United States Department of Agriculture
Soil Conservation Service

Northeast NTC
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Chester, PA 19013

Subject: SOI - Ground-penetrating Radar (GPR) assistance at Old Fort Niagara, Youngstown, New York

Date: May 29, 1987

To:
Paul A. Dodd
State Conservationist
Soil Conservation Service
Syracuse, New York

File code: 430-7

Purpose:

To use ground-penetrating radar (GPR) techniques to detect subsurface historical remains within Old Fort Niagara.

Participants:

James A. Doolittle, Soil Specialist (GPR), SCS, Chester, PA
Tyrone M. Goddard, Soil Scientist, SCS, Syracuse, NY
Dr. Patricia Scott, Ass't Director of Archaeology, Old Fort Niagara Association, Youngstown, NY
Dr. Stuart D. Scott, Associate Professor, SUNY, Buffalo, NY

Background:

Old Fort Niagara represents one of the most significant archaeological sites within the Great Lake region. Military occupation and settlements at this site dates back to 1679. Historic documents have indicated the presence of more than two hundred buildings and fortification elements (Dunnigan, 1985) within the historic site. Most of these structures were erected and later demolished to "meet the requirements of defense, habitation, and storage".1. Sketches of schematic plans have been prepared based on contemporary plans, descriptions, and notes .

A ground-penetrating radar site evaluation was requested to provide a rapid, non-destructive survey which would pin point buried structures or artifacts. Results from this site investigation will be compared with existing schematic plans and records, and used to assist archaeological research and conservation at Old Fort Niagara.

Discussion:

The radar survey was confined to the grassy parade ground within the Fort. Grids were constructed in the north and northwest portion of the parade ground with flags at ten foot intervals. Thirty-five transects were completed with the radar.

The survey was successful. The radar revealed many subsurface features including suspected structural sites, foundation walls, rubble, drainage ditches, and sewer and cable lines. The survey charted the location of a natural drainage channel, confirmed the existence of historic remains, and provided a graphic record of subsurface conditions which will assist future studies and excavations.

The study was reported in a local paper (Gazette, 4/24/87) and the article has been enclosed in this report. Additional technical comments concerning this survey are enclosed in the accompanying attachment. All of the radar's profiles have been turned over to the Scotts for review and interpretation. Additional copies of the profiles have been saved on magnetic tape and are available on request.

JAMES A. DOOLITTLE Soil Specialist (GPR)

Enclosure

cc:
Arthur B. Holland, Director, NENTC, SCS, Chester, PA
Dr. Stuart D. Scott, Assoc. Professor, SUNY, Buffalo, NY
Diane E. Gelburd, National Cultural Res. Specialist, SCS, Washington, D.C.

Attachment

The USDA-Soil Conservation Service cooperates with numerous agencies and organizations to protect, survey, document, and exhibit archaeological resources. Recently, the need for SCS to disseminate archaeological public awareness information was stressed in a national bulletin (USDA-SCS, 1987).

The excavation of an archaeological site is often a long, labor-intense process. In recent years, ground-penetrating radar (GPR) techniques have been used to locate buried artifacts in various areas of the United States and Canada (Bevan, 1984a and 1984b; Bevan and Kenyon, 1975; Bevan et al., 1984; Kenyon, 1977; Parrington, 1979; Vaughan, 1986; Vickers and Dolphin, 1975; and Weymouth and Bevan, 1983). These studies document the nondestructive efficiency of using GPR methods to pinpoint buried artifacts. The data collected from these studies have been used to locate buried artifacts, facilitate excavation planning, and aid site interpretations.

During the past six years SCS has expanded the use of ground-penetrating radar (GPR) techniques. In an effort to transfer this technology, SCS has used GPR techniques at various archaeological sites. These sites include: Cahaba, Alabama; Marshall Hall, Maryland; Quaker Meeting House, Easton, Maryland; and Barratt Chapel, Frederica, Delaware. The GPR field study at Old Fort Niagara, Youngstown, New York, provided a unique opportunity to futher test field procedures and develop interpretative skills while working with co-operating agencies to preserve our cultural heritage.

Ground-Penetrating Radar

The GPR used by in this investigation is the SIR (Subsurface Interface Radar) System-8 manufactured by Geophysical Survey Systems, Inc. The SIR System- 8 consists of the following major components: model 4800 control unit, ADTEK SR-8004H graphic recorder, ADTEK DT-6000 digital tape recorder, and model 30 program control unit (microprocessor). The microprocessor did not significantly improve the interpretation of subsurface features and was not used in this investigation. These components were "shock mounted" within a vehicle.

