The Application of Ground Penetrating Radar in Analyzing Archaeological Cave Sites

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Abstract

According to the Department of Environment and Natural Resources (DENR), there are more than 3,000 located caves in the Philippines. Among these caves, only a few have been identified with archaeological significance. This is in part due to problems determining whether a cave or rock shelter is likely to contain deposits of substantial depth, and/or of archaeological potential without undertaking expensive and time-consuming archaeological excavations. To address this problem, archaeologists in the Philippines are currently testing whether the Ground Penetrating Radar (GPR) is an effective technique in targeting buried geomorphological features such as rock fall and paleochannels, deposit depth within cave and rock shelter sites. This aims to outline a possible procedure using GPR to identify anomalies in caves and to discuss a methodology that might aid the archaeologist in determining whether a cave has archaeological potential. These includes determining what geomorphological features might be present below the ground and identifying the best locations within a cave or rock shelter for conducting an excavation. Using the available GPR equipment, Tanggapan Cave and Munsayac Cave located in Biak na Bato National Park was initially surveyed using a grid survey method. The survey showed the underground features of Tanggapan Cave and Munsayac Cave which were previously excavated last 2017 up to 2019. The GPR survey conducted last 2022 showed signatures of anomalies such as cavity, fracture, subsidence, and possible objects buried underground. The said signature is also often seen in the karstic landscape and network of the caves of any higher place.

Keywords: *Archaeology, Caves, Ground Penetrating Radar (GPR), Radargram, Geomorphological features, Excavation*

1 Introduction

From the various time periods recognized by various archaeologists, the Province of Bulacan (Figure 1) has always been mentioned as a place of interest. This Province is among the expanded works of the American Government under the presidency of Mackinley to study social, cultural, and political aspects of the country. The main initiative of these studies is to collect archaeological material from potential sites. The archaeological investigation of Otley Beyer (Evangelista, 1950) emanated to Bulacan from the construction of Novaliches Dam in the Province of Rizal which eventually initiated the Rizal-Bulacan Archaeological Survey.

The excavations continued until the mid-1930s to include a narrow strip inside the Province of Bulacan. In fact, the collection of archaeological material by Beyer's field assistants continued through the following years. In total, 120 sites were surveyed, and in five years' time, it reached nearly half a million sites (Evangelista, 1960).

In Barangay General Tiburcio De Leon in the City of Valenzuela (Pugad Baboy Site), a former administrative land of Bulacan, an Obsidian and Tektite similar to Rizal, Cavite and Batangas was found. Some of these materials are shown to him by his comrades (Neri, 2005).

During the 1950s, Wilhelm G. Solheim II, an archaeologist from the University of Arizona worked on many archaeological sites in the Philippines. His main interests are burial sites and research studies on traditional potteries. He has intensive educational experience in Southeast Asia and in some instances as a professor at the University of Hawaii. Karl Hutterer, Don Bayard, Warren Peterson, and Chester Gorman are among the archaeologists he trained (Dizon, 1994).

During past archaeological projects in the Philippines, Bulacan was included in some surveys, especially in the area of Sierra Madre, but there is no archaeological excavation that mainly focuses on the study of its archaeological characteristics related to the early period of human settlement.

Figure 1. Boundary of Bulacan from neighboring Provinces (Base Map: Google Satellite)

The northeastern side of Bulacan is part of the Sierra Madre Mountain Range. The town of Doña Remedios Trinidad (DRT) is located on its foot (Figure 2) and several barangays in the town of San Miguel.

According to the reports of the City Environment and Natural Resources Office (CENRO Baliuag, 2018), there are still a few Dumagats residing in the municipality of DRT in upland areas, far from the main roads. Their main source of living and income is the cultivation and farming of native bananas and sweet potatoes. This is an indication that living in the upland of Bulacan is still possible in the present time.

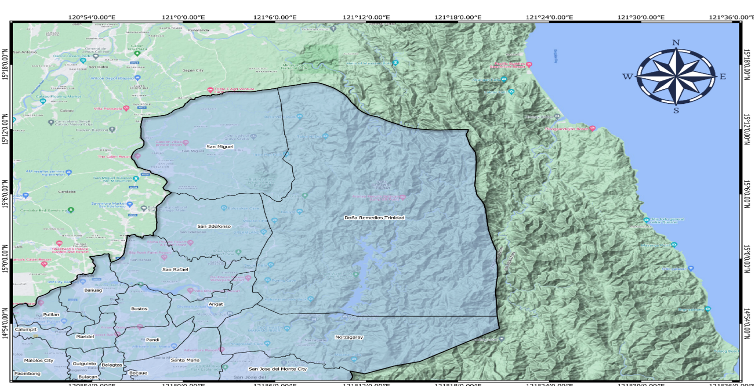

Figure 2. The part of Bulacan in the Sierra Madre Mountain Range

The geographical location of Bulacan in relation to the variety of landscapes in the Luzon Main Island resulted in dynamic changes in the livelihood, culture, and traditions of Bulakenyos from the past to the present. While the Northeastern part of the province has a long tradition of livelihood practices in the upland area, the eastern-west part of Bulacan specializes in fishing and salt-making due to its proximity to Manila Bay (Figure 3).

However, these different characteristics of the province are both potential evidence and indications of possible archaeological sites in connection with the period of trading, hunting, and fishing.

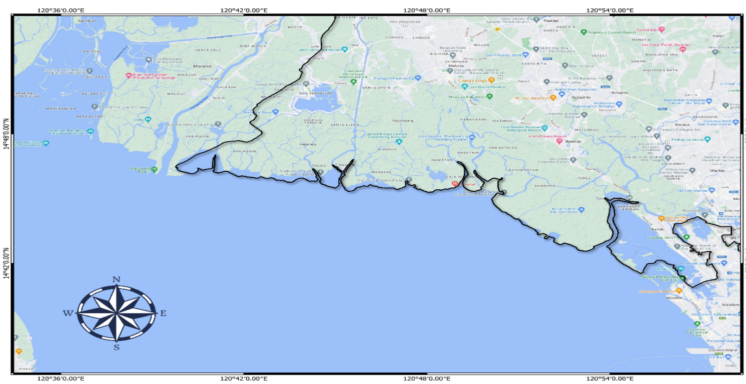

Figure 3. Municipalities of Bulacan in Manila Bay (Google Earth Engine Map)

The distribution of people and their settlement is always in relation to the environmental climate and physical geography, and in some cases, the result of adaptation to socio-economic conditions and cultural material (Evans at O'Connor, 1999). Thus, the landscape in a particular site does not only influence the identity of the people living nearby or within the physical geographical territory itself, their behavior to stay or leave also depends on the natural changes of the area. Some of the significant considerations are the variety of food that can be gathered, the sufficiency of the water supply, and the risk of natural threats in the location.

