GPR and Archaeology on Saipan
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Chapter 1. Introduction

In September, 2008, the Commonwealth of the Northern Mariana Islands (CNMI), Department of Community and Cultural Affairs, Division of Historic Preservation (DHP), Saipan, awarded The LAMAR Institute of Savannah, Georgia a grant, “To Demonstrate the Use and Interpretation of Ground Penetrating Radar (GPR) for Archaeological Applications for the DCCA-Historic Preservation Office”. This work was funded by a grant from the National Park Service to the DHP. The LAMAR Institute responded to RFP08-DCCA/HPO-030 and was awarded the contract (491429-OC). The project was completed on September 25 and this report submitted to HPO on September 26, 2008. This monograph contains a revision of this contract report (Elliott and Elliott 2008), supplemented by a report on GPR investigations at Kalabera Cave on Saipan.

The LAMAR Institute is a 501(c) 3 non-profit organization whose mission is archaeological research and public outreach. The institute has extensive experience in GPR survey, archaeological research, educational workshops, and public interpretation. The Saipan GPR workshop was taught by Daniel Elliott (President) and Rita Folse Elliott (Education Outreach Coordinator) of the LAMAR Institute. Both teachers have extensive experience conducting GPR surveys in Georgia and South Carolina. Mr. Elliott has completed more than two dozen GPR survey projects. Ms. Elliott has assisted on approximately one dozen projects. Mr. Elliott received extensive training in GPR technology, including instruction from Larry Conyers and Dean Goodman, two world-renowned specialists in the field. Mr. Elliott also received training from Jim Cook, Mala GeoScience, USA. Mr. Elliott also participated in a 2006 Remote Sensing Workshop, offered by the National Park Service and held at Fort Frederica National Monument, St. Simons Island, Georgia.

The LAMAR Institute Saipan GPR Demonstration workshop consisted of classroom instruction and “hands-on” field GPR survey and data collection on three historic sites on the western side of Saipan. This effort represents the first use of GPR technology anywhere within the CNMI. The workshop served as a test case for the applicability of this technology in this unexplored environment, as well as a learning opportunity for CNMI cultural resource managers and others with related interests in understanding subsurface deposits.

Saipan’s geology consists of sedimentary and igneous deposits (Cloud et al. 1956). The areas covered by the GPR study included the lower western side of Saipan, south of the town of Garapan, and the northern area which contains karst topography. Kalabera Cave is located in the latter area and it is a limestone cavity (Figures 1 and 2).
Saipan’s soils are derived from these metamorphic and igneous rock formations, as well as soils formed in association with the active reef and beach deposits. GPR Block A is located on Chinen-Urban land complex soils. GPR Blocks B and C are located on Chinen clay loam soils (NRCS 2008). GPR Blocks D, E, and F were located at
Kalabera Cave. Soils in this area are derived from weathered limestone.

Figure 2. Soils of Saipan.
Chapter 2. The Workshop

The purpose of the project was to provide a training and demonstration workshop to introduce consultants, academic organizations, resource managers and other governmental personnel and others to the advantages of using GPR as a non-intrusive technology to collect subsurface information for archaeological investigations and other applications.

The target audience for this project was HPO Staff, and employees in other CNMI agencies. Eighteen participants who attended included:

- Yubert Alepuyo, CNMI Division of Environmental Quality
- David B. Rosario, CNMI Division of Environmental Quality
- Zeno C. DLGuerrero, Commonwealth Utilities Corporation
- Miguel H. Naputi, Commonwealth Utilities Corporation
- John San Nicolas, CNMI Coastal Resources Division
- John Delos Reyes, CNMI Coastal Resources Division
- Julie Ann Duenas, CNMI Coastal Resources Division
- Marilyn Swift, Swift and Harper Archaeological Resource Consultants
- Pedro (Roy) C. Sablan, Jr., Director CNMI HPO
- Ronnie H. Rogers, Staff Archaeologist, CNMI HPO
- John D. Palacios, Specialist, CNMI HPO
- Roque N. Magofna, Historic Preservation Technician, CNMI HPO
- Herman C. Tudela, Jr., Historic Preservation Technician, CNMI HPO
- John S. Castro, Jr., Historic Preservation Technician, CNMI HPO
- Thomas M. DLGuerrero, Archaeological Field Technician, CNMI HPO
- Lufo Q. Babauta, Archaeological Field Technician, CNMI HPO
- Antonelli M. Rosario, HPO Technician, Rota HPO
- Gilbert M. Borja, HPO Technician, Tinian HPO