The model 3110 antenna (operating at a center frequency of 120 MHz) with the model 705DA transceiver provided the best balance of probing depth and resolution. The antenna was towed behind a four-wheel drive vehicle at an average speed of 2.0 km h-1.

The Survey Site

Old Fort Niagara is located on a point of land at the junction of the Niagara River with Lake Ontario. The site is located in an area of Hudson silt loam, 3 to 8 percent slopes (Higgins et al., 1972). Hudson is a member of the fine, illitic, mesic Glossaquic Hapludalfs family. Areas of Hudson soils are known to have relatively high electrical conductivities and are generally not suited to GPR operations.

The moist, high clay content, and calcareous nature of Hudson soils severely attenuates the radar signal and restricts its probing depth. In an earlier study conducted at Cornell University's Aurora Experiment Farm, the probing depth of the GPR was restricted to less than 50 cm in an area of Hudson soils.

The performance of the GPR is highly site specific and soil dependent. The maximum probing depth of the GPR is, to a large degree, determined by the electrical conductivity of the soil. Soils having high conductivities, such as the Hudson soils, rapidly dissipate the radar's energy and restrict its probing depth. The principal factors influencing the conductivity of soils are: (1) water content, (2) the amount and type of salts in solution, and (3) the amount and type of clays.

Moisture is the primary determiner of conductivity. Conductivity is essentially an electrolytic process that takes place through moisture-filled pores. As the soil becomes more saturated the rate of signal attenuation increases and the probing depth is restricted.

Hudson is a moderately well drained soil with a perched water table at depths of .45 to .60 meters during the months of November through April. Internal drainage is slow. This survey was conducted in early spring when the soil was moist throughout. Returning to the Fort at a drier period of the year would probably result in an increase probing depth for the radar.

Conductivity is related to the concentration of dissolved salts in the soil solution. Hudson soils formed in lake sediments. These sediments are calcareous. Reaction of the substratum ranges from neutral to moderately alkaline.

The electrical properties of many soils are strongly influenced by the amount and type of clay minerals present. Ions absorbed on the surface of clay particles can become partially dissociated or exchanged, and contribute to the conductivity of the soil. Generally, smectite and vermiculite clays have a higher cation exchange capacity (CEC) than illite clays. However, illite clays have a higher CEC and are more conductive than kaolinite or gibbsite.

Hudson soils are fine-textured and are illitic. Clay content ranges from 35 to 60 percent.

Generally, areas of Hudson soils are recognized as being an inhospitable environment for the use of GPR techniques. However, several factors have extended the radar's probing depth and contributed to the success of the GPR investigation at Old Fort Niagara. These factors include the electromagnetic characteristics of the included soils, the the fill materials, the buried artifacts; and the limited required depth of probing.

Commonly included with Hudson soils are areas of Cazenovia (fine-loamy, mixed, mesic Glossoboric Hapludalfs), Claverack (sandy over clayey, mixed, nonacid, mesic Aquic Udorthents), and Ovid (fine-loamy, mixed, mesic Aeric Ochraqualfs) soils. These soils have lower clay contents in the solum and are less attenuating to the radar signal. Though not confirmed in the field, it is possible that the survey sites are located in areas of these less restrictive soils.

The fill materials are suspected of being more resistive and therefore less attenuating and depth restricting than the surrounding lake sediments.

The majority of the artifacts discerned on the radar's graphic profiles are not deeply buried. Rates of signal attenuation and probing depths become less critical as the required profiling depth of a radar survey becomes shallower. Also, the artifacts are composed of dissimilar materials which significantly contrasted with the soil and give rise to relatively strong radar reflections. As a general rule, the more abrupt and electrically contrasting an interface separating two materials, the stronger the reflected radar signal.

Survey Procedures

The study areas within Old Fort Niagara have been extensively research by Dr. Patricia Scott and Dr. Stuart Scott. Since 1979, the Scotts have excavated and identified several buried structures and recovered numerous artifacts. Maps, based on historic documents, have been prepared depicting the assumed locations of various structures. The primary objectives of this survey were to: (1) locate a filled drainage channel and (2) confirm the presence and chart the locations of former architectural structures.

