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# **GEOPHYSICAL FORENSIC FOR ARCHAEOLOGICAL EXPLORATION IN MUAROJAMBI, INDONESIA**

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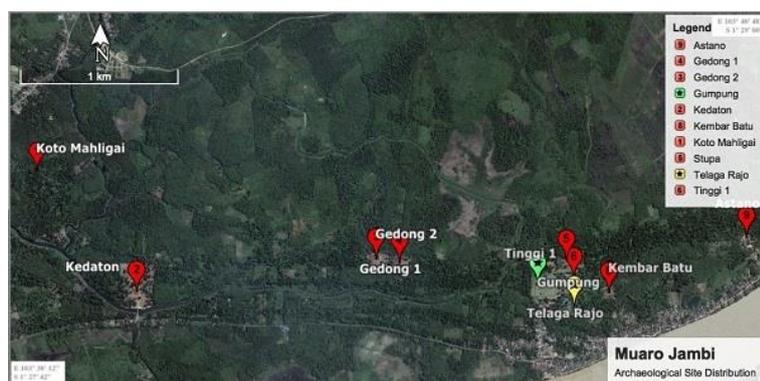
## **ABSTRACT**

In July 2011, archaeological exploration tried to apply the physics method for the first time in Muarojambi, Indonesia. We combined physics with geosciences and called it geophysical forensic. Our method is known as Ground Penetrating Radar (GPR). GPR used high-frequency electromagnetic (EM) waves between 10-3000 MHz to imaging subsurface based on dielectric permittivity's physical parameters. Changes in the electrical properties, rock magnetism, and water content of the material under the surface will provide a response recorded on the radargram as a function of distance to time (two-way travel time). Data processing performs to reduce the noise recorded when collecting data. We have successfully obtained four GPR lines; three lines gathered near Gumpung Temple and one line at Telago Rajo Pool. The GPR method succeeded in giving a subsurface image and possibility of the archaeological objects near the Gumpung Temple and Telago Rajo Pool.

**Keywords:** geophysical forensic, gumpung, ground-penetrating radar, Muarojambi, Telago Rajo

## INTRODUCTION

Muarojambi has many unexposed archaeological objects. Muarojambi, as an archaeological site, has a high historical and cultural value related to the Srivijaya Kingdom. Srivijaya is the most maritime power in Southeast Asia during the ancient period [1]. Since 1820 many archaeological objects founded. Only ten objects have been given names and identified in a scientific publication [2]. More than 82 objects still unpublished. It was costly to do archaeological exploration with a conventional method like excavation. We need a fast and accurate method to support archaeological exploration. FIGURE 1 shows the distribution of archaeological objects in Muarojambi.



**FIGURE 1.** Muarojambi Archaeological Site Distribution.

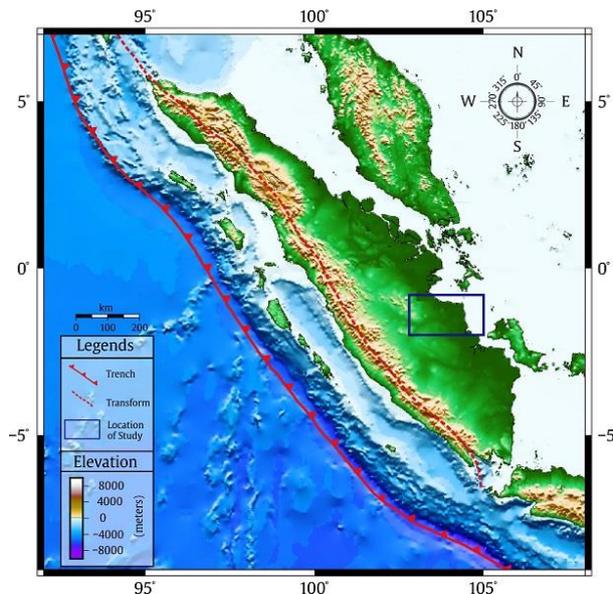
The application of physics to support archaeological exploration is still limited in Indonesia. This study intends to reveal archaeological objects below the surface of the land using geophysical forensic. The combination of physics and analysis of geology, geophysics/earth physics, and archaeology supports the Muarojambi temple complex.

Our research objective is to get the possibility of archaeological objects in Gumpung Temple and Telago Rajo Pool. A previous study [6] presented the possibility of the archaeological object in Kedaton Temple, Muarojambi.