The project goals were:

- To provide academic information relating to GPR concepts, theory, operation, and applications.
- To provide the use of GPR hardware and software for participants during the workshop.
- To demonstrate proper data collection methods.
- To allow participants working with the instructors to gather GPR data on actual sites in Saipan.
- To determine if GPR technology can be used successfully on Saipan’s limestone, sand, and clay soils.
- To collect real data on a variety of sites, environments, and stratigraphic sequences in Saipan.
- To demonstrate to participants the techniques for using various types of software in the process of interpreting the data collected.
• To provide a list of GPR hardware and software resources for participants.

HPO Archaeologist Ronnie Rogers and other HPO staff coordinated closely with LAMAR Institute prior to and throughout the workshop. The actual training component of the workshop occupied three days (September 23-25, 2008). In addition, HPO staff and LAMAR Institute instructors undertook on-island logistical arrangements for the workshop on September 22. Potential study sites were selected and permission to access these sites was secured during this time. On September 26, Rogers provided additional context information while LAMAR Institute instructors compiled data from the workshop, conducted initial interpretations, and created this report.

The workshop followed an established, yet flexible agenda. On Day 1 (Tuesday, September 23) participants met in the classroom for a day of instruction. Following introductions, Daniel Elliott presented a series of Microsoft PowerPoint media-presentations. These provided an introduction to GPR, with an overview of its history, physics, archaeological applications, and hardware and software. Participants then saw a variety of GPR case studies on actual sites in the Southeastern United States, which included photographs and radar images (radargrams). They were exposed to basic “Dos and Don’ts” in GPR and allowed ample time for questions. Throughout the day, the session was punctuated by quiz questions on topics being discussed, with small prizes awarded for correct answers. This technique enabled instructors to evaluate whether the class was absorbing the content, and stimulated interest throughout the delivery of technical content, allowed participants to review new information, and offered participants a lighthearted way to interact with each other and instructors.

Day 2 (Wednesday, September 24) consisted entirely of fieldwork. Participants met at the first site, on the grounds of the Marianas Eye Institute on Beach Road (Highway 33). Daniel Elliott demonstrated how the radar machine functioned and the proper technique for calibrating it and making the appropriate settings for the site’s environment and soils. The instructors then explained the technique for establishing a GPR grid and the spacing of transects. Instructors demonstrated the proper use of the GPR machine in collecting data, in recording GPR field notes, and in making a site plan map. Workshop attendees then actively participated in laying out a metric grid and collecting data. After lunch, participants met at the second field site, at the Old Japanese Jail. After a brief explanation of the grid alignment and location by instructors, participants established a grid at this location and collected the GPR data.

Day 3 (Thursday, September 25) began in the classroom as participants had the opportunity to see the radargram data they collected the previous day downloaded into software files. Daniel Elliott used a LCD projector to demonstrate techniques used with various software programs to maximize the amount of information that could be interpolated and interpreted from the data set. The GPR data were processed using GroundVision and Easy 3D.
software packages, which were both written for the RAMAC X3M equipment (Mala GeoScience 2008). Examples of GPR data, which was processed with *GPR-Slice* software, also were demonstrated (Goodman 2008). Participants were exposed to various filtering techniques, colorations, and other options used to enhance the data without changing it.

After lunch, participants regrouped at a third field site. They met at the Old Japanese Hospital grounds, where the current Museum of History and Culture, Northern Mariana Islands occupies one of the extant structures. Workshop participants established a grid and collected GPR data prior to returning to the classroom where they made an initial evaluation and interpretation of the data. Instructors followed this with a summary and question/answer period.

Participants then received a certificate upon completion of the three-day workshop. Certificates were signed by Ms. Cecilia Taitano Celes, Secretary of Community and Cultural Affairs, Mr. Pedro (Roy) C. Sablan, Jr, Director of CMNI Historic Preservation Office, and Mr. Daniel T. Elliott, President of The LAMAR Institute.

