A GEOPHYSICAL SURVEY OF THE GREAT PLAZA, AND
GREAT BALL COURT AT CHICHÉN ITZÁ, YUCATÁN, MEXICO
(February 4-10, 1993)

by
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Abstract
A geophysical survey of selected areas of the Great Plaza and Great Ball Court at
Chichen Itza was carried out February 4-10, 1993 using ground penetrating radar, and
electrical resistivity. Ground penetrating radar was used to survey more than six
kilometers of transects, and 144 Megabytes of data was recorded by the computer. The
electrical resistivity of 30 meter squares in both the Great Plaza and Great Ball Court
was measured in 1,800 discrete locations. Analysis of the data from the ground
penetrating radar survey has provided topographic contours of the bedrock from radar
reflection time depth estimates, and identified discrete natural or cultural features. The
resistivity method detected conductivity variations in the survey areas with some effects
due to contemporary cultural features.
"It seems that I am in the land
of the gods--the rising sun comes
up very big and hot looking through
the thin cool early morning mist
that hovers over these pyramids
and temples with the dawn..."
Georgia O'Keeffe at Chichen Itza.
February 23, 1951.

**Introduction**

Plans for a ground penetrating radar project originated in 1977 with discussions between Lawrence Desmond, an instructor of archaeology at Foothill College, and Lambert Dolphin and Roger Vickers, geophysicists with the Radio Physics Laboratory of nearby SRI International in Menlo Park, California. Both Dolphin and Vickers had extensive experience using ground penetrating radar, and in 1974 they had participated in a joint project in which SRI International had collaborated with Egypt's Ain Shams University, and the Egyptian government's Organization of Antiquities to survey the pyramids at Giza. In 1977 they returned to continue their survey using electrical resistivity, acoustical sounding and aerial infrared imagery. The main problem they faced at Giza in the use of ground penetrating radar was high radio frequency losses due to the type of limestone in the area which made radar a poor choice for a remote sensing survey of that location.

Chichen Itza, which sits on limestone bedrock, seemed to Desmond to be an ideal location to carry out a ground penetrating radar survey, but Dolphin and Vickers cautioned that without analysis of the limestone it was not possible to predict the effectiveness of radar. And, such an analysis would not provide a complete answer since the quality of limestone bedrock might vary in different areas. They suggested samples be gathered, tested and if the results looked promising attempt a survey.

In 1985, four limestone bedrock samples from the vicinity of Chichen Itza were analyzed by SRI International. Thomas Yetter, an assistant to Dolphin at the Radio Physics Laboratory, made the radio frequency loss measurements. Early in 1986, in a report of their analysis, Dolphin stated, "What you can see...is that the limestones are quite low in losses even when wet and the losses are not severe at high frequencies where resolution is excellent. We are greatly encouraged to see that ground penetrating radar appears so ideally suited for probing into structures and into the ground at Chichen Itza" (Dolphin 1986).

Encouraged by the Dolphin-Yetter report, the Instituto Nacional de Antropologia e Historia (INAH) was contacted to determine when a project might be scheduled. At the same time efforts were made to find a geophysicist who had equipment available and would be willing to carry out a survey at Chichen Itza.
Early in 1991, at a meeting of the American Association for the Advancement of Science, William Sauck was asked by Desmond if he would be interested in carrying out a ground penetrating radar survey at Chichen Itza. Sauck agreed enthusiastically, and asked to be sent the Dolphin-Yetter limestone analysis. Sauck, a geophysicist with the Institute for Water Sciences at Western Michigan University, had experience applying geophysical techniques to archaeology in tropical environments and so was an excellent choice for the project. In his opinion a survey at Chichen Itza would have a good chance of success.