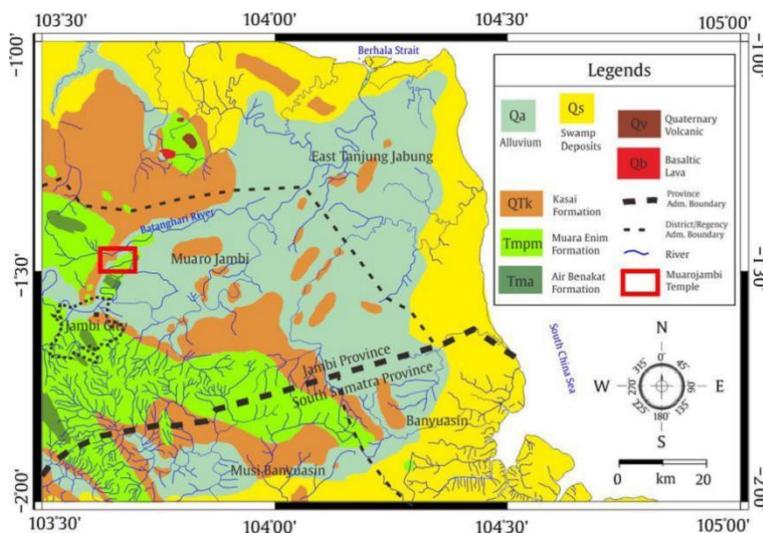
## METHODS AND MATERIALS

Muarojambi is located in the lowlands area, not exceeding 20 meters above sea level. Although located 100 kilometers from the present coastline, the existence of the Batanghari River and its connected branches allows this area reached using water transportation. This area is far from geological hazards like earthquakes, tsunami, and volcanic eruptions.

FIGURE 2 shows the tectonic map of Sumatra, plotted using Generic Mapping Tool [3]. The study area is located in Marosebo District's Muarojambi Regency, indicated with a blue rectangular block in FIGURE 2. FIGURE 3 shows a geological map of Muarojambi modified from [4].



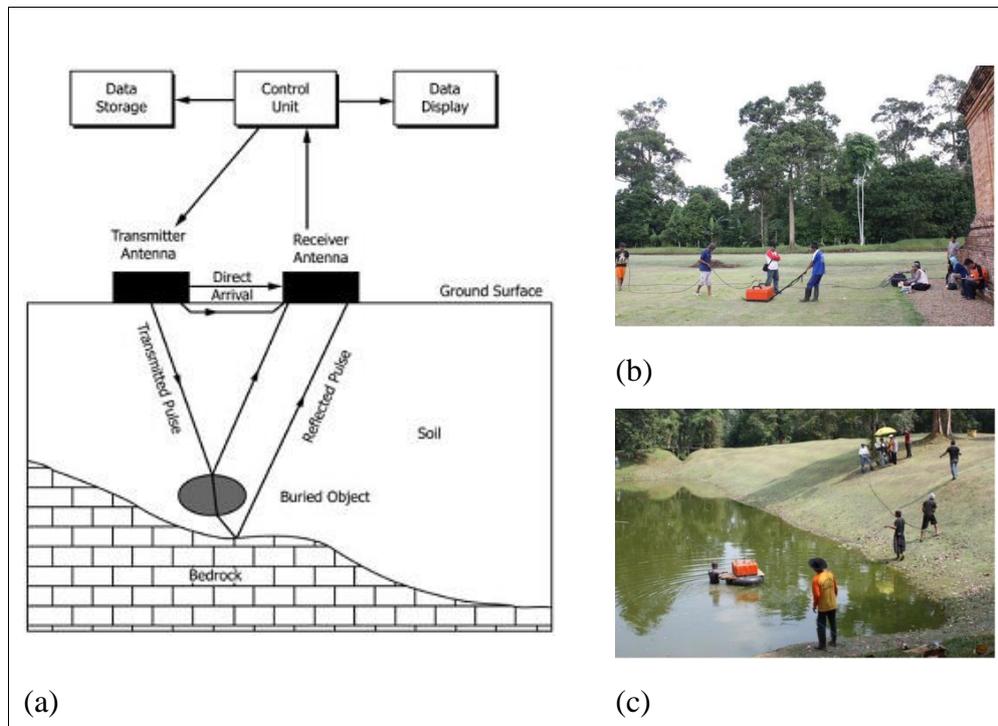
**FIGURE 2.** Tectonic map of Sumatra. Map generated using Generic Mapping Tools [3]. This map shows the plate tectonic interactions between the Indian-Australian Plate and the Eurasian Plate. A purple line with a triangle is subduction (convergent) creates a trench. The orange line dash line is a transform (strike-slip) create Great Sumatra Faults Zone. Plate boundary generated from [5]. Location of the study indicated with a blue rectangle.