On Saturday, September 27, 2008, GPR survey was conducted at Kalabera Cave. This was a combined effort of the LAMAR Institute GPR team (Dan Elliott and Rita Elliott) and SHARC archaeologists (Marilyn Swift, Randy Pearson, and Mike Fleming). SHARC is currently conducting a Phase I survey of Kalabera Cave and its environs for the CNMI government. The addition of GPR survey to their study was an added bonus that will enhance our understanding of the archaeological potential of this important cave site. GPR data from three survey blocks were collected. Block D and E were overlapping samples that were located within the first chamber of the cave. The results of SHARC’s research project are reported separately.

HPO, Saipan provided access to relevant reports, copies of aerial photographs, and an assortment of equipment such as metric tapes, chaining pins, pin flags, flagging tape, graph paper, clip boards, and access to printers and use of a LCD projector. HPO also arranged access to the conference room at the Office of Aging, Department of Community and Cultural Affairs, where the classroom sessions of the workshop were held. The snacks, beverages, and refreshments in the field and classroom provided by HPO were much appreciated, particularly in the heat of the field work. The LAMAR Institute provided the GPR machine hardware and software described in Chapter 3. It also provided a laptop computer and digital camera. Institute instructors downloaded *Microsoft Powerpoint* presentations on GPR and other digital information onto flash sticks of individual workshop participants. Instructors also gave this information to HPO Archaeologist Ronnie Rogers, for his widespread distribution on CD, flash stick, and/or print, to those workshop participants who were unable to provide flash sticks during the workshop.
Chapter 3. Ground Penetrating Radar

Ground penetrating radar has been proven successfully to locate buried cultural and natural features without the need for unnecessary or excessive ground disturbance, thereby eliminating or reducing the need for costly “prospecting” that frequently defines traditional archaeological survey and research. GPR, when used in conjunction with accurate position fixing methods, either GPS or standardized transects, can provide location and depth information of buried objects or features. Using the accurate location information available, anomalies can be mapped and targeted for ground-truthing, which would require minimal ground disturbance, saving time, cost, and preserving the remainder of the site (Conyers and Goodman 1997; Conyers 2004).

Traditional archaeological techniques involve digging, thereby destroying part of the object that is being investigated. Additionally archaeological investigations based on digging often miss important features. Remote sensing can assist traditional archaeological practices by identifying the locations of features prior to excavation, so that excavation efforts are more efficient, resulting in recovery of more data at less expense. Ground-truthing to identify remote sensing anomalies can be directed to the area of interest and unnecessary destruction of features and wasted efforts at non-productive locations can be minimized.

Ground penetrating radar was considered difficult to interpret and unreliable as a remote sensing technique less than a decade ago. Many recent advances in hardware and software have made radar easier to use and interpret. Advances in computer capabilities allow for complex three dimensional analyses of remotely sensed data, sometimes eliminating the need for ground-truthing. No one has used ground penetrating radar to search for cultural resources in the CNMI. One GPR project is known from Guam.

Equipment
LAMAR Institute instructors brought a full complement of GPR hardware and software to the workshop for training and data collection. Hardware consisted of the following:
MALÅ RAMAC X3M GPR system, a 500 MHz shielded antenna, MALÅ computer monitor interface, and a MALÅ cart. Software included MALÅ Easy 3D and GPR-Slice programs.

MALÅ GeoScience is a world leader in tools for non-invasive, non-destructive sub-surface investigations based on GPR technology. Their products are convenient, durable, and relatively easy to operate. Since 2001, the LAMAR Institute has chosen their product for its GPR work. The LAMAR Institute’s New Ebenezer Battlefield Project was, in fact, the first archaeological application of MALÅ GeoScience equipment in North America. The LAMAR Institute maintains a good working relationship with this firm.