In the observation of Flemming, landscape archaeologists have always cultivated detailed and well-organized documentation of physical traces through extensive and deeper studies inside the actual target landscape, and this technique is scientifically correct (Thomas, 2010).

In the more emphatic explanation of Renfrew and Bahn (2012), it is more important to understand the important past events of the landscape before making any speculations about the possible cause of the changes and the people's adaptation to its new condition. In contemporary history, the Province of Bulacan is a home of individuals who played a significant role in achieving the independence of the country. This event is also rooted in the strategic location and natural formation of landscapes in the province that served as shelters and temporary camps of the Filipino Army against the colonists.

Since President Quezon established Biak na Bato as a National Park in 1937, several major government programs and private projects have been undertaken in the area. Between 1999 and 2000, Miriam Peace conducted projects involving environmental protection and conservation (DENR-PAMB Manual of Operations 2020-2030).

The Miriam Peace established under the Miriam College, a private school, is one of the main centers of their institution. In 1999, with the help of a grant from the Foundation for the Philippine Environment (FPE), an initial environment scanning and community organizing was initiated in Biak na Bato community.

One of the experts they commissioned was Patrick Gamman, a geologist (Jose Rey Munsayac personal interview– PI, 2017). Through this project, the recording and variety of mapping began (although no publication has been released) with the caves that the local narratives indicated as the camp where General Emilio Aguinaldo stayed in Biak na Bato National Park (Figure 4).

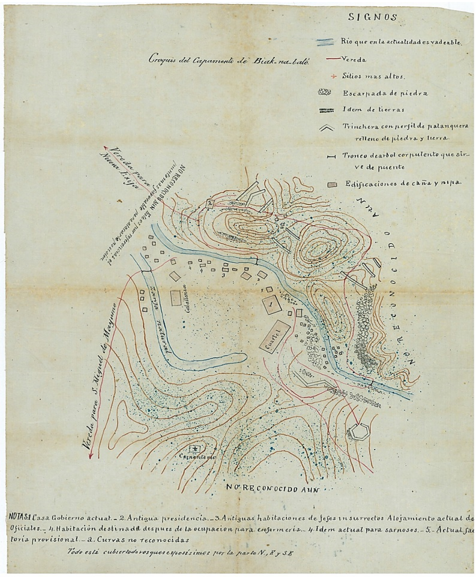

Figure 4. The exact location of the camp established by Aguinaldo in Biak na Bato

During the time of President Marcos, there was a change in its land area, but the major change was created when President Corazon Aquino signed the decree designating the larger part of its total land area as mineral, aquatic, and forest reserve (Figure 5).

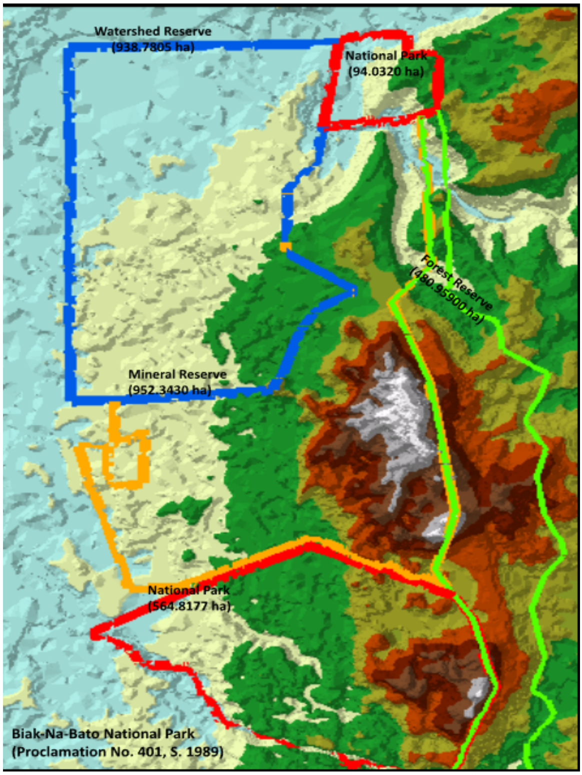

Figure 5. Protected Area and the Designated Reservations from the PAMB Manual of Operation prepared by Asst. PASU Jayrald Gatdula

The map from Figure 5 shows two separate locations of the remaining land area of the National Park (red line), LOT A with a total lot area of 94.0320 hectares and LOT B with a total lot area of 564.8177 hectares. The other areas have been designated as Watershed Reserve (blue lines) with a lot area of 938.7805 hectares, Mineral Reserve (yellow lines) with a lot area of 952.3430 hectares, and Forest Reserve (green lines) with a lot area of 480.95900 hectares (PAMB-DENR Manual of Operations 2020-2030).

In 2019, the National Mapping and Resource Information Authority (NAMRIA) conducted ground delineation on the boundaries of the mineral reserve, which was part of the original lot area of Biak na Bato based on the declaration of Quezon. This activity did not go through the Protected

Area Management Committee since the mineral reserve area is no longer recognized as part of the Protected Area (PA) due to the proclamation issued by former president Corazon Aquino (PAMB Quarterly Meeting 2022). However, it is important to look at the rationality of this initiative by the national government agency which prefers to identify the ground boundaries of the mineral reserve rather than the protected area that needs more protection. This is due to any change, movement, and development to be made on the more extensive reserve lands in BNBNP will certainly affect the physical status of the PA. Through time, these physical changes in the landscape of Biak na Bato can result in potential damage to the tangible and intangible cultural traces of the landscape based on the collected data.

According to Mark Evan Mathisen (1981), in his research on the geological record of the Central Cagayan Valley, the Paleogene Sierra Madre is a volcanic arc consisting *of intermediate igneous rock and intrusive diorite.*

The northeastern part of Bulacan, considered a *hilly mountains category* (still part of the Sierra Madre) is dominated by the Madlum, Lambak, Makapilapil, and Tartaro's geologic formation (Faustino-Eslava, 2013). These formations influence the characteristics and changes of the landscape of Biak na Bato including the extent of limestone formation in the area. Based on the initial forecast of the DENR Region III (PAMB Report, 2018), more than 200 caves have not yet been discovered or if some were already found, no initial studies have been conducted. This was also mentioned by Mr. Jose Rey Munsayac (PI 2015), who has been a longtime resident of the area.