**FIGURE 3.** Geological Map of Muarojambi, modified from [4]. The study area is located in Marosebo Sub-District, Muarojambi Regency, indicated with Red Rectangular Block near Batanghari river.

Geophysical forensic is the application of non-destructive geophysical methods to study, discover, and map invisible objects buried or hidden either in layers of soil, rock, underwater, on walls [7]. Geophysical forensic is about creating a more efficient investigation. It can covers large areas rapidly [8]. Geophysical forensic can detect various phases of burial over different periods [9]. Geophysical forensic give recommendation for archaeological excavation [10].

The Ground Penetrating Radar (GPR) method is nearly the same as the seismic reflection method. FIGURE 4a shows the basic principle of GPR [11]. If the mechanical waves are used in seismic, the GPR method uses high-frequency electromagnetic (EM) waves from 10 to 3000 MHz [11]. The EM wave is transmitted by transmitter antennas, then the energy is detected by the receiver antenna. The transmitter antenna is often joined with the receiver antenna and called a transducer.



**FIGURE 4.** (a) Basic Principal of GPR [11]; (b) GPR acquisition at Gumpung Temple; (c) GPR acquisition at Telago Rajo.

We use the GSSI SIR-20 GPR System with a 200 MHz antenna for data acquisition. Basic processing like editing, move start time, gain recovery, and stacking doing in RADAN 6. Filtering and visualizing doing with MATGPR [12].

## RESULT AND DISCUSSION

The Gumpung Temple condition was clear from noise. FIGURE 5 shows an image from UAV (drone). Our GPR line position is near the main temple. It was flat terrain condition. We can not see the anomaly in the surface.



**FIGURE 5.** Image of Gumpung Temple using UAV (drone). Red line shows our GPR scans.

FIGURE 4b and 4c show photo documentation while data acquisition at Gumpung Temple and Telago Rajo Pool (in local language Telago Rajo mean the place where king and queen take a bath). FIGURE 4 shows the location of GPR data acquisition.