The X3M radar control unit, the shielded antenna, computer monitor, and power supply are mounted on a wheeled, graphite cart, manufactured by MALÅ GeoScience. The cart has a calibrated wheel system, which records distances covered by the radar coverage.
The X3M system, manufactured by MALÅ GeoScience, is an integrated radar control unit, fitted directly on a shielded antenna and powered externally. The built-in electronic design is lightweight and compact and is easy to operate. No bulky cables are required since the unit communicates directly with the computer monitor. The X3M radar system operates with the 100, 250, 500 and 800 MHz MALÅ GPR shielded antennas. The LAMAR Institute uses the 500 and 800 MHz shielded antennas for archaeological applications. The XV11 Monitor, manufactured by MALÅ GeoScience, includes a full size trans-reflective TFT color screen with 640 x 480 pixels. This monitor is suited for rugged, outdoor performance. The monitor contains a computer module that records the GPR data for later download.

All radargrams for this training project were collected using the 500 MHz shielded antenna. Transects were spaced at 50 cm intervals. All radargrams were collected from south to north and progressed along the lines from east to west. Radargrams were collected with the following machine settings:

- Sampling Frequency: 4975 MHz
- Number of Samples Per Scan: 512
- Time Window: 103 nanoseconds
- Trace Interval: 0.047 meters
- Antenna Separation: 0.18 meters
- Number of Stacks: 4
- Time Zero (ground surface): 30 nanoseconds

The field survey began with the establishment of a survey grid with a compass and metric tapes. The GPR equipment was assembled, the collection settings were adjusted, and several trial passes were made over the area to insure that the machine was operating satisfactorily. The measurement wheel on the RAMAC X3M cart was then calibrated. Once the machine was fully adjusted the survey data collection commenced. A series of uni-directional radargram were recorded for each of the three study sites. The class participants collected these data under careful supervision of the Elliotts. Every class participant was allowed to operate the equipment and collect several radargrams from each site. Participants also assisted in recording notes about each radargram and in shifting the metric tapes along the grid, which enabled an accurate data collection.

All radargrams were collected using a 500 MHz shielded antenna. Data was recorded from south to north. Grid North was established on Magnetic North. The radargrams progressed from east to west. Each radargram commenced at a common baseline and terminated at another baseline, or, in several cases, were terminated at major obstacles such as trees, a water fountain, or massive chunks of concrete rubble.

The LAMAR Institute uses three software packages from MALÅ GeoScience for acquiring and processing GPR data. These are Ground Vision (Version 1.4.5), Easy3D (Version 1.3.3), and Object Mapper (Version 1.0.13). Ground Vision is a Windows-based data acquisition software platform whose primary function is data acquisition, but also includes tools for filtering, printing of GPR data and includes support for multi-channel operation. Ground Vision is the dedicated data acquisition software platform for MALÅ’s single or multi-channel GPR systems. Ground Vision offers an easy-to-use user interface with
file management, printing and other key features. Each measurement and its associated settings are stored in files. Filtering can be performed during data acquisition measurements, or afterwards during post-processing. Ground Vision software supports GPS coordinate logging during measurement. All radargrams can be printed as such, or post-processed by further software (MALÅ GeoScience 2008).

*Easy 3D* is Windows-based visualization software designed for GPR radar data. Easy 3D operates with a set of homogeneous profiles acquired with the Malå GPR unit and associated Ground Vision software. Easy 3D includes visualization of data, filtering of data, automatic "movie" function of sections or time slices, zoom functions and a report editor to insert objects in the 3D cube as an interpretation aid. Straight lines, curves, hyperbolas, circles as well as 3D objects can be inserted into the 3D radargram to report defined utilities, buried objects or else (MALÅ GeoScience 2008).
Chapter 4. Areas Examined, Including GPR Results and Interpretations

Three areas on the western side of Saipan were selected for GPR survey in the workshop. These were the Mariana Eye Institute, the Old Japanese Jail, and the Old Japanese Hospital. Archaeologists conducted additional survey was conducted at Kalabera Cave, following the GPR training course. The location of the three workshop study sites is shown in Figure 3. The location of Kalabera Cave, which is on the northern part of Saipan, is not shown here.