In the spring, Desmond, James Callaghan, director of the Fundacion de la Universidad Autonoma de Yucatan, A.C., Archaeologist Agustin Pena Castillo, co-director with Archaeologist Peter Schmidt of INAH's Proyecto Chichen Itza, and Alfredo Barrera Rubio, regional director for INAH in Yucatan met in Merida to discuss the project. It was agreed that the project would come under the direction of Proyecto Chichen Itza, and the Great Plaza and associated Great Ball Court would be the focus of our work. There were a number of other project locations suggested such as the area north of the Xtoloc Cenote, and the vicinity of the High Priest's Grave where additional chambers of known caverns might be located. But, a greater priority was given to a survey of the Great Plaza and Great Ball Court areas in order develop a contour map of the bedrock topography and determine the extent of terracing. Also, any remains of buried structures or other cultural features located during the process of subsurface mapping might add to our understanding of the architectural chronology at Chichen Itza. We set the date of our work to be the first two weeks in February 1992.

But, serious illness in Dr. Sauck's family caused us to postpone the project, and INAH agreed that its schedule allowed for the work to be carried out in February 1993. Late in 1992 with the assistance of James Callaghan, who had taken on the responsibility of field director, a number of last minute details were arranged with INAH such as authorization for the temporary import of equipment, project transportation, and official letters.

Since the project was part of INAH's Proyecto Chichen Itza we wanted to report our findings as quickly as possible to INAH archaeologists so that they could incorporate them into their on-going project. To provide a report of activities before Desmond returned to the University of Colorado, survey maps were prepared daily by John Muehlhausen and Kristen Zschomler, and notes were made by Sauck of the location of anomalies from the ground penetrating radar video display. In that way we were able to make a presentation at the INAH office in Merida, and provide a written summary of our work before departing.

**Background**

Ground penetrating radar uses high frequency radio waves which reflect from both natural and cultural subsurface features, and provides a two dimensional cross-sectional presentation which is used to evaluate details of subsurface conditions. Current ground penetrating radar systems are comprised of a central processing unit
and software which controls the capture and modification of radar data in RAM memory, and then transfers the data to a digital cassette. A video display provides an operator with real time monitoring of the subsurface as the antenna moves over it. Antennas come in a number of sizes and the choice comes after some testing at an individual site. From the small amount of data available to him on the subsurface of Chichen Itza, Sauck decided on two antennas: a 500MHz which is used for exploration down to two to three meters from the surface, and a 100MHz antenna for deeper surveying.

Ground penetrating radar systems also allow investigators to review survey data in color on a video display by recalling data from computer memory and tape or by printing the data out as hard copy in color or black-and-white. The system allows for a number of adjustments to maximize the radar antenna output to conform to a particular geophysical setting, provides further modification of captured data by filtering out external radio frequency noise and electronic artifacts generated by the equipment itself, and the color pattern of radar reflections can be changed at the monitor or on hard copy. These adjustments allow for a variety of analytical approaches and help in the visual identification of subsurface features. The plotted radar data is presented in two parts on one sheet in this report with field data below and processed data above (Figures 7, 8, 9, 10, 11).
The instrument used in this project is called a Subsurface Interface Radar System-10 and was manufactured by Geophysical Survey Systems, Inc. It was loaned to the project by the Institute for Water Sciences of Western Michigan University (Photos 1, and 2).

To survey the subsurface of the Great Plaza and Great Ball Court the central processing unit and monitor were mounted in the back of a pickup truck loaned by INAH, and Sauck controlled the unit from there (Photos 3, 4, 5). The radar was run on twelve volt auto batteries, and the antenna, connected to the central processing unit by a 15 meter cable, was dragged behind the moving truck by archaeologists along previously established transect lines (Photo 6).