Linear features such as drainage lines or buried wall foundations are easily detect by conducting several parallel traverses with the GPR. Generally, reliable detection of a buried structure requires similar imagery on three to six transects. Buried wall foundations and filled drainage lines are most easily identified when radar transects are made in a direction which is perpendicular to their orientation.

The most efficient method to chart the location of buried artifacts is to prepare a grid on the area to be surveyed. The grid spacing is dependent upon the purpose of the survey, the time available for the survey, the features being identified, and the desired level of accuracy. Bevans (1984b) described three levels of surveying intensities for the GPR. These levels include: (1) locating a buried site, (2) defining the boundaries of an archaeological site, and (3) charting the internal features of a delineated site. Generally, the spacing between grid lines decreases as the intensity increases with each of these levels.

The expected size of the features being located with the radar will dictate the grid spacing. In relatively detailed surveys, Vaughan (1986) used a 1 meter spacing to locate grave sites while Bevan et al. (1984) used a 1.5 meter spacing to locate buried wall foundations. For the survey of Old Fort Niagara, the grid spacing was 3 meters. The 3 meter spacing was determined by (1) the reconnaissance nature of the survey (Bevan's level 2), the time available (3 days), the features being identified (a filled drainage channel and major buried architectural features), and the desired level of accuracy (detection of most major buried structures).

Grids were constructed in the north and northwest portion of the parade ground. An engineering transit was used to establish grid corners and surface elevations. A wire, with markers affixed at 3.05 meter intervals, was stretched between opposite grid corners. Flags were placed in the ground at each 3.05 meter marker along the wire to establish transect end points. The wire was then extended between each opposing transect end points and flags were placed in the ground at each 3.05 meter mark to complete the grid. In this manner, two grids were established with markers at 3.05 meter intervals. The two grids were irregular in shape and consisted of a total of thirty-five grid lines. The length of the grid lines varied from 31.4 to 79.2 meters.

After the grids had been established, properly marked and recorded, the antenna was towed by the four-wheel drive vehicle along each grid line at an average speed of about 2.0 km h-1. As the antenna past each flagged reference position along a grid line, the operator depressed an event marker which impressed a dashed vertical line on the graphic profile. The dashed vertical lines represent know reference points along the graphic profiles and were used to determine the location of identifiable images.

Interpreting the Graphic Profiles

The interpretation of the radar's imagery requires more time and effort than the acquisition of the profiled data. Interpretations require excavations to correlate the radar imagery with observed features and to determine what features were and were not detected.

The enclosed figure demonstrates how a profile should be analyzed for interpretations. The two profiles in this figure are, with the exception of the annotation, identical. The effective depth of consistent probing is about 30 nanoseconds. This corresponds to an approximated probing depth of about 1.1 meters (assuming a dielectric constant of 15 for wet clayey soils). The dashed vertical lines identify reference points which have been spaced at 3.05 meter intervals.

In each profile, the first two horizontal black lines are reflected images from the surface. The next dark band is a composite reflection from several surface and near surface features. Images are generally displayed in groups of multiple dark bands unless limited by high rates of signal attenuation or the proximity of two or more closely spaced interface signals. These bands, produced by oscillations in the reflected signals, limit the ability of the radar to discriminate shallow or closely spaced interfaces.

Below the images from the surface and near surface features are the images from subsurface interfaces. Interfaces can be categorized as plane reflectors or point objects. Most soil horizons, layers of debris, and filled pits or drainage channels will appear as plane reflectors: parallel multiple bands similar to those appearing throughout this figure.

Small objects, such as rocks, buried pipes or foundation walls (when crossed perpendicular to their long axis) will appear as point objects and will produce hyperbolic patterns similar to the images designated by the letter "a" in the lower profile. Variations in the shape of the hyperbola are caused by variations in: (1) the angle at which the feature was crossed, (2) the speed of antenna advance across the top of the feature, (3) the velocity of pulse propagation, and (4) the shape and orientation of the buried object.

Unless sufficient ground-truth observations are made, few images can be identified with a high degree of confidence on radar profiles. In some instances, researcher are tasked with making interpretations as excavations progress and independent of the radar specialist. This task can be simplified by dividing the radar profiles into areas of similar graphic imagery or signatures. This has been accomplished in the lower profile. In this profile eleven distinct zones have been identified. Note that each zone has a unique graphic signature and is abruptly terminated by vertical breaks. The unique graphic signatures in each zone are based on a discrete site history. Abrupt vertical breaks in the radar imagery are indicative of mans activities. Naturally occuring soil horizons or geologic strata will seldomly be abruptly truncated. Note that several zones are superimposed. Superimposed layers were expected in areas known to have had a complicated history of use.