Based on his mountaineering companion's narratives living within the Biak na Bato, they often encounter undiscovered caves while trekking around the area. Unfortunately, some of the caves are not passable due to erosion, blocking the entrance with boulders and debris.

Using the local narratives of the early staff of DENR and some famous historians in Bulacan as a basis, it can be concluded that Biak na Bato is one of the most significant places where the events that shaped our independence happened. Based on its geological and geographical profile, the location of Biak na Bato can be determined as an ideal place for settlement during the early times. It was during the period of migration when people lived by gathering food in the mountains, hunting in the forest, fishing, and eventually farming.

Although several research studies have been published regarding the natural resources and the anthropogenic characteristics of Biak na Bato, no comprehensive study has been conducted that tackles the potential discovery of historical and prehistorical data of the site.

The researcher from the conducted study is a native Bulakenyo and has broad familiarity with the areas involved in this research. It is important to point out this detail because the awareness of the changes that occurred/occurring in the province is a crucial aspect in fully analyzing the natural and anthropogenic landscape in the area.

The researcher's position as the Director of the Center for Bulacan Studies helped him with his involvement in Biak na Bato. Since 2015, he served as the resource person of Bulacan State University (BulSU) in the Protected Area Management Board (PAMB). Through the ongoing partnership with DENR, the BulSU was formally recognized as a member of the PAMB Committee.

TANGGAPAN CAVE

The Tanggapan Cave is located at the East to West position and the orientation of its entrance (Figure 6) is facing the East (121° 3' 48.75" E, 15° 7' 4.26 N), and the end part of the West is connected to a rock shelter. The upper area of the Southern part collapsed, forming a rock shelter. In 2016, under the leadership of Dr. Armand Salvador Mijares and the technical specialty of Dr. Emil Robles, the cave was mapped using the Nikon Total Station (Official Report, 2016).

Figure 6. Entrance of Tanggapan Cave (Photo taken from inside the cave)

The rock shelter in the West (Figure 7) is near the Balaong River which is located in the lower part of the mountainous area of the site. The owners of the cattle are commonly using the river as a bathing area for their animals and were accustomed to passing through the cave.

The cave and the rock shelter area were both excavated by illegal treasure hunters. There are still signs and damages of illegal activities in the Northern and Southern walls of the cave. The far eastern area of the rock shelter was also excavated, while the western part was used for charcoal-making activities.

Figure 7. Rock shelter in Tanggapan Cave

There are currently no major references regarding the history of the cave. Based on the local narratives of the native tour guides in BNBNP, it is said that the cave served as the office for accepting and welcoming Bulakenyos or Filipinos who wished to join the army of Gen. Emilio Aguinaldo. In addition to this local record, J. Munsayac (PP, 2017) also mentions that this cave was used as a slaughterhouse for cattle and animals to be served in the barangay during feasts or special occasions.

MUNSAYAC CAVE

The Munsayac Cave is still part of the Sierra Madre Mountain Range but is no longer part of the BNBNP. According to Ofelia Conag (PI, 2016), former Protected Area Superintendent, the said location is still among the places where the administrative border has not yet been delineated. It is also still unclear which municipality occupies the cave, but it is certain that it is within either the town of San Miguel or Doña Remedios Trinidad.

In the year 2015, the Center for Bulacan Studies first visited the cave based on the preliminary preparations of Bulacan State University and UP School of Archaeology for the beginning of a collaborative project related to the archaeology of Bulacan. The supervision and guidance of Dr. Armand Salvador Mijares regarding the precise identification of caves with potential archaeological data, Munsayac Cave was defined as a potential cave that has been inhabited by humans for a long time period (Center for Bulacan Studies Field Report, 2015). According to Mijares, caves with wide ceilings and openings, enough lighting in the cave entrance, no bats inside, and close to a potential water supply are caves with a high probability that people have lived in the past to the present (PI, 2016).

The archaeological excavation of Tanggapan Cave in Biak na Bato National Park started in 2017 (National Museum of the Philippines, Permit No. CPD-SA-2016-15) led by Dr. Mijares. During this period, preliminary surveys are also conducted in Munsayac Cave. The cave is located in the property area of the Munsayac clan with the coordinates of 15° 06’ 04” N and 121° 04’ 14” E. The opening of the Munsayac Cave in the Northwest has a limestone talus and a recent rock fall was observed on the upper part. The cave has two chambers and two sinkholes. The antechamber is located in the north side and the inner chamber is located on the far south area of the cave. Between the two chambers, there is a sinkhole penetrable by the sunlight. Overall, the lower part of the cave is descending to the south (Archaeological Field Report, Munsayac Cave, Mijares 2018).

Before reaching the cave, a vegetable farm of the community located in the Northwest direction can be seen during the trek. If you stand from the highest elevated platform of the mountainous area and look on the west side where the Munsayac Cave is located, you will see the vast plateau which is an ideal place for hunters. This area is a great help with the efficiency of hunters in spotting wild animals wandering in the plateau.

LANDSCAPE AND TWO TYPES OF APPROACH

In the interpretation of Gosden and Head, landscape crosses two approaches, the conceptual and physical conditions (1994). While the broad definition can be used, it also makes it difficult to understand its orientation and the use of its terminologies. The first approach refers to a landscape that is isolated from inhabitants (Crystal, 1990). In other words, landscape is defined as a representation, structure, and cultural symbol (Daniels and Cosgrove, 1988). Ingold (1993) emphasizes that the argument for the two definitions was fruitless, instead, he pointed out that both definitions are already established. He also defined the landscape as the world known by its living settlers, a pattern of activities, and a way of living in a defined location and external form of human activities that remain visible and can possibly be discovered by archaeologists after the disappearance of its ancestors.

Post-procedural theory characterized landscape archaeology as an empirical exaggeration discipline during the 21st century and focused more on Cartesian approaches. It insists on looking beyond the evidence and developing the approach according to experience and archaeology of inhabitancy. According to Fleming (2016), this analysis is not appropriate, even the rejection of the traditional mode of fieldwork and integration of Cosgrove's rhetoric. The post-processual approach involves a phenomenological approach to the past landscape and is hyper-interpretive, it is based on research initiated by Tilley and Edmonds (Fleming, 2006). Also part of this argument is the questionable results from the conducted phenomenal work. In his research summary, he identified the new approach to the post-processual landscape as problematic. He mentioned that the new idea is always open to archaeology, however, abandoning the heuristic and argument-grounded strength of conventional landscape archaeology would not be a good indicator.