Photos 3 and 4. James Callaghan driving truck with ground penetrating radar system in the back with William Sauck monitoring the subsurface image. Pic: L. G. Desmond. 1993

To layout the transect lines, a datum was set at the base of the northeast corner of the Castillo Pyramid and lines were laid out in the Great Plaza at 10, 5 and 2.5 meter intervals. Most of the survey was carried out in 10 meter intervals but in areas of special interest 5 and 2.5 intervals were used. Flags marked each 10 meters along a transect so that the location of the antenna along a line could be electronically marked by a switch operated by the archaeologist pulling the antenna (Photos 7 and 8). Thus, when the data from a transect is played back or printed, each 10 meters is marked on the video screen or on the print out. This provides the geographical control used in mapping bedrock contours and locating in three dimensional space unidentified subsurface features for further investigation.
In the Great Ball Court a similar system was used with two north-south transects the length of the court (Photo 9), two east-west transects in the center and one east-west in each end zone (Photo 10). A single transect was run from the Platform of Venus to the Cenote of Sacrifice (Photo 11).


Electrical resistivity is a well tested technique used to measure subsurface conductivity (how difficult or easy it is for an electrical current to travel through the ground). Different kinds of soil have different resistances to the flow of current. A loose, dry, sandy soil will probably have a higher resistivity than a moist, silty soil with a high concentration of ions, and a cavity will have very high resistivity.

In archaeology, measurements are usually taken systematically in the area to be investigated so that visual identification of soil change boundaries can be made using a dot-density computer generated printout. The data this technique provides to the archaeologist is one of several sources used to develop a research strategy and make decisions concerning excavations.

The type of resistivity instrument used in this project is called a RM15 Resistance Meter and was made by Geoscan, Inc. (Photo 12). Measurements were made by John Muehlhausen of the Institute for Minnesota Archaeology in Minneapolis which loaned the instrument to the project. The RM15 runs on eight "AA" 1.5 volt batteries and has two electrodes spaced at one meter that are attached to a light weight frame along with a portable computer (Photo 13). Two other electrodes which provide a return for the current flow and a voltage reference are connected to the computer with a long wire, and then inserted into the ground at distance of 30 meters from the area of survey. The electrodes are arranged in what is called a pole-pole array.

In operation, the electrode/computer unit is moved to each location to be measured and the electrodes are inserted into the ground (Photo 14). The computer senses when the electrodes have been inserted sufficiently for electrical contact, and then it measures and records the applied current and the voltage difference at that location.

Photo 14. William Sauck (L) and John Muehlhausen taking resistance measurements in the vicinity of the northeast corner of the Castillo Pyramid. It was at this location that a buried trench dug into the Great Plaza by the Maya was detected by GPR and resistivity in this project. PIC: L. G. Desmond, 1993.

At Chichen Itza, two 30 meter squares with data points at one meter grid intervals were surveyed using resistivity. One was at the northeast corner of the Castillo Pyramid (Photo 15), and the other at the center of the Great Ball Court (Photos 16, and 17).

Software developed by Geoscan, called Geoplot, calculates the resistivity for each set of field readings in the computer and plots the data with a dot-density pattern. The darker the area on a plot the more resistivity recorded, and the lighter the more conductive the area.

**The scope of the research**

The following field objectives and priorities were carried out. For ground penetrating radar: 1) Survey the subsurface of the Great Plaza to the east and north of the Castillo Pyramid (Photo 18), 2) survey north-south to the west of the Castillo Pyramid with one transect, and to the south of the pyramid east-west with two transects, 3) survey the platform of Venus using a 500 Mhz antenna.
Great Ball Court with two transects north and south, two transects east and west in the center, and one east-west transect in each end zone, 4) survey the center of the sacbe from the Platform of Venus to the Sacred Cenote with one transect, and 5) survey the area five meters from the base of the north and west side of the Platform of Venus (Photo 19) to detect a previously noted floor one meter beneath the surface. The floor had first been drawn by Augustus Le Plongeon in a profile (Photos 20 and 21) of his excavation of the Platform of Venus in 1884, and then noted again in 1980 by archaeologist Peter Schmidt during trenching for the "sound and light" installation (Photo 22).
Electrical resistivity examination of two areas was carried out: A 30 meter square was surveyed in the center of the Great Ball Court, and a 30 meter square at the northeast corner of the Castillo Pyramid.