Figure 3. GPR Blocks A, B and C (U.S.G.S. 1999).
GPR Block A was located on the grounds of the Marianas Eye Institute on Beach Road (Highway 33). Human remains were discovered immediately west of this area in the early 1990s, as documented in a report by Jones (1992). Jones reported finding human remains in association with glass seed beads and he concluded that these burials were Carolinians. Refugees from the Caroline Island chain were settled by the Spanish government on Saipan after they suffered a devastating typhoon in the 1840s. Graves at this cemetery may date to the mid-19th century. The landscape on this part of Saipan was extensively modified following the Battle of Saipan in World War II. Immense piles of building rubble were spread over the land, including the study area. A sketch map of the area examined by Jones, which was named the Guma Capuchino Site, was presented in his report (Jones 1992:22, Figure 6). Their study was situated along the eastern margin of Beach Road, extending less than 5 meters from the road. The present study was located immediately east of the area examined by Jones. The extent of human remains in the present study area is unknown.

The area selected for GPR survey consisted of a well-maintained grassy lawn with large trees along its perimeter. Figure 5 is a view of Block A during data collection.

Several modern features were observed on the surface. A large sign and fountain was located in the northwestern portion of the study area. A large sewer drain and various utilities lead to these two modern features. A large junction box for a buried telephone cable system was located on the southwestern portion of GPR Block A. The western edge of the GPR Block was defined by several large trees. Two large push piles were situated south of the study block.

Prior ground disturbance, a short distance west of GPR Block A, had unearthed human remains, one or more tombstones, and grave offerings. The precise location of every find was not recorded, although several members of the class recalled aspects of these finds. One tombstone was marked with the “Sablan” surname and dated to the late 19th century. Local tradition holds that this was a cemetery that was established during the Spanish period and remained in use into the early 20th century (Jones 1992). No additional historical research was conducted on this cemetery by the present survey team.

Several expectations for GPR Block A were defined prior to the survey. The
The area was thought to have the potential to contain numerous human graves. The area was suspected to have been bulldozed in the immediate post-World War II period. Additional ground disturbance probably took place when the Eye Institute building was constructed. This building was formerly used as a residence for Capuchin monks (Jones 1992).

A total of 72 radargrams was collected for GPR Block A. The longest of these was 30 m and the shortest was just over 21 m. The general area covered by the survey measured 34 meters east-west by 30 meters north-south. The survey block was irregular in shape, as necessitated by several obstacles on the ground. Figure 6 shows the layout for the radargrams in Block A.

Figure 5. Radargram Layout, Block A.

Examples of the output are shown in Figures 7 and 8. Two filters were applied to these radargrams—time gain and background removal. A buried stratum is evident across this entire radargram in Figure 7. This buried zone is suspected to represent a 20th century fill zone. This zone was evident in several of the easternmost radargrams, but became less pronounced as the survey proceeded to the west. It was not clearly evident as a continuous zone in the western radargrams, although vestiges of it were apparent in some radargrams. Figure 8
shows a representative radargram from the western portion of this survey block.

Figure 6. Radargram 1, Block A.

Figure 7. Radargram 71, Block A.

All of the radargrams in GPR Block A displayed signal loss at depths greater than 2 meters. The inability to penetrate below that depth is likely due to the limestone content of the underlying soils. At shallow depths (0-150 cm) the radar signals were very pronounced.