The spatial analysis in Europe is usually linked to traditional archaeological landscapes (W.H. Hoskins). This tradition is rooted in concentration on deriving of cultural significance from different elements of landscape and the relationship of these spaces to each other (Harris, Lock citation by Villa, 2011).

Airborne remote sensing is currently used in the study of landscape in archaeology or other related fields. Archaeologists using this method are given the opportunity to identify any geological and cultural phenomenon that is often difficult to find (Sever in reference to Lowe, 2000). However, this approach is not enough to produce a more conclusive interpretation of the significance of landscapes that has a great influence not only on the flora and fauna in the area, but more importantly on the people who live/living in that particular territory and other people who can also be significant factors in changing natural landscapes.

In America, the first approach of GIS was conducted during the 1980s, an analysis of spatial data, and since then, GIS has been used in many archaeological spaces at various times and purposes. It has been an effective approach in analyzing and calculating the line of sights and view sheds. This is a method that comes from the field of military siting and communication facilities. However, visibility analysis was used differently in archaeology. The GIS data has the most accurate physical representation of visual materiality for any landscape analysis. It has the capability to describe the place and objects that can be found at a particular vantage point (Tschan; 2000, Ilobera; 2003 and Fitzjohn; 2007 cited by Verhagen, 2018).

GIS has already been used for almost two decades for archaeological studies. There are two branches that are commonly used, landscape study and intra-site approach. Both of these branches have their own unresolved problems.

The primary capability of the GIS in archaeology is to provide an effective process in gathering sufficient quantitative data based on the mathematical computation of analysis called processual archaeology, the archaeology of the 1960s. In this context, although GIS has become very useful, there are also some limitations to be considered from its usage. In fact, GIS is incapable of engaging in a more hermeneutic approach in treating archaeological material as dynamic, and dialectical, and incapable of maintaining a careful action regarding the relationship of objects, contexts, and interpretations which current post-processual archaeology suggests. The reason for this is that GIS is highly dependent solely on maps that represent space. These maps are uni-dimensional, neutral, and hollow in the social interpretation of the world and are very different from real-life experience or understanding of archaeological research. In this situation, the limitation of the GIS leads to the subject of whether the questions used in the research were fair or not, and whether the data collected were allocated to the conducted analysis (Haciguzeller, 2012). In general, GIS technology has restrictions on the process performed in archaeology and only exposes the gap between current theory and GIS methodology to provide a comprehensive outcome.

To fully understand these limitations, a closer understanding of the two branches of archaeology (landscape and intra-site) that primarily use GIS is necessary.

GROUND PENETRATING RADAR

There is a continuous development of approaches and technological advancements (from outside the archaeological field) for the study of landscape in relation to natural and anthropogenic changes. Among these is the use of Ground

Penetrating Radar (GPR).

The archaeological community immediately studied the possibility of the usage of GPR as a geophysical technique. It was initiated to study its use in identifying areas and sites with archaeological equipment and related units of stratigraphy (Conyers and Goodman, 1997).

Its first application in archaeological study was made in Chaco Canyon, New Mexico, year 1975 (Vickers citing Conyers and Goodman, 1976). The main purpose of the GPR approach is to discover the location of the buried structure at a depth of one meter. Experimental traverses were conducted in four locations in the area. The result showed that some of the anomalies detected on the radar reflections represented the buried structure.

From 1980s to 1990s, the GPR was continuously used and was successful in archaeological investigations. Most activities during this period were called “anomaly hunting”. These practices are used to search and locate possible cultural pieces of evidence in specific and undetermined depths, which is commonly followed by an archaeological excavation.

The application of GPR can be improved in archaeological areas/sites. Most archaeologists who originally used it were only interested in embedded cultural evidences, but later with the help of more advanced software and high-end computers, the GPR data can also be used to reconstruct old landscapes in an archaeological site (Conyers and Goodman, 1997).

Geophysical archaeology involves data collection that will allow the Archaeologists to study and map archaeological materials that the traditional methods cannot provide. Physical and chemical changes in underground archaeological materials becomes an advantage in the study of Archaeologists. Through sensitive instruments, data signals are measured, mapped, and interpreted in the GPR system and become usable information (Johnston, 2017).

GPR is a tool and method for collecting and recording underground data and information. Overseas archaeologists have been using this technical method for a long time and it is also commonly used in other scientific fields such as geology, environmental studies, and engineering.

The GPR works by sending a signal to a target material and recording its return strength and speed to the receiver. This energy pulse is shown on the controller monitor and its strength or amplitude that hits the material.

For example, the dry sand, there are 5 dielectric constants in wet sand there are 30 dielectric constants. These data can be determined based on their dielectric constants.

The Ground Penetrating Radar system has a specific and effective recognition of underground geological formation. Dry and less wet rocks are the best condition to perform a survey. In the past and even in current use, it is shown that it is still one of the most effective methods in the detection of phenomena related to karstic formation and caves. In the study conducted by Chamberlain, et al. (2000), he gave an example in defining a cave in a limestone landscape. This is by posting the process of parallel profile data from the GPR grid survey and the data output becomes a representation of time slices. Another example of using the GPR method in the cave is the study conducted by Beres et al. (2001), comparing the data output of GPR with microgravimetric measurement. The recorded and observed anomalies in the profile were confirmed by measuring the force of gravity.

GPR USE AND PURPOSES

In archaeology, the issue of conservation of places with cultural and historical value has always been important. The practice of archaeological excavation is a critical activity that requires comprehensive management planning. Therefore, the use of tools with a geomorphological approach is a significant contribution to archaeological studies, which does not require archaeological test pits to initially understand the nature of archaeological sites. GPR as one of the relative methods in remote sensing, is much more effective and offers a non-destructive approach to the natural and anthropogenic properties of the research site's soil.

The main purpose of using the GPR is to obtain an initial record of the archaeological excavation site or other sensitive sites where cultural remains are located, such as the tombs and burial sites, which can be avoided by the archaeologists because of existing traditional beliefs (Johnston, 2017).

The main advantage of using the GPR method is to gather underground data without performing an earth-moving activity. This allows for extensive study in a large space and at the same time, protecting and preserving it.

Part of this research study is the development of initial protocols of using GPR as a preliminary tool for identifying an archaeological site.

GPR CALIBRATION

The accuracy of the GPR data is more likely to be achieved if the surveyor considers important factors that can affect the output. Here are the following methods and considerations for the calibration (Bigman, 2018).