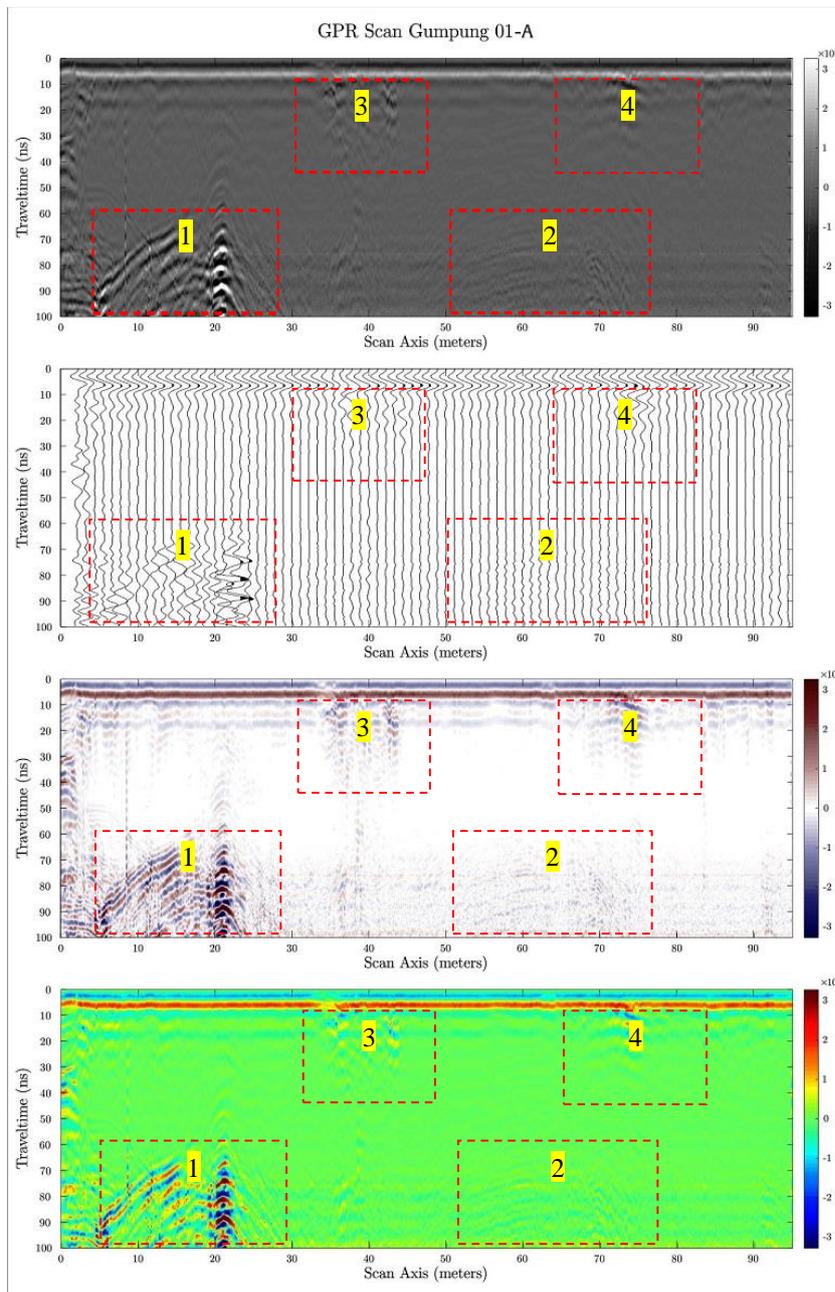


**FIGURE 6.** Location of GPR data acquisition; Gumpung Temple show with green balloon symbol. Two parallel blue lines West-East direction on Gumpung are Line 01-A and Line 02. Telago Rajo Pool show with yellow balloon symbol. Blue line at Telago Rajo Pool is Line 04.

We have successfully imaging three GPR in Gumpung Temple and one GPR in Telago Rajo Pool. We compare each GPR imaging with four view modes: grayscale, wiggle, blue-red, and jet view.