It is believed that all delineated zones appearing in the enclosed figure represent unique areas of historical use(s). Many may corespond with the location of former structures. Most of the planar imagery are assumed to represent layers of debris, earthen floors to structures, or sequential deposits of fill. Most of the hyperbolic patterns in this figure are believed to be foundation walls. Zone "5" appears to have the highest concentration of rubble and buried wall foundations.

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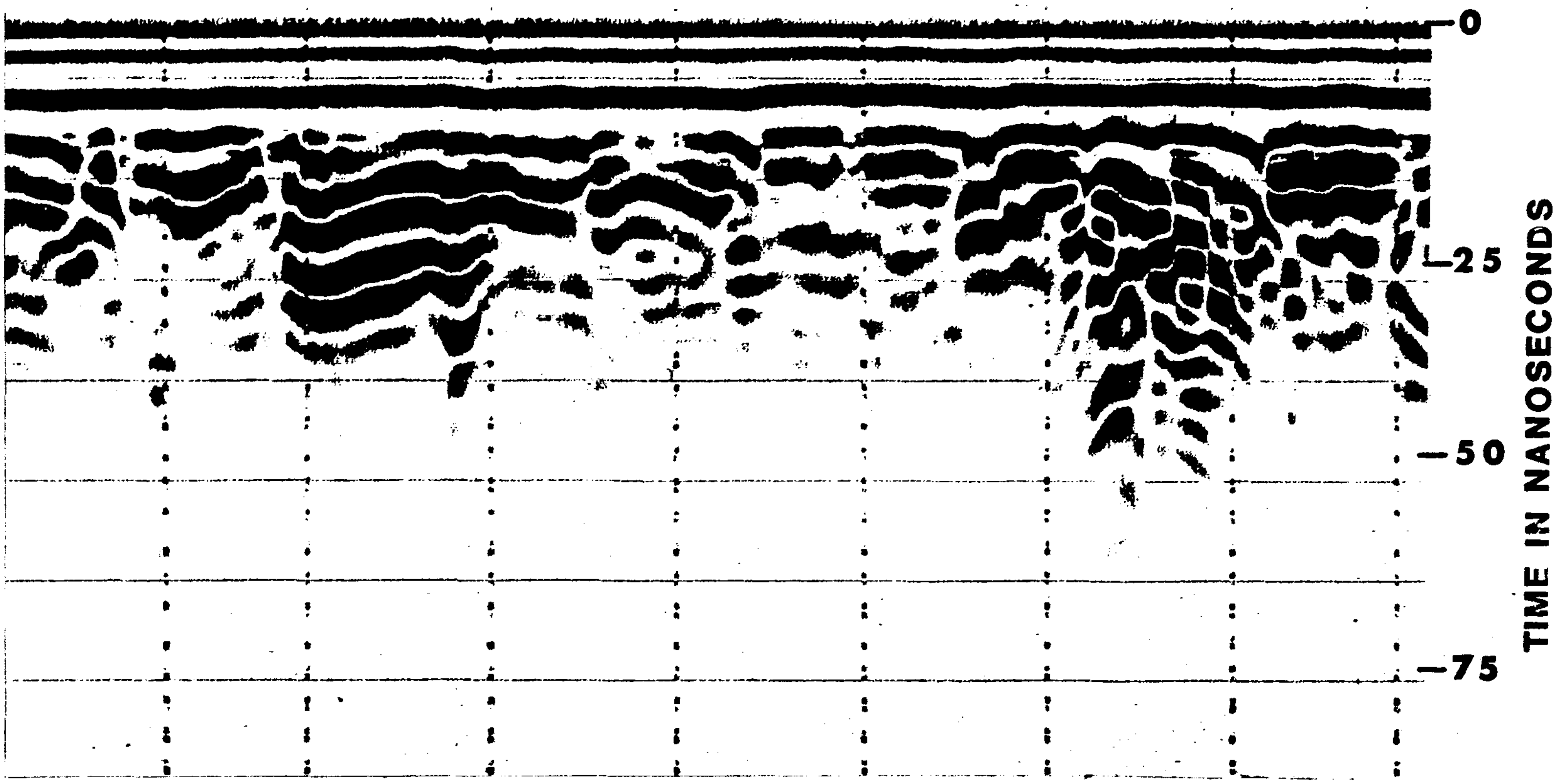
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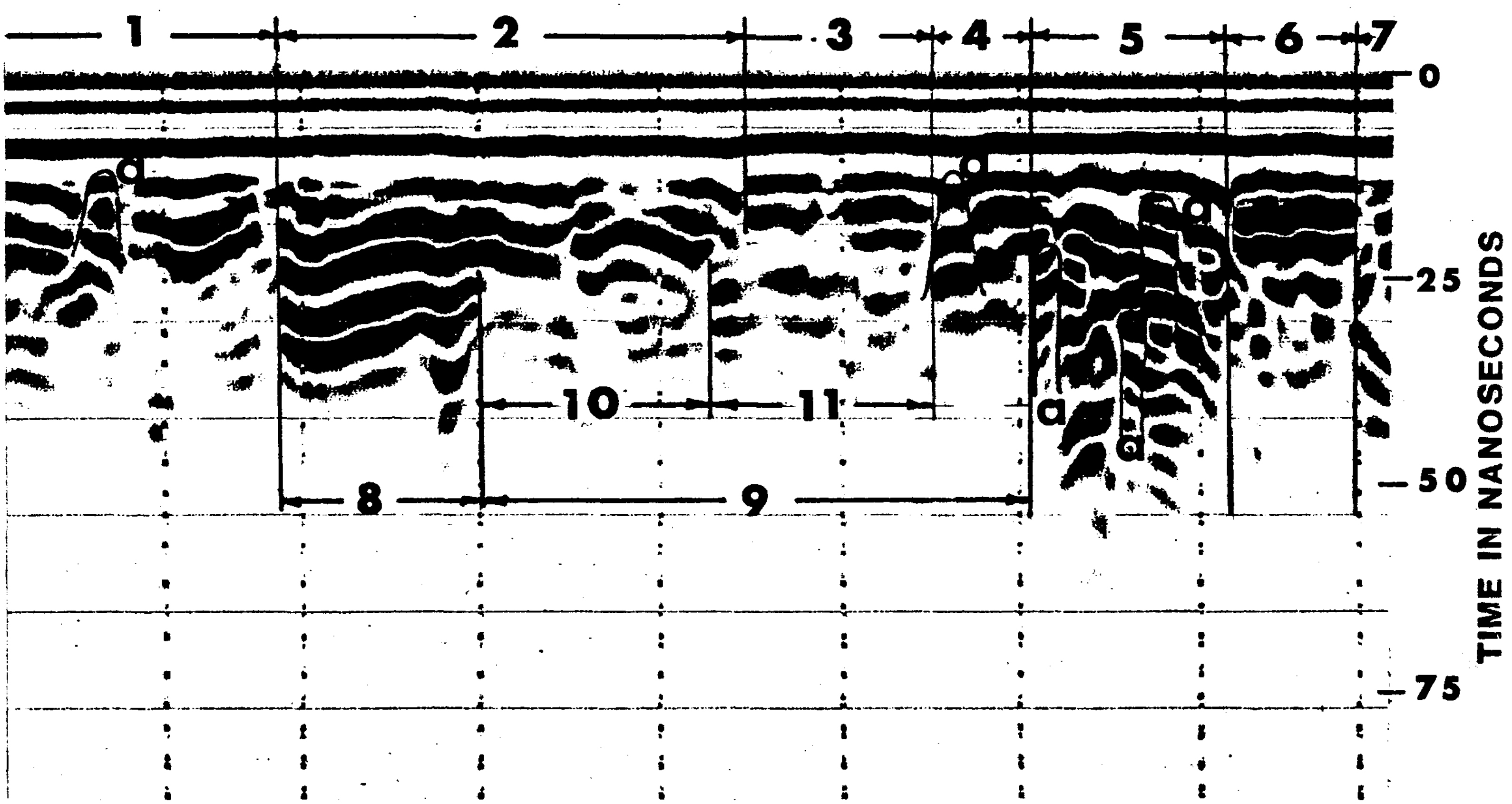
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TIME IN NANOSECONDS