The radargrams from Block A were imported into the Easy 3D software program for 3 dimensional mapping. Figure 9 shows a plan view of Block A at approximately 37 cm depth. Figure 10 shows a plan view of Block A at approximately 54 cm depth. Figure 11 shows a front profile view of Radargram 52. A strong hyperbolic reflection, possibly a human grave, is indicated by the cross lines in this image. Figure 12 shows a plan view at 97 cm depth and the cross lines pinpoint the location of the reflection highlighted in Figure 11. Figures 13 and 14 show a radargram and plan view at 67 cm depth with another example of a suspected grave anomaly. Figure 15 is a plan of Block A viewed with the program GPR-Slice. This map allows for better visualization of radar anomalies, which appear in blue, within the study block. Many of these may represent human burials.
Figure 8. Plan of Block A, 37 cm Depth.
Figure 9. Plan of Block A, 54 cm Depth.
Figure 10. Front View of Radargram 52, Block A (Cross Lines Indicate Strong Hyperbolic Reflection, Possible Grave).
Figure 11. Plan of a Portion of Block A, 97 cm Depth (Cross Lines Indicate Strong Hyperbolic Reflection, Possible Grave).
Figure 12. Front View of Radargram 52, Block A (Cross Lines Show Strong Hyperbolic Reflection, Possible Grave).
Figure 13. Plan of a Portion of Block A, 67 cm Depth (Cross Lines Show Location of Strong Hyperbolic Reflection, Possible Grave).
Old Japanese Jail, Garapan, Saipan
The Old Japanese Jail (CNMI HPO Site SP5-0020) occupies the Axial uplands, one of six geomorphologic subdivisions of Saipan. It is characterized by sloping limestone terraces and volcanic hills (Allen 206:5). The Jail was selected as one area for study by the GPR demonstration project for several reasons. First, it allowed a comparison with traditional archaeological techniques. The location was recently investigated using traditional archaeological methods (backhoe trenching). These trench locations had been selected to intersect areas where structures were shown on archival aerial photographs. This recent archaeological investigation allows a comparison of the capabilities of GPR, a non-destructive method for detecting and mapping subsurface anomalies, to traditional destructive archaeological techniques that offer cover less ground. Second, the jail site is public land and the grounds are maintained with few obstructions, making the location suitable for using radar effectively.

Japanese officials completed construction of initial portions of the jail from 1929-1930 (Allen 2006). In 1935, over 100 people were detained at one time in the jail. These included Korean,
Okinawan, Taiwanese, Chamorro, Kanaka, and foreigners. During World War II, four Americans were imprisoned at the jail. Allen (2006:30) cites one as having died there, one executed by the police. American pilots and artillerymen bombed the jail extensively during World War II. The Japanese had used concrete in construction for almost 25 years prior to building the jail in Saipan. They formed the jail walls from concrete shipped from Japan and applied to the building in layers (Allen 2006:31). This concrete includes iron rebar and a finished surface treatment of mortar/cement veneer measuring one centimeter or more thick and having “…small pebble-sized inclusions” (Allen 2006:32).

GPR Block B was located within the Old Jail site. The southeastern corner of this block was located near the southwestern edge of the jail cell block. Forty-four radargrams were collected from Block B and Figure 16 shows the radargram layout for this block. A photograph showing of the field survey of Block B is reproduced on the report cover.

Figure 16. Radargram Layout, Block B.
Figure 17 shows a radargram from the east side of GPR Block B. The northern one-half of this transect displays strong radar reflection, which indicates deeply buried disturbance that is probably of cultural origin.

Figure 17. Radargram 74, Block B.

Figure 18 shows a radargram from the central part of GPR Block B. In this view a large depression is visible in side view, which extends for about 18 meters. The soils appear to be disturbed to a depth of more than 75 cm.

Figure 18. Radargram 89, Block B.
Figure 19 shows a plan view of Block B at approximately 22 cm depth. Two of the exploratory backhoe trenches are clearly visible as light gray linear areas in this image.

Figure 19. Plan View of Block B, 22 cm Depth.
Figure 20 shows a plan view of Block B at approximately 74 cm depth. A large disturbed area is apparent in this view, which is located immediately east of the ruins of the administrative building. This area of large disturbance continues to a depth of 1 meter or more. Figure 21 is a plan of Block B viewed with GPR-Slice. Strong anomalies appear in blue.
Old Japanese Hospital
The Old Japanese Hospital is located in south Garapan. The Northern Marianas Museum of History and Culture now occupies one of the hospital’s extant structures. Old aerial photographs indicate several buildings on the grounds, although these buildings have not been located and mapped in modern times. This area was a well-maintained grassy lawn that was well-suited to GPR application.

GPR Block C was located north of the Museum building. It covered several cultural features, including a large concrete cistern, a portion of a bunker, and an area of suspected hospital staff housing. A total of 28 radargrams was collected from Block C. Figure 22 shows data collection in progress at Block C. Figure 23 shows the layout of the radargrams in Block C.
Figure 23. Radargram Layout, Block C.
Figure 24 shows a radargram from the east side of GPR Block C. This transect crossed over a pronounced berm on the western edge of a bunker, along its south-central section.

Figure 24. Radargram 117, Block C.