Fitting. /matching of a hyperbola. The visible hyperbola in the receiver depends on the speed of scanning of the specified target range. The depth of the scanned soil also affects the hyperbola, the deeper the penetration, the hyperbola becomes more visible, and with the shallow penetration, the smaller the hyperbola (Figure 8).

Recording time.It is also important to consider the length of recording time from the beginning of scanning and the estimation of the target's depth. Here is a summary of examples that can be done (Bigman, 2018);

a. . for example the most reasonable depth of the target is two (2) meters from underground (below ground surface- BGS) based on reasonable estimation,

b.and based on hyperbola fittings carried out on the type of soil that exists in the area the wave of GPR is 10 cm/ns,

c. and there is 100 cm per meter size which means that for a 2-meter depth, there is a total distance of 400 cm travel of the GPR signal to get back to the receiver from the lowest depth penetrated.

d. To obtain the closest estimation of the recording duration in the GPR receiver, it is necessary to divide the GPR wave velocity into the hyperbola fitting (10 cm/ns) and the total depth of the target (400 cm)-

400cm/10cm = 40 ns (recording time needed)

e. It is also important to place extras at the time of recording, to get it, you can multiply the reasonable length of time intervals, for example:

40 ns x 1.5 = 60 ns (recording time with footage)

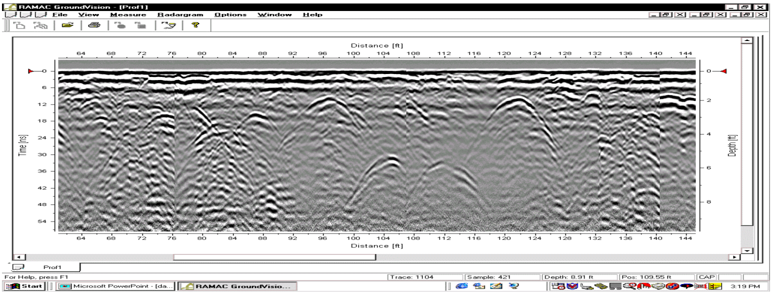

Figure 8. Example of a radargram

Background removal (Filter). The main requirement in the profile of a GPR scan is its clarity in analyzing any underground target. However, the influence of objects and structures around the area is inevitable. The background filter process removes horizontal images from the profile including the so-called digital noise (Bigman, 2018).

Gains or multipliers in data. The process of further enhancement of images projected in GPR to better see the inclusion and changes that have been made underground (Bigman, 2018).

Static Correction. It is applied due to the signal impact of different elevations of the target site (Bigman, 2018).

Subtract-mean. The subtract-mean or the dewow filter removes weak frequencies that are often considered as noise (Bigman, 2018).

GROUND PENETRATING RADAR SYSTEM

GPR creates two different types of visual reflection: layers and targets. The layers are shown as continuous reflections as can be seen on the wall of a pit made by a backhoe. In order for the layering to be seen as a reflection, it is necessary to have enough dielectric to see the difference of each line. Meanwhile, underground objects with identified cross-sectional areas will appear as hyperbolic targets like a fish in a fishfinder. They have the almost perfect reflection profiles on radargram. Targets can be hyperbola from the tree roots, rock, animal cave, brick or other physical materials under the site (Leach, Geophysical Survey System, MN10-376 Rev. A).

Figure 9 shows the difference in the dielectric constant of the materials that can possibly be hit during the survey. Most materials near the surface of the earth are not the same dielectric, depending on the depth of the location, water content, material type, and other possible materials.

Air	1	Frozen Soil/Permafrost	6
Snow Firn	1.5	Dry Salt	6
Dry Loamy/Clayey Soils	2.5	Syenite Porphyry	6
PVC	3	Wet Granite	6.5
Asphalt	3 - 5	Travertine	8
Glacial Ice	3.6	Wet Limestone	8
Dry Clay	4	Basalt	8 – 9
Dry Sands	4	Wet Basalt	8.5
Dry Granite	5	Tills	11
Limestone	4 – 8	Wet Concrete	12.5
Concrete	4 – 11	Volcanic Ash	13
Soils & sediments	4 – 30	Wet Sands	15
Coal	4.5	Saturated sand (20% porosity)	19 – 24
Frozen Sand & Gravel	5	Wet Sandy Soils	23.5
Shale	5 – 15	Dry Bauxite	25
Dry Concrete	5.5	Saturated Sands	25
Dry Limestone	5.5	Wet Clay	27
Dry Sand & Gravel	5.5	Peats (saturated)	61.5
Potash Ore	5.5	Organic Soils (saturated)	64
Sandstone	6	Sea Water	81
Dry Mineral/Sandy Soils	6	**Water**	81

Figure 9. Relative Dielectric Permeability Geophysical Survey System Inc.

Figure 10 shows the part of the report used by the Center for Bulacan Studies after a month and a half of post-processing of GPR raw data from the Tanggapan Cave. The report presented the following basic information about the site surveyed and the technical descriptions of the GPR.

2 Results

Figure 10. Material used in the presentation of the results of the GPR survey at the Tanggapan Cave to the committee of the Protected Area Management Board.

According to the report, the purpose of the survey was to investigate and map its archaeological potentiality. The area has typical tropical conditions, and a cave system, but the actual climate is not determined. The surface of the cave is earthy and sandy.

The GPR used in the survey has a central frequency of 450 mhz. After collecting the GPR raw data, it is processed through ReflexW and Reflex3DScan software. This type of antenna is capable of scanning underground up to 30 meters, but its ability to scan anomalies and features decreases depending on the wetness and dryness of the target area. The objects around the site can also interfere with the electromagnetic signal being released by the antenna.

The survey team is composed of researchers from the Bulacan State University and City Environment and Natural Resources Office of the Province of Bulacan. The researchers from the Center for Bulacan Studies spearheaded the survey.

Figure 11 shows the actual shape of the grid used to execute the GPR survey of the Tanggapan Cave.

The survey grid design is composed of nine (9) parallel GPR X profiles at four (4) meters, with actual survey design direction from right to left viewed from the top; and five (5) parallel GPR Y profiles at two (2) meters, with actual survey design direction from top to bottom (top view). The GPR scan has a space of 0.5 meters intervals. This diagram (Figure 11) is for visualization only. This model was created using the website https://www.nctm.org/Classroom-Resources/Illuminations/Interactives/Isometric-Drawing-Tool/.