GPR imaging Line Gumpung 01-A is shown in FIGURE 7. There is the possibility of an archaeological object on the 2D GPR Cross-section in FIGURE 7. GPR anomaly (1) located between scan-axis 4.0-28.0 meters at 60-100 ns; approximately 3.0-5.0 meters depth. GPR anomaly (2) located between scan-axis 52.0-76.0 meters at 60-100 ns; approximately 3.0-5.0 meters depth. GPR anomaly (3) between scan-axis 30.0-48.0 meters at 10-40 ns;

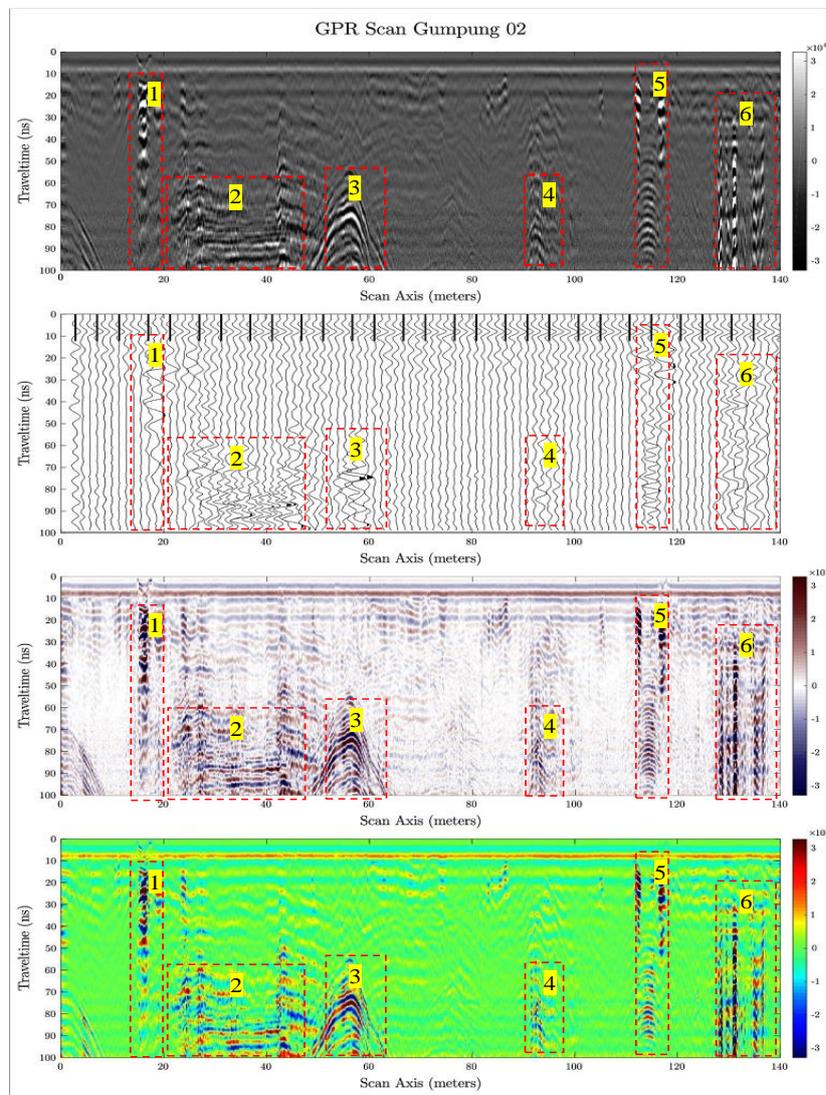
approximately 0.5-2.0 meters depth. GPR anomaly (4) between scan-axis 65.0-83.0 meters at 10-40 ns; approximately 0.5-2.0 meters depth.