Archaeologists peer below fort with radar's aid

By JOHN CURRAN
Niagara Gazette

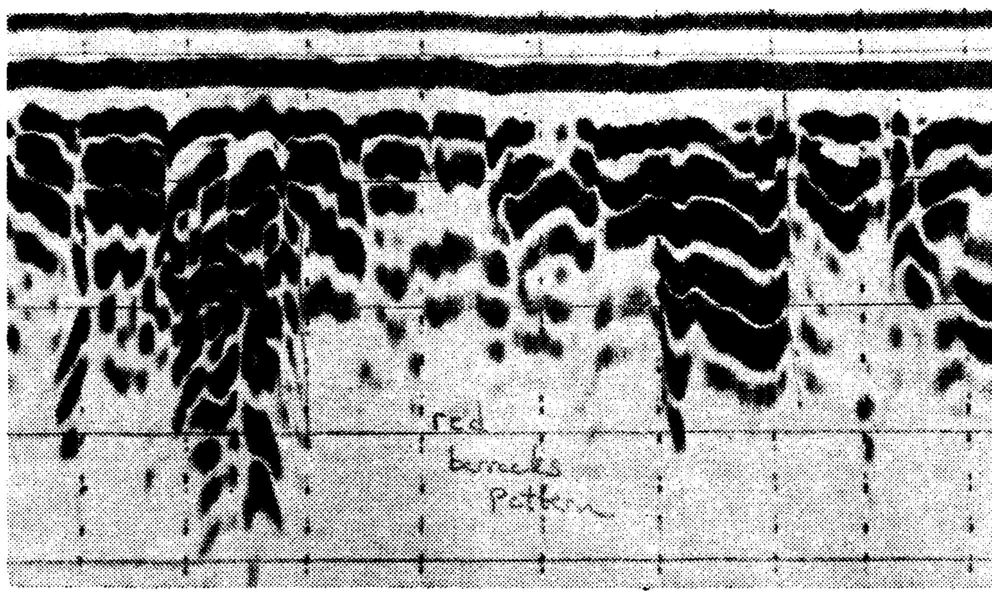
YOUNGSTOWN — Indiana Jones may use a bullwhip and a pistol to find his artifacts, but at Old Fort Niagara, they're counting on considerably more modern techniques to find out what lies beneath.

Using ground-penetrating radar, archaeologists and a U.S. Department of Agriculture soil specialist spent three days this week doing a subsurface survey of a 250-by-120-foot area on the fort's main parade plain.

Unlike movie hero Jones, they didn't find any lost arks, but archaeologists Stuart and Patricia Scott said Thursday the probe confirmed the existence of foundation walls, drainage ditches and sewer lines they already knew were there. It also showed a cannonball.

"Our philosophy is to learn as much as you can, with the least destruction," said Mrs. Scott, who, with her husband, conducts the fort's Archaeology in Progress program. "The point is to find out as much as we can about the archaeology and history of the fort without excavating, which is costly, time-consuming and damaging," said Mrs. Scott.

Enter James Doolittle, a Philadelphia-based U.S. Department of Agriculture soil specialist who travels around the country with a Jeep and $70,000 worth of radar equipment conducting subsurface investigations for government agencies and not-for-profit groups.



JAMIE GERMANO — Niagara Gazette

In the top photograph, Archaeologist Stuart Scott operates a ground-penetrating radar used at Old Fort Niagara to identify artifacts underground. The other photo is a graphic picture formed by radar images of subterranean structures. For three days a week, a soil specialist using ground-penetrating radar scanned the ground beneath a parade plain, producing "pictures" that confirmed the existence of foundation walls from former buildings.

The ground-penetrating radar is used in mining, agriculture and archaeology, Doolittle said.

The area of investigation was divided into a grid, and Doolittle dragged the radar over the area, row by row. The device sends electromagnetic waves into the ground, which bounce off of subsurface structures and paint a graphic picture of what lies below.

The information is transcribed onto cassette tapes that can be reproduced and used for archaeological research.

"I didn't think it was going to work here, because of the high clay content of the soil, which absorbs the energy. But it's worked very well. For what they want to see, it reveals quite a bit," Doolittle said.

The archaeologists already had maps that told them where some structures used to stand. "We've had some spectacular results," said Mrs. Scott. "We've been able to confirm what we'd already suspected, and say "There's a wall we didn't know about," she said.

Her husband said it will take two years to "ground test" the results of the underground survey, but he said once that is done the radar method can be used to probe areas for which no maps exist, and to identify subterranean structures.

"It's really exciting," said Mrs. Scott.