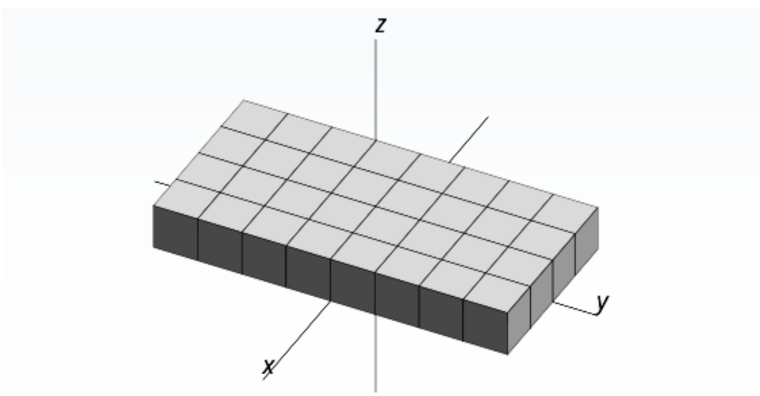

Figure 11. 3D model of survey grid (002) made in the rock shelter of the Tanggapan Cave

Figure 12 shows the grid in the rock shelter area of the Tanggapan Cave. The researchers called it a ”powder approach” in setting the GPR grid because the powder used in this process is any powder that can easily see marks on the ground but cannot influence the electromagnetic signal emitted by the GPR. This method can be used in closed spaces similar to caves and those that don't have too volatile winds. Unfortunately, this approach is not effective in open areas where the wind is rapidly changing. For the areas with strong winds, a grid printed in a tarpaulin can be used. However, it is important to note that the use of any metal objects can negatively influence the GPR signal. If this happens, ringing anomalies on the diagram will appear.

Figure 12. Actual survey grid made in the rock shelter of the Tanggapan Cave

Figure 13 is an illustration of the locations and proximity of GPR GRID, Test Pit 2 (TP), TP3 and Sinkhole (S). The recording of the surface features in the target site for a GPR survey is important because it is highly likely that these features seen in the area may affect or influence the GPR signal and reflections on the radargram.

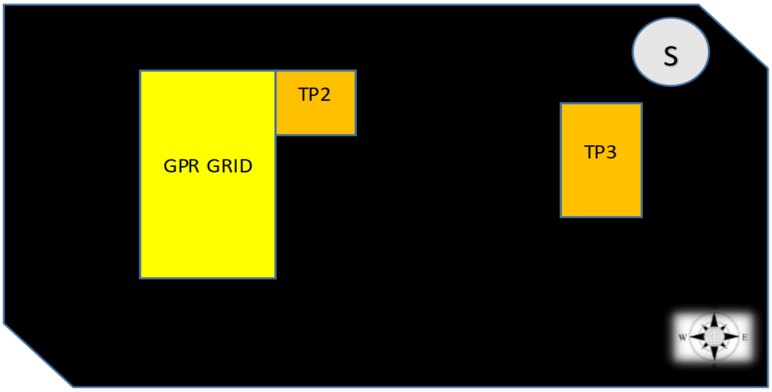

Figure 13. The location of the GPR Grid 002 survey, positioned in the stone cave behind the Tanggapan Cave

The orientation of each surveyor included in the GPR survey is necessary. Here are some of the main processes that the researcher developed through actual experience in the conducted GPR survey: (1) placing of any gadget carried in airplane mode or if possible to turn off any devices near the area to be surveyed, (2) before setting the grid, it is important to clean the surface area where the scan will be conducted, the most important reminder is to remove any metal, stone, and other debris on the surface, (3) as much as possible, select a spot with an equal level of ground, (4) record the location of objects or features in an area that cannot be removed before conducting the survey, they may also reflect on the radargram, depending on the composition of its material, (5) check/interview with the community to see if there has been heavy rainfall in the area in recent days, (6) appoint a personnel for recording the file name in each grid line survey, (7) photograph the grid made and any photos captured during the actual survey, (8) Conducting 2D and 3D survey is beneficial since it provides different basic radargram analysis, (9) Make it clear to the personnel assigned on carrying and pulling out the antenna that the speed and slowness of walking matters, (10) It is important for the antenna to pass through the set grid at every end of all the grid line.

According to the conducted GPR survey, it was identified that the minimum number of individuals required in the survey is four. Thus, here is the distribution of tasks for each individual included in the survey: (First person) he was assigned to wear the GPR monitor and give the go signal if the antenna can now be pulled across the grid line, (Second person) he was tasked to pull the antenna and has the control over how fast the scan will be made, (Third person) he will be of help to the first person in carrying and returning the antenna to the survey starting point on the grid, and the (Fourth person) was the one assigned to record the file name of each line in the grid that the antenna already passed through.

Figure 14 shows the actual GPR survey. The removal of any objects that may interfere with the signal of the GPR antenna was administered first in the covered part of the grid.

Figure 14. Photo captured during the conducted GPR Survey in the Rock shelter at Tanggapan Cave

Figure 15 shows the 3-dimensional GPR Model that corresponds to the 227th time/depth slice, 61st y-cut, and 8th x-cut. Parallel x-scans and parallel y-scans were processed separately. The following filters were applied such as static correction, subtract mean, and background removal at the gain function.

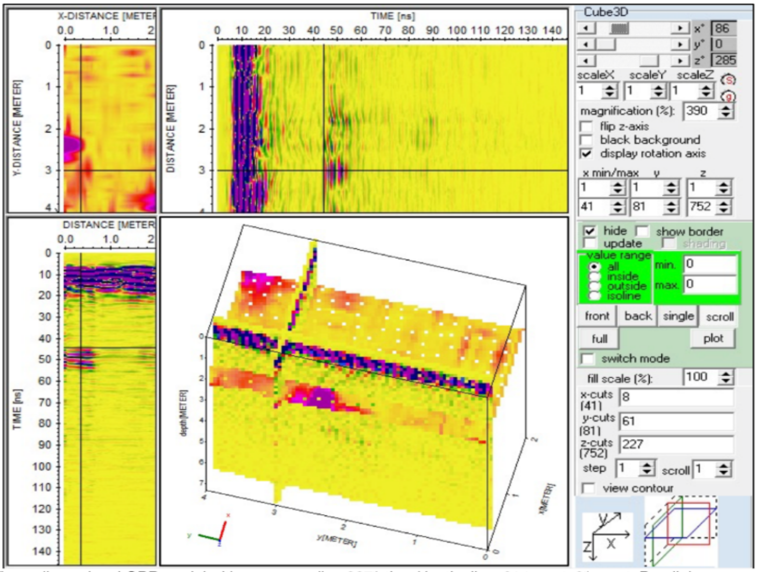

Figure 15. Print screen of the post process of GPR 002 Radargram from the Rock shelter in the back of the Tanggapan Cave

The GR_002 data was the one that is been used as the sample for the post-processing. One of the parameters used is the *static correction* together with the initial parameter reading using the mean. Subtract-mean filter was additionally used as well. The application of these filters is part of the main step in the process where temporal filtering is used in removing any signal with low frequency from the data reduced in the zero level mean. The removal of the background of all the parts of the Radargram is also used to remove the nearly horizontal signature signal. This step becomes the way for the weak signals such as weak point targets in the processed section be visible. Lastly, the gain function filter from 0 ns at 3 ns [1/pulse width linear gain] was used to further investigate the underground. The Gain enhances the shape of the captured images due to the weak signals and geometrical spread and loss.

