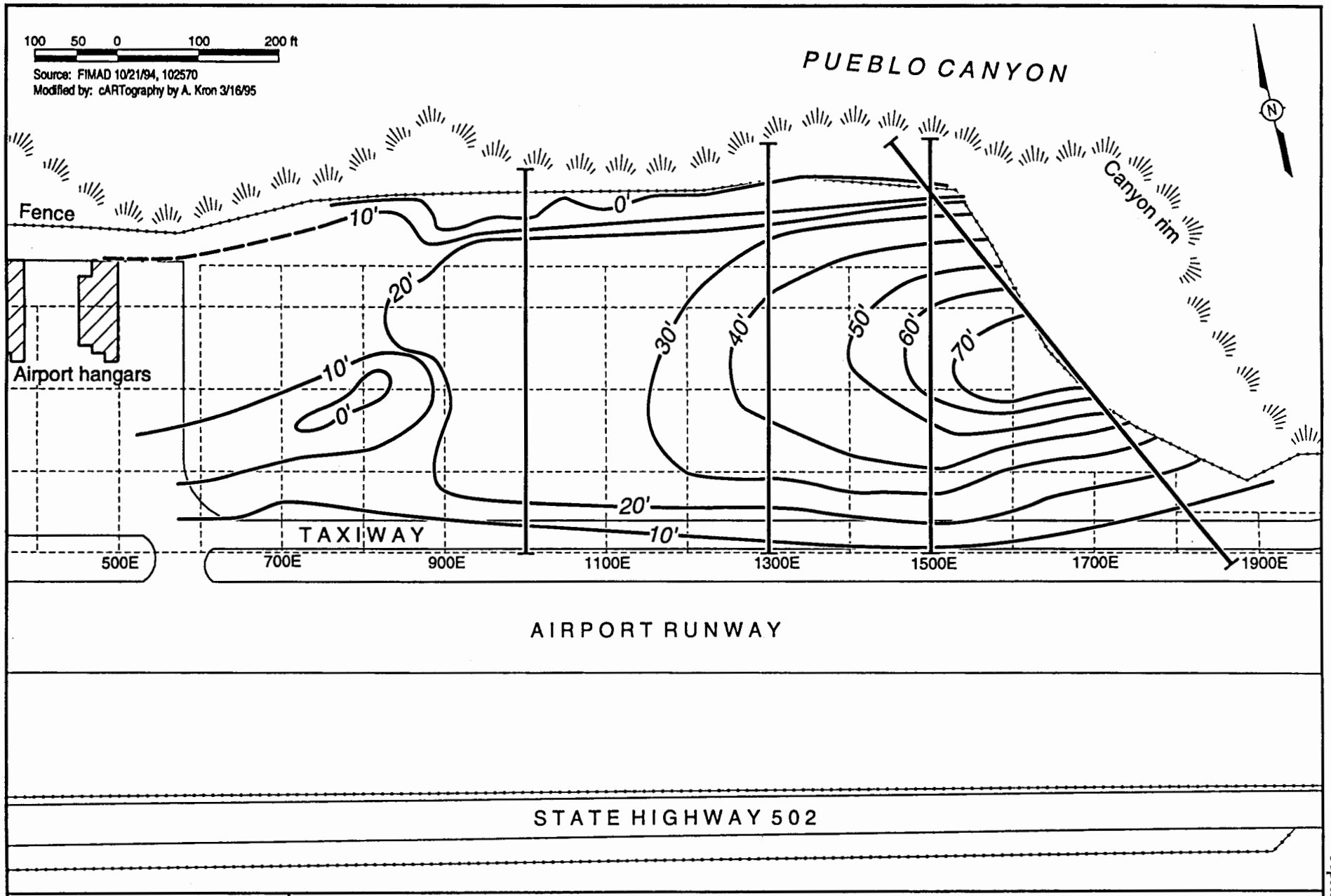
Geophex

Figure 14. Index map showing VES survey locations.



