Identification of Sediment Layer Using Ground Penetrating Radar (GPR) Case Study Teluk Betung

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Abstract: Ground penetrating Radar (GPR) is an active geophysical method that utilizes electromagnetic waves as a source of waves. The basic principle of this method is transmitting the EM signal from the transmitter (TX) to the bottom of the surface. When there is a difference in the wave, a layer will be reflected by the wave and will be received by the receiver (RX). Measurements were carried out using GSSI instruments with a frequency of 270 Hz with a depth estimate of about 6 m. Field acquisition Data was carried out with a griding measurement technique with a 5 m length and a second with long profiling The path varies from 18 – 36 m. Interpretation is done with the correlation of core drill data on Grid 1 as deep as 60 m and Grid 2 as deep as 74 m. On Grid 1 gets 4 layers each line while Grid 2 gets 3 layers. Its sedimentation Material can be analyzed from the core and amplitude drill correlation varying from the signal (high and low) and the varied signal Facies (parallel and wavy). In the correlation result in Grid 1 and Grid 2 dominant layer of clay and sand. On the Grid 1 layer consists of the first layer 0-0215 m is the sand, the second layer 0215 – 0.5 m is the sand, the third layer 0.5 – 2 m is and the last layer is the clay. As for Grid 2, The layers consists of the first layer 0 – 0.16 m is sand, the second layer 0.16 – 2 m is and the last layer is the clay. From the link path results indicate the alteration of the layer on the Grid 1 to Grid 2 that is the missing sand layer. Grid 1 is a coastal area so it gets high attenuation. Grid 2 attenuation is reduced and the amplitude increases because away from the beach. Changes in the sediment layer are materials dominated by clay and sand in each layer in the Teluk Betung area, so this area shows the process of deposition of tidal flat (tidal) that has a recent.

Keywords: GPR, Sediment, Facies

Introduction

The deposition environment in the costal area is transitional deposition environment. The process of transitional precipitation is sedimentation on the boundary of marine deposition and/or continental deposition environment. Sedimentation in the transition environment is derived from different transportation of sedimentary material from the river and/or sea [1].

Sedimentary material accumulates in transitional environment, mostly in the form of sand and/or clay that will continue to accumulate forming a layer of sediment so as to change morphology. In this reseach we focus in Teluk Betung that has never been done research on that area, so it is necessary to do study for the subsurface estimation. In this case, Ground Penetrating Radar (GPR) methode is applied correlated core drill data to determine the characteristics of subsurface sediment [2]. In addition, GPR has excellent penetration depth to the sedimentation, 20 m with frequency of 200 MHz [3]. Also, this method is used to study the identification of bedrock and superficial layer analysis with good results [4]. The ground penetrating radar method can map for large-scale, small-scaled coatings from the coastal barrier [5]. Using an antenna with a frequency of 100 MHz and 200 MHz, GPR can clearly distunguist between the sediment layer and the erosion surface [6]. Based on the problem above we employ GPR method to study sediment in the area of Teluk Betung which is the area of the sediment accumulation.

Method

GPR is an active geophysical technique that uses electromagnetic waves. The electromagnetic wave spreads as a essentially non-dispersive. The signal is transmitted and propagated through the medium below the surface, which is scattered or reflected in the impedance change which raises the wave as the signal is transmitted [7]. The concept of GPR base on electromagnetic theory (EM). The mathematically Maxwell equation illustrates the physical parameters of the EM field, while the constituent relationship calculates the material properties. Combining them to illustrate GPR signals quantitatively [8].

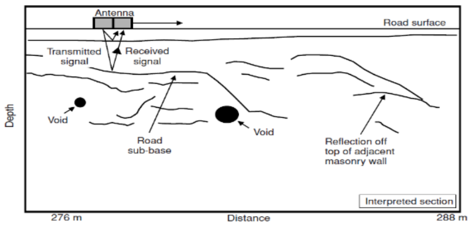

Figure 1 Working principle Method ground penetrating radar (GPR)

In mathematical equations, the Maxwell used in the ground penetrating radar method is shown

$$\vec{\nabla} \times \vec{E} = -\frac{(\partial \vec{B})}{(\partial t)} \tag{2.1}$$

$$\vec{\nabla} \times \vec{H} = \vec{J} + \frac{(\partial \vec{D})}{(\partial t)} \tag{2.2}$$

$$\vec{\nabla} \times \vec{D} = q \tag{2.3}$$

$$\vec{\nabla} \times \vec{B} = 0 \tag{2.4}$$

The constituent relationship is the means of explaining the material response to electromagnetic fields. For GPR, the Constitutif equation is shown as:

$$\vec{J} = \tilde{\sigma}\vec{E} \tag{2.5}$$

$$\vec{J} = \tilde{\varepsilon}\vec{E} \tag{2.6}$$

$$\vec{J} = \tilde{\mu}\vec{H} \tag{2.7}$$

electrical conductivity $\tilde{\sigma}$ characterizes the free charge movement when there is an electric field. The factor that causes the decline of signal strength is due to the spread of waves through a medium below the surface. The loss of energy occurs as a consequence of the reflection and transmission of each surface and each time a radio wave crosses the line.