The three-dimensional GPR model in Figure 15 only shows a limited image of the result of the survey. To resolve these limitations, the multiple x-cuts (figure 16), y-cuts (figure 17) and depth/time slices (figure 18) also need to be presented.

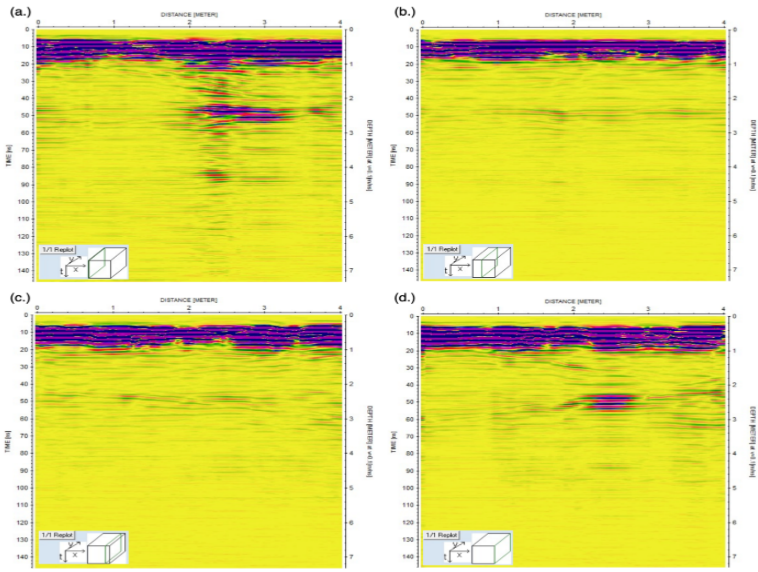

Figure 16. Different x-cuts of GR_002: (a) 1st at 0.000m, (b) 17th at 0.8000m, (c) 33rd at 1.6000m, (d) 41st at 2.000m. All radargrams were set in 1x and 1y scales and were applied with filters that are mentioned.

The x-cuts of GR_002 are from the y-scans of the actual GPR Survey. The same filters were also applied to the following radargram of the first process sequence. For the 1st to 17th x-cuts (0 to 0.8 metro) at a depth of 2 meters at 4 meters (figure 52. a, b) anomalies are seen. These anomalies are described with the use of linear and clustered reflection. The anomaly that is seen at a depth of 2 meters is also seen at the 33rd and 41st x-cuts (1.6 to 2 meters). On the other hand, the reflection that shows an anomaly at a depth of 4 meters became weaker in this interval (figure 52. c, d). The liner reflection is possibly related to the soil layering. The signature on the clustered reflections is consistent with the signature that shows cavity, fracture, subsidence, or possibly any objects that have been buried underground. The characteristics of these signatures are often seen at the karstic formation or on caves in an interconnected area.

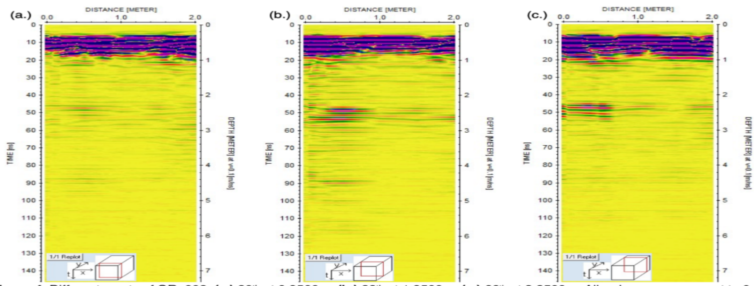

Figure 17. Different y-cuts from GR_002 (a.) 20th and 0.950m, (b.) 38th and 1.8500m, (c.) 66th at 3.2500m. All the radargram was set in 0.5 x at 1y scales and were applied with the same filter application.

Meanwhile, the y-cuts of GR_002 are from the x-scans of the actual GPR survey. The same filters are also used in these radargrams from the initial processing sequence. For the 20th to 66th x-cuts (0.9500 to 3.2500 meters), the same anomalies are seen at the depth of 2 meters to 4 meters (figure 17. a, c). These anomalies are clearer to view on the 38th x-cut and 1.8500 meters (figure 18. b) Same interpretation can possibly be made here.

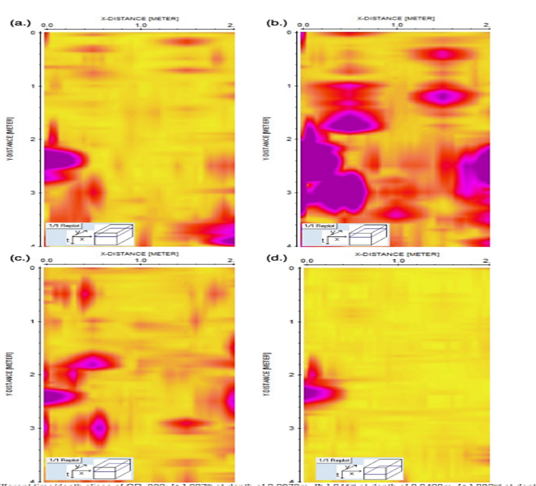

Figure 18. Different time/depth slices from the GR_002: (a.) 227th with a depth of 2.2070m, (b.) 241st with a depth of 2.3438m, (c.) 282nd with

a depth of 2.7441m. All the radargram was set in 0.5 x at 1y scales and were applied with the same filter.