**FIGURE 7.** GPR Imaging Gumpung 01-A; (a) Grayscale view; (b) Wiggle view; (c) Blue-Red view; (d) Jet view.

GPR imaging Line Gumpung 02 is shown in FIGURE 8. There is a possibility of the archaeological object on the 2D GPR Cross-section in FIGURE 8. GPR anomaly (1) located between scan-axis 16.0-20.0 meters at 5-95 ns; approximately 0.25-4.75 meters depth. GPR anomaly (2) located between scan-axis 20.0-48.0 meters at 60-100 ns; approximately 3.0-5.0 meters depth. GPR anomaly (3) between scan-axis 52.0-62.0 meters at 60-100 ns;

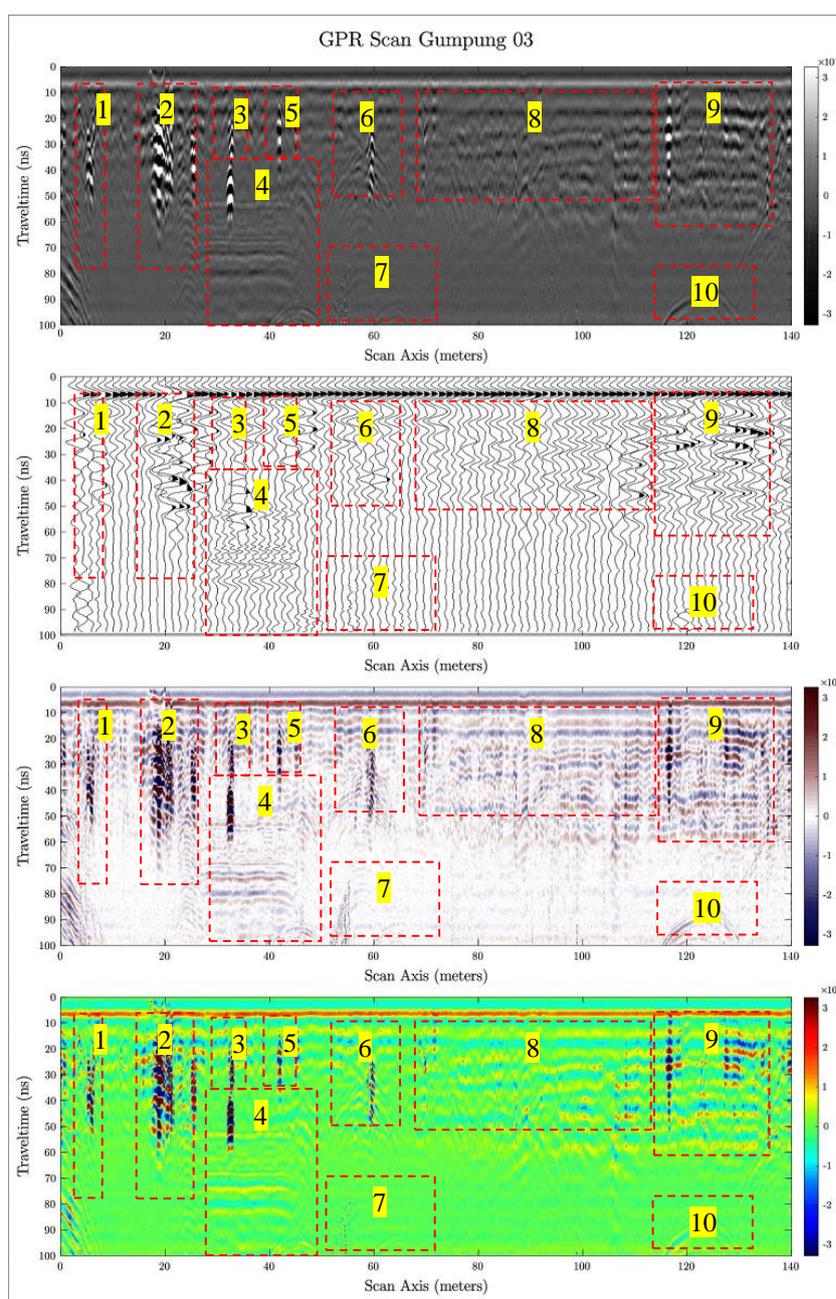
approximately 3.0-5.0 meters depth. GPR anomaly (4) between scan-axis 90.0-95.0 meters at 60-100 ns; approximately 3.0-5.0 meters depth; GPR anomaly (5) between scan-axis 110.0-120.0 meters at 10-90 ns; approximately 0.5-4.5 meters depth. GPR anomaly (6) between scan-axis 130.0-140.0 meters at 20-100 ns; approximately 1.0-5.0 meters depth.