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$$\alpha \begin{cases} \sqrt{\frac{\omega\mu\sigma}{2}} & untuk\ \omega\varepsilon \ll \sigma \\ \frac{\sigma}{2}\sqrt{\frac{\mu}{\varepsilon}} & untuk\ \sigma \ll \omega\varepsilon \end{cases} \tag{2.8}$$

Skin depth

$$\frac{1}{\alpha} = \delta \tag{2.9}$$

When radio waves reach the boundary of the coating, some of them are reflected and some of them are transmitted through the interface. This causes both reflections and waves to be transmitted. The amplitude of the reflected wave is comparable to the waveform defined by the reflection coefficient (R). For radio waves, the reflection coefficient can be expressed as a function of relative permittivity. Assumptions from the radio waves arrive at an upright angle to the interface, the reflection coefficient indicated:

$$R = \frac{Reflected\ Amplitude}{Incident\ Amplitude} = \frac{\sqrt{\varepsilon_1} - \sqrt{\varepsilon_2}}{\sqrt{\varepsilon_1} + \sqrt{\varepsilon_2}} \tag{2.10}$$

Where ε_1 is a relatively medium permitivity that carries incidents and bounce waves, the reflection coefficient is

$$T = \frac{RTransmitted\ Amplitude}{Incident\ Amplitude} = \frac{2\sqrt{\varepsilon_2}}{\sqrt{\varepsilon_1} + \sqrt{\varepsilon_2}} \quad (2.10)$$

The interpretation of the core drill is an interpretation done to set the data of the well logging core or drill core to be or associated in the GPR cross-section to make a withdrawal at the boundary of the layer (horizon) [8].

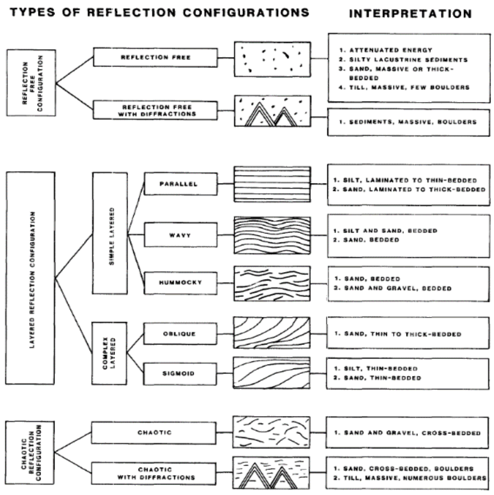


Figure 2 Example facies ground penetrating radar in coastal barrier [9]

Facies analysis is an analysis done to distinguish the shape of the signal that is flexion or that has until the reflector forms the Facies that will be distinguished so that it can be assumed rocks or layers obtained by the shape of The Facies. Based on the results of Berres and Haeni (1991) and Jol and Smith (1991) about the Facies analysis of the GPR, the analogy of the results of the analysis of Facies on the seismic reflection method and provides examples and interpretations of the most common for reflection configuration

Sample core and acquisition design

Research is conducted by taking core drill data and geophysical surveys using ground penetrating radar. The core drill is using a simple tool with a 1.25 m long iron pipe that is done manually to take a 1 m long sample. Acquisition of data using GSSI instrumentation with a frequency of 270 Hz carried out by GPR method in several different lines, the type of measurement performed is a measurement of the reflection or continuous reflection profiling (CRP). The measurements of the Teluk Betung transition area are done in 2 ways i.e. grid paths and profiling paths. This acquisition design uses is.

Figure 3 acquisition design

Results and Discussion

Result of data acquisition with GPR Instrumentation (GSSI) with frequency 270 MHz get wave speed (travel time wave) and performed data processing based on flow chart processing to get a cross-section with high resolution Making interpretation easy.

Core Drill data is used to be correlated with GPR data to help the interpretation of the undersurface layer. With the result of core drill data and amplitude change in GPR cross-section result. This core drill data is taken using an iron pipe tool, the result of the core drill data on 2 grid paths gets varying depths of 76 and 60 cm.

Each aquisition path of GPR data is done by drilling for correction or make it easier to conduct analysis on the cross-section of GPR. The resulting data from a grid 1 and grid 2 were performed correlation with GPR data