The time/depth slices of GR_002 were generated by combining the x-cuts and y-cuts of this data set. The same filters are also used in these radargrams from the initial processing sequence. For the 227th to 28th time/depth slices (with a depth of 2.2070 to 2.7441 meters), the same clustered anomalies can be observed, Figure 18 at a and c, shows the top view of the bottom part with anomalies on the radargram. These anomalies were observed in Figure 15 B. Same interpretation can be applied here. Furthermore, it is still consistent with the signature of the cavity, fracture, subsidence, and any objects buried underground. The said signature is also often seen in the karstic landscape and network of the caves of any higher place.

The plan and approach to using a GPR at the Tanggapan Cave were formed and developed based on some research studies that are taken into consideration. The position of the grid was based on the size and position of the archaeological excavation conducted in the year 2017. This is also due to the fact that these specific areas inside and outside of the cave have the most anticipated spots where anthropogenic activities occurred in the past such as cooking, forming and making utensils, etc. The geological movement of the cave which is the same as the discovered rock flow in TPI was also used as the basis of the approach in using GPR. It was identified in the radargram inside the Tanggapan cave that this feature did not continue to the other parts of the cave and also was limited to approximately 1 meter away from the TPI.

THE KARSTIC CHARACTERISTIC OF BIAK NA BATO

The microtektites that were both found in the Munsayac and Tanggapan Cave (Figure 19) show an indication that there is an old Pleistocene layer in the area, especially on the open sites. There is a big possibility that that the microtektite that has been found was deposited in the early Holocene stage and it goes through a second process of deposition through the sinkhole of the two caves that are mentioned.

Figure 19. Micro-tektites recovered from Tanggapan Cave

The Biak na Bato was first known as the historical site related to the revolution of General Emilio Aguinaldo. Up to this date, the historical basis of this is used in every discussion on the reasons why Biak na Bato is an essential place. But after all, this site also holds the same natural features that need to be protected just like on other protective landscapes of the country. The biological essence of this site is rooted within the limestone formation that is spread along the rivers and mountainous parts of the area. The hundreds number of caves which until now haven't obtained any complete and recorded studies almost certainly have a hidden form of life that is yet to be uncovered.

The karstic formation on Biak na Bato (Figure 20) continuously changes physically at the same time with the adaptation of the people who reside here who have witnessed and experienced its change. It was natural for these people in any period to adapt to this particular situation they are in. Through this process, cultural patterns are formed which often leave physical markings that can be studied archaeologically in the present. However, the real challenge in conducting this study is the extensive changes the area will go through due to natural and anthropogenic influences. To the sites similar to the Biak na Bato, which obtains wide karstic formations, it serves as an advantage towards its archaeological essence. The caves that were naturally formed as formations for a long time serve as the "matigas" or solid foundation that protects the traditional cultures that are originated by the people living in such period of time from their daily life activities related to lifestyle and tradition.

Figure 20. Karstic Formation in Biak na Bato National Park

TANGGAPAN CAVE AS TEMPORARY HABITATION

The archaeological materials retrieved from the Tanggapan cave such as animal bones (Figure 21) that were made with modification show an indication that this cave was used as a temporary shelter in a particular period during pre-historic times. It was possible that these bones were used as accessories or for a particular cultural pattern at that time. The process of designing is an activity that requires a long period of practice. The meticulous preference in forming its shape can be based on the needs or the interests of one who creates it himself. Its creation did not originate from the repeated production of stone tools which specifically identifies the purpose of creating that can be of used in processing food. The modified animal bones at Tanggapan Cave were just small pieces and it was certainly irrelevant in the practice of processing food. Aside from this, the bones compared to the stones are softer and require a greater amount of control in creating.

Figure 21. Retrieved animal bone in Tanggapan Cave belonging to Macaque specie

Figure 22. Retrieved animal bone in Tanggapan Cave belonging to warty pig specie

The proximity of Tanggapan Cave to the Balaong River (Figure 23) is also an indication that this cave was possibly considered by the people of pre-historic times as their temporary shelter. The river immediately brought encouragement for these people to stay in a particular place, since it provides the natural grace of nature.

Figure 23. Balaong River in Biak na Bato National Park

According to the oral narrative of the people from Sitio Balingkupang, they encountered the caves near the Tanggapan Cave have many remains of animal bones. However, according to Mr. Jose Rey Munsayac, his grandfather who legitimately resided in Biak na Bato, the following caves in the area was used as slaughtering area for animals like buffalos and pigs. He can also attest that the primary reason is the river where the source of water is available for washing the slaughtered animals.

The perspective from the environment from pre-historic times and contemporary history are the same, the parameters of where these people will live are between the distance and proximity of the source of water and food. Such natural resources are around, these caves serve as a natural shelter that can be used to cover them from heat and rain. This also holds a space for their traditional and cultural activities which before were only in relation to food and its preparation. Which also became their place to rest but eventually became their place to live in.

3 Conclusion

Continuous development of modern technology has been emerging from the current bad condition of preserving heritage and culture. The anomalous changes in the landscape due to uncontrolled rapid land conversion have been affecting the value of cultural property within its range. Illegal activities such as treasure hunting are also adding to the disturbance of the natural context of previous generations. With these destructive factors, development in research approaches and enhancement of the technological capabilities of researchers are made. One of these approaches is the introduction of Ground Penetrating Radar (GPR) in archaeology applications in the Province of Bulacan.

Ground Penetrating Radar is one of the modern systems that has proven its importance in producing accurate data recording of potential sites. Initial identification of archaeological sites can be determined using the GPR. Generally, the GPR system allows surveyors and researchers to pinpoint a certain location within the site wherein anomalies of possible materials are present. For the previously excavated sites, GPR can help in the identification of possible extensions of trenches where artefacts can be found. It can also be used to avoid certain locations where sinkholes and rockfalls are located.

The previous GPR Survey conducted in Tanggapan Cave and Munsayac Cave in Biak na Bato National Park proved that the changing technology can benefit both archaeological research and the cave itself. The anomalies found within the caves were identified as signatures of cavity, possible buried objects, fracture and subsidence. Conducting the GPR survey in the archaeological site can reduced the possibilities of damaging a certain artefact and avoid hazardous areas that can harm the archaeologist and damage the cave itself.

Overall, GPR is highly recommended in archaeological research and excavation activities. Excavations have lesser risks of damaging artefacts, buried materials, and structures. The new technological system and its non-intrusive survey feature, GPR plays a significant role in archaeology, especially in cave sites where hazardous factors are present.

Overall, GPR is highly recommended in archaeological research and excavation activities. Excavations have lesser risks of damaging artefacts, buried materials, and structures. The new technological system and its non-intrusive survey feature, GPR plays a significant role in archaeology, especially in cave sites where hazardous factors are present.

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