The fixed remote probes of the resistivity instrument were placed 30 meters from the grid edge and the moveable probes were set one meter apart on the frame. With the one meter probe separation, readings to an approximate maximum depth of 1.5 meters were made. Resistivity measurements were then taken at one meter intervals inside each grid for a total of 900 readings per grid.

Finally, an important component of this project was to test the effectiveness of ground penetrating radar and resistivity for exploration of the subsurface at Chichen Itza, and, successful or not, to provide technical information about the project.

**Field surveys**

I. Ground Penetrating Radar using 500Mhz and 100Mhz antennas See Figures 1, 2, and 3.

Great Plaza
1. North from the Castillo Pyramid to the Platform of Venus, and west from the Temple of the Warriors to north-south line 70W.
Photo 23. John Muehlhausen pulling 500 Mhz radar antenna from south to north near west stairway of the Castillo.
2. East from the Castillo Pyramid 50 meters (50E) toward the Temple of the Warriors. (Photo 23)

3. West from the Castillo Pyramid: One line north-south, 70W, and lines east-west 10N and 20N to the east wall of the Great Ball Court.

4. South of the Castillo Pyramid two transects east-west 65S and 70S. (Photo 24)

Platform of Venus
1. Area west and north of the northwest corner: three transects south to north to detect known floor approximately one meter below the surface with an edge about 8 meters from the platform base.

Great Ball Court
1. Two north-south transects in the Great Ball Court with the west transect set 10 meters east of the west wall and the east transect 10 meters west of the east wall.
2. Two transects were made east-west in the center of the Great Ball Court. One was between the rings set into the east and west walls and the other 10 meters south and parallel to that line.
3. One transect was made in each end zone and was run parallel to the east-west wall
in each area. The north end line was 15.4 meters south of the north wall, and the south end line was 18 meters north of the south wall.

Sacbe from the Platform of Venus to the Sacred Cenote.
1. One transect down the center of the sacbe to about 20 meters before the Sacred Cenote starting at the northwest of the Platform of Venus.

II. Resistivity
See Figure 6.

Great Plaza
1. A 30 meter square area from the datum in northeast corner of the Castillo Pyramid. From datum to 15N and 15S, and to 30E.

Great Ball Court
1. A 30 meter square area wall-to-wall and 15 meters north and 15 meters south from the rings in the east and west walls.
Ground penetrating radar survey results

The first step in analysis of ground penetrating radar data requires the processing of the digital information recorded from radar reflections by filtration and color manipulation. The ground penetrating radar data was printed by a color plotter, but has been reproduced for this report in black-and-white (Figures 7, 8, 9, 10, 11). The lower portion of the printout is unprocessed field data including both internally and externally generated noise, the upper section has been processed, and notations on the plotted data are by Sauck.

Based on radar soundings, Sauck has plotted the bedrock topography contours of the area north of the Castillo Pyramid, east-west transects 39N to 69N, and from the Temple of the Warriors to north-south transect 70W (Figures 4 and 5). Two way radar reflection times in nano-seconds (10-9sec) are noted on the contour lines of the subsurface map. Using a reasonable value (12) for relative permittivity, we estimate that 23 nano seconds is equal to one meter. Rather than convert the depths to meters at this time, excavation data will be used to calibrate the radar reflections to absolute depths in a forthcoming report.
In the area at 66.5N, 60E, about 10 meters to the west of the Temple of the Warriors, is a small bedrock mound (Figures 4, 5 and 7).

The subsurface topography to about 80 meters west of that mound is fairly even, but at 66.5N, 10W is evidence of the east side of an oblong mound which is most likely of bedrock and measures about 20 meters east-west, and 30 meters north-south (Figures 4, 5, and 8).

In addition to the relatively even bedrock topography from the Temple of the Warriors subsurface mound to a point 80 meters west, there also appear to be few cultural features. Beyond 80 meters west (66.5N, 10W) and to the west of the Platform of Venus, stratified fill, possibly floors, and other cultural features become abundant on the upper part of the radar sections (Figure 8).