Figure 25 shows a radargram from the west side of GPR Block C. This transect crossed over a large concrete cistern on its southern end. Reflections from several metallic objects are apparent in this radargram. The cistern is clearly indicated on the southern (left side) of this radargram from approximately 1-7 m from its begin point. Within the cistern radar signature are numerous reflections created by iron rebar within the concrete. The northern section of this radargram (from about 27-35 m) displays a large area of radar reflections beneath the surface. These may indicate structural remains.

Figure 25. Radargram 140, Block C.
Figure 26 shows a plan view of Block C at approximately 37 cm depth. The concrete cistern is clearly visible in the lower left portion of this image. Concentrations of rebar are indicated in this area by a series of closely spaced object reflections. Another area of strong radar reflections is indicated in the northern portion of Block C. This area also contains rebar reflections and probably is the location of a former structure.

Figure 27 shows a plan view of Block C at approximately 55 cm depth. In this image the cistern is clearly evident in the southwestern (lower left) part of the study block. Figure 28 is a plan of Block C viewed with GPR-Slice. Strong anomalies appear in red. The cistern appears as a large depression in the upper left of this image.

Figure 26. Plan of a Portion of Block C at 37 cm Depth (Cross Lines Indicate Concentrated Area of Rebar Reflections).

Figure 27. Plan of Block C at 55 cm Depth (Cross Lines Indicate Large Area of Strong Reflections).
The classroom portion of the project was successful. Participants remained attentive and frequently asked relevant questions about the technology and its application for their respective needs. The instruction provided them with a well-rounded initial exposure to GPR technology and its potential. Figure 29 shows the class in session.

The field collection of GPR data also was completed successfully. Periodic heavy rains threatened the survey team, but a large amount of radar data was collected despite these conditions. Figures 30 and 31 show fieldwork in progress.
Figure 30. GPR Fieldwork in Progress, Block A.

Figure 15. GPR Fieldwork in Progress, Block C.
Chapter 5. GPR Survey at Kalabera Cave

Following the conclusion of the formal GPR Workshop, an additional site location on Saipan was investigated using GPR. The location was Kalabera Cave, which is a noted natural cave on the northern end of the island. Preliminary Cultural Resource investigations of the cave were underway as part of a broader Environmental Assessment of the cave and its surrounding environs (Figure 32). The GPR survey of Kalabera Cave provided important remote sensing data that proved useful for archaeologists working there. That survey included GPR Blocks D, E, and F. Blocks D and E contain overlapping samples located within the cave (shown as GPR#1 in Figure 32) and Block F was located on the talus slope outside the cave entrance (shown as GPR#2 in Figure 32).

Blocks D and E were located in the interior chamber of Kalabera Cave. These two sample blocks have mostly overlapping coverage of the same cave interior floor, although the fringes of both collection grids differ as a result of the overhanging rock ledges and other obstacles. Figure 33 shows Block D at the beginning of data collection.

Block D covered an area 7 m by 4 m. Figure 34 shows a plan map of GPR Block D at 32-35 ns Time Depth. Figure 35 shows Block D at 41-44 ns Time Depth. Figure 36 shows Block D at 51-
54 ns Time Depth. Figure 37 shows Block D at 61-64 ns Time Depth. Figure 38 shows Block D at 71-74 ns Time Depth.

Figure 33. Block D at Beginning of Data Collection, View to North West.

Figure 34. GPR Block D at 32-35 ns Time Depth (North is Up).

Figure 35. GPR Block D at 41-44 ns Time Depth.

Figure 36. GPR Block D at 51-54 ns Time Depth.

Figure 37. GPR Block D at 61-64 ns Time Depth.

Figure 38. GPR Block D at 71-74 ns Time Depth.

Block E covered a portion of the interior of Kalabera Cave, just inside the entrance, and was collected with radargrams oriented perpendicular to those collected for Block D. As a result of this different orientation a larger space in the cave interior was surveyed—an area 8 m by 7 m. Figure 39 shows Block E at 30-34 ns Time Depth. Figure 40 shows Block E at 39-43 ns Time Depth.
Depth. Figure 41 shows Block E at 59-63 ns Time Depth. Figure 42 shows Block E at 71-74 ns Time Depth.