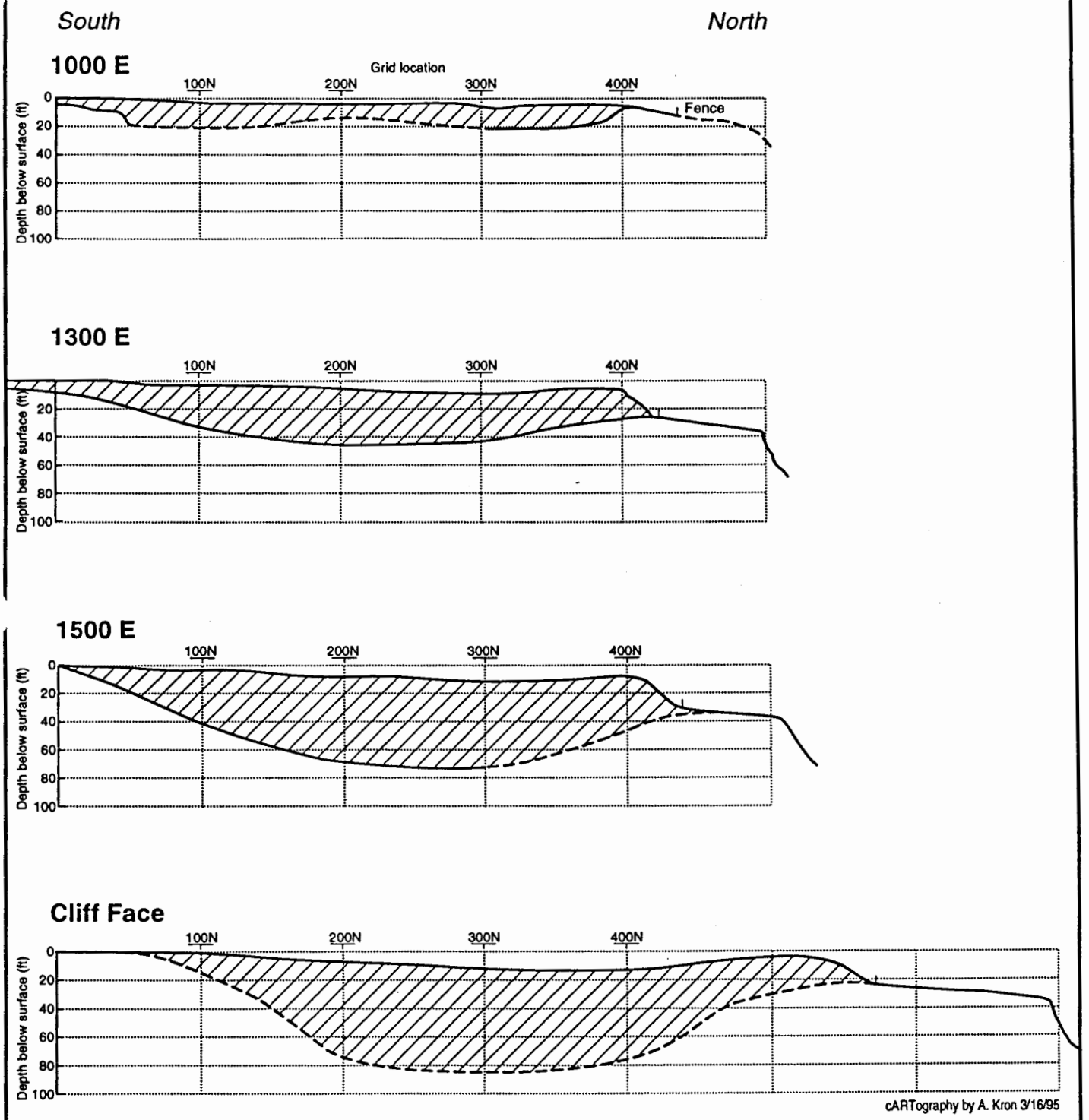
Geophex

Figure 15. VES plot from 1400E—300N.



Geophex

Figure 16. Isopach map of landfill thickness and locations of cross sections.



Geophex

Figure 17. Four cross sections of the landfill structure.