**FIGURE 8.** GPR Imaging Result Gumpung 02; (a) Grayscale view; (b) Wiggle view; (c) Blue-Red view; (d) Jet view.

GPR imaging result Line Gumpung 03 is shown in FIGURE 9. There is a possibility of the archaeological object on the 2D GPR Cross-section in FIGURE 8. GPR anomaly (1) located between scan-axis 2.0-8.0 meters at 5-55 ns; approximately 0.25-4.75 meter depths. GPR anomaly (2) located between scan-axis 12.0-24.0 meters at 10-60 ns; approximately 3.0-5.0 meters depth. GPR anomaly (3) between scan-axis 30.0-35.0 meters at 20-50 ns; approximately 3.0-5.0 meters depth. GPR anomaly (4) between scan-axis 25.0-55.0 meters at 50-100 ns; approximately 3.0-5.0 meters depth; GPR anomaly (5) between scan-axis 40.0-45.0 meters at 10-50 ns; approximately 0.5-4.5 meters depth. GPR anomaly (6) between scan-

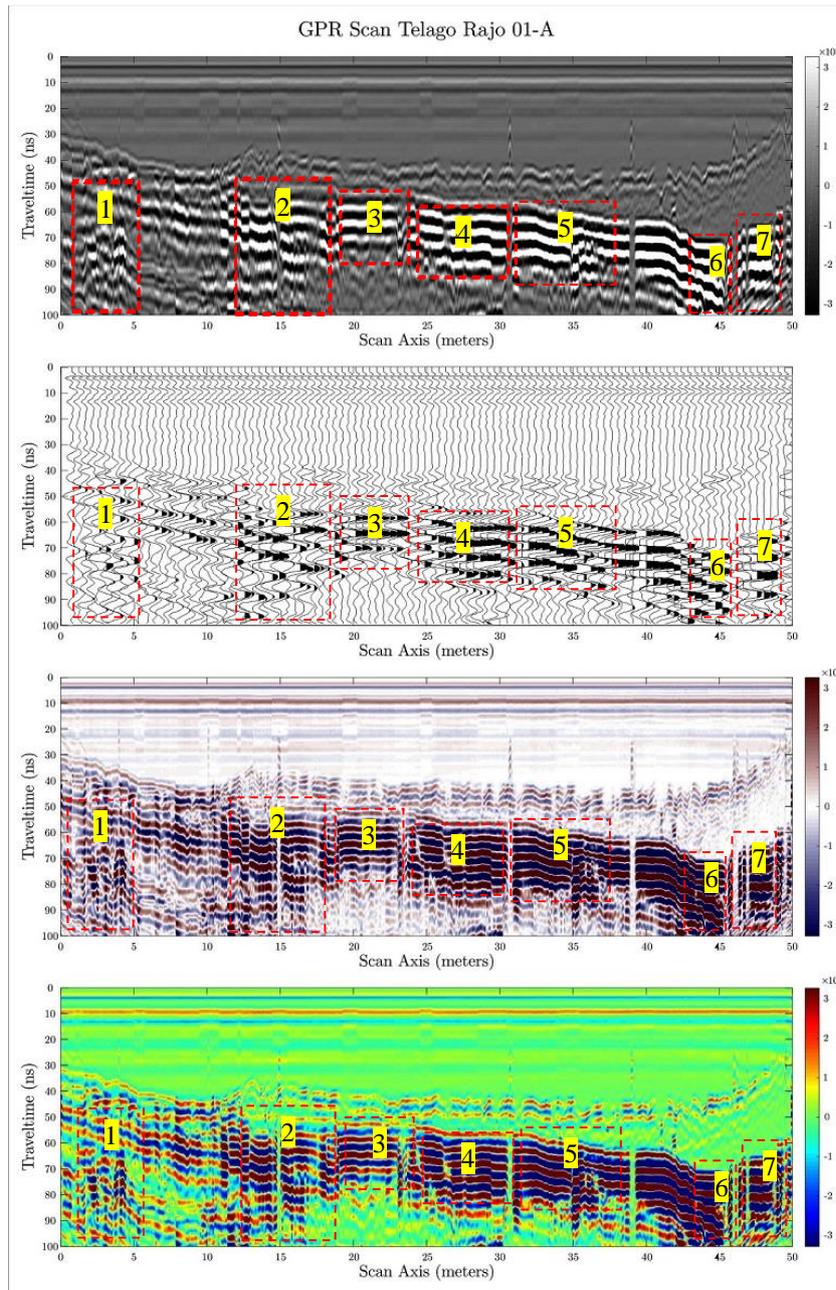
axis 50.0-70.0 meters at 30-55 ns; approximately 1.0-5.0 meters depth. GPR anomaly (7) between scan-axis 50.0-70.0 meters at 80-100 ns; approximately 1.0-5.0 meters depth. GPR anomaly (8) between scan-axis 70.0-115.0 meters at 10-60 ns; approximately 4.0-5.0 meters depth. GPR anomaly (9) between scan-axis 115.0-138.0 meters at 10-70 ns; approximately 0.5–3.5 meters depth. GPR anomaly (10) between scan-axis 110.0-130.0 meters at 85-100 ns; approximately 4.25–5.0 meters depth.



**FIGURE 9.** GPR Imaging Gumpung 03; (a) Grayscale view; (b) Wiggle view; (c) Blue-Red view; (d) Jet view.

GPR imaging result Line Telaga Rajo 01-A is shown in FIGURE 10. There is the possibility of an archaeological object on the 2D GPR Cross-section in FIGURE 10. GPR anomaly (1)

located between scan-axis 2.0-6.0 meters at 60-100 ns; approximately 3.0–5.0 meter depths. GPR anomaly (2) located between scan-axis 12.0-18.0 meters at 55-95 ns; approximately 2.75-4.75 meters depth. GPR anomaly (3) between scan-axis 19.0-24.0 meters at 50-75 ns; approximately 2.5–3.75 meters depth. GPR anomaly (4) between scan-axis 24.0-31.0 meters at 60-80 ns; approximately 3.0-4.0 meters depth; GPR anomaly (5) between scan-axis 32.0-39.0 meters at 60-80 ns; approximately 3.0-4.0 meters depth. GPR anomaly (6) between scan-axis 43.0-46.0 meters at 70-100 ns; approximately 3.5-5.0 meters depth. GPR anomaly (7) between scan-axis 46.0-50.0 meters at 65-90 ns; approximately 3.25-4.5 meters depth.



**FIGURE 10.** GPR Imaging Telago Rajo; (a) Grayscale view; (b) Wiggle view; (c) Blue-Red view; (d) Jet view.

## CONCLUSION

We have conducted four GPR lines that show the possibility of archaeological objects. All objects show an anomaly recorded in four view modes. These objects can be confirmed and validated using the hand auger, shallow drilling, or trenching before going to an excavation. GPR has successfully to give the possibility of hidden objects in the subsurface.

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