Figure 39. GPR Block E at 30-34 ns Time Depth.

Figure 40. GPR Block E at 39-43 ns Time Depth.

Figure 41. GPR Block E at 59-63 ns Time Depth.

Figure 42. GPR Block E at 71-74 ns Time Depth.

Block F was located outside of the Kalabera Cave entrance on the talus slope. It covered an area 10 m by 5 m. The terrain was very irregular as a result of rock outcroppings, talus rocks, and vegetation (Figure 43). Despite these adverse factors for GPR data collection, the grid was completed. Figure 44 shows Block F at 29-33 ns Time Depth. Figure
45 shows Block F at 38-42 ns Time Depth. Figure 46 shows Block F at 48-52 ns Time Depth. Figure 47 shows Block F at 58-62 ns Time Depth. Figure 48 shows Block F at 68-72 ns Time Depth. North is the left of the page in these views.

Figure 43. GPR Block F During Data Collection, View to Northwest.

Figure 44. Plan of GPR Block F at 29-33 ns Time Depth.

Figure 45. Plan of GPR Block F at 38-42 ns Time Depth.

Figure 46. Plan of GPR Block F at 48-52 ns Time Depth.

Figure 47. Plan of GPR Block F at 58-62 ns Time Depth.

Figure 48. Plan of GPR Block F at 68-72 ns Time Depth.
Chapter 6. Summary Interpretations

The GPR in Archaeology Workshop achieved its multiple goals. GPR technology was demonstrated to 18 workshop participants who completed the program and received a training certificate (Figure 49). These students were provided with a broad spectrum of introductory information about GPR technology. The classroom activities, which included lectures, Powerpoint presentations, general discussion, and a question and answer period, provided the students with lively stimulation. They were introduced to the scientific basis for GPR, its applications, and its limitations. The indoor classroom was interspersed with two field sessions that allowed participants the opportunity for hands-on learning. The participants were allowed to establish a site grid, collect GPR data, and record information on the radargrams. The project provided solid remote sensing data for three important historic period sites in addition to the learning opportunity that was provided to the 18 participants in the workshop.

GPR Block A contains a variety of information about the subsurface resources. These range from the locations of two or more modern utility lines, an area of modern fill, and possibly one or more human graves.

GPR Block B contains information on the location of two exploratory backhoe trenches, which were excavated in 2006 (Allen 2006). The GPR maps also provide information on one large subsurface feature located immediately east of the administrative building ruin. That feature was intersected by one of the aforementioned backhoe trenches. The full horizontal extent of this feature is approximately indicated by the GPR data.

GPR Block C contains information on several historic features associated with the former Japanese hospital complex. These include a bunker, a cistern, and a suspected area of staff housing. The cistern was clearly evident from the GPR mapping and this information should prove useful in mapping similar features on Saipan in the future. The area of suspected staff housing appears to have been nearly obliterated by the bulldozer. The GPR maps of this vicinity show a very large area of disturbance and rubble. One or more building ruins may be contained within this area that is marked by multiple strong radar reflections.

GPR Blocks D, E and F demonstrate the potential utility of GPR technology for karst situations on Saipan. These sampled areas were subsequently tested by archaeological excavation, which verified the findings. GPR technology is effective in these environments and it should be embraced as a tool for future...
studies of limestone caves in the northern Pacific region.

The application of GPR technology to Saipan’s cultural resources was shown to be effective and useful as a tool for locating and understanding buried resources. Overall, the GPR survey was shown to be effective at penetrating to depths of at least 1.5 meters below ground surface. A variety of materials and feature types was imaged with the GPR equipment. Radar reflections typical of large metal objects and iron rebar were frequently recognized in the survey blocks. At least one soil horizon was isolated in the eastern part of Block A. That soil interface is suspected to be the contact between a modern limestone rubble fill layer and an underlying sand or clay subsoil. Large depressions and possible building cellars were recognized. Many smaller radar reflections, less than 1 meter in horizontal extent, are indicated over all three study locations. These may represent individual large artifacts, or possibly clusters of artifacts or small pit features. The determination of the applicability of this technique for cave research was an added plus.
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