At 66.5N, 30W or 100 meters west of the Temple of the Warriors is a near-surface disturbance. It appears to be within two meters of the surface and has given a very strong radar reflection. Excavation is needed to determine if it is a natural or cultural feature (Figures 4, 5, and 9).

The transect 60W, from the northwest corner of the Castillo Pyramid, to 59N shows a number of strong reflections which we think are floors between 10N and 20N, and between 50N and 57N (Figures 10 and 11).
The floor excavated and drawn by Le Plongeon in 1884, and noted by archaeologist Schmidt in 1980 (about one meter below the surface in the area to the northwest of the Platform of Venus), was not detected using the 100 MHz radar antenna. It is most likely that the mixed fill of the terrace did not allow the floor to be distinguished. Another antenna with a higher frequency might be able to locate it, but only if there is a contrast in electrical properties between the floor and the fill.

Bedrock topography and other information from survey transects of the Sacred Cenote sacbe, the Great Ball Court and other locations will be available in a forthcoming report.

**Resistivity survey results**

Data captured by the Geoscan RM15 was transferred to a desk top computer and printed using Geoscan Geoplot software to produce dot-density plots of each survey grid (Figures 12 and 13).

![Figure 12](image.png)
A 30 meter square area at the northeast corner of the Castillo Pyramid was surveyed from 0N to 15N, 0E to 30E, 0N to 15S (Figures 6 and 12). An area of low resistivity (white), noted at about 15 meters east, begins at the north boundary of the grid. It is about nine meters in width and becomes more resistant (darker areas) 15 meters south. Another area of low resistivity, 2N to 15S, cuts diagonally into the grid (Figure 12).

The low resistivity is likely due to highly compacted and chemically very conductive fill, but these resistivity anomalies (high or low) are subtle and it is difficult to know whether they represent natural or cultural features without a general resistivity survey of the Great Plaza.

Within the Great Ball Court a 30 meter square was surveyed using resistivity (Figures 6 and 13). The grid was set with 0N and 0E under the ring on the west wall of the court.

The most clearly defined area of low resistivity is a one-two meter wide area beginning at 15N, 0E (the northwest corner of the grid) which cuts diagonally to 15S, 14E. A second diagonal, about the same width, begins at 14S, 6E and cuts through the grid to about 6S, 30E or across the bottom of the grid to the east wall. These low resistivity areas appear to be the result of filled excavation trenches. Also in the area surveyed
there are a number of other areas where changes in resistivity are subtly represented by light and dark in the plot and will remain uninterpreted until further fieldwork and analysis is carried out.

**Conclusions**

**Ground penetrating radar**

This project has demonstrated the successful use of ground penetrating radar at Chichen Itza. We recommend an additional survey to provide topographic contours of the total subsurface, and to map the limits of the Great Plaza. The responses of different antennas should be studied on site to determine the optimal frequencies for use at Chichen Itza, and at the same time examination of radar reflection signatures should be made systematically to enable the identification of natural and cultural features in the fill.

**Volume of the Great Plaza**

Our survey indicates an enormous amount of earth was transported by the Maya to build the Great Plaza. The survey covered approximately 250 meters north/south by 350 meters east/west or about 8.75 hectares of the Great Plaza. Based on an average fill thickness of 2.5 meters, Sauck estimates that 220,000 cubic meters of soil and rubble weighing about 440,000 metric tons was deposited in the area in order to cover the undulating limestone bedrock and create a flat plaza. The final depth of the plaza is the result of a number of layers or floors added by the Maya over a considerable amount of time, and is part of the overall plan devised by the Maya to provide open space for religious and political assemblies, and to create a setting which would enhance their city with its temples and pyramids.

**Resistivity**

Electrical resistivity testing was carried out in a very limited area, but the survey results have shown the technique to be well adapted to the environment of Chichen Itza. No less than a survey of the whole Great Plaza and Great Ball Court should be made to allow for analysis of the total resistivity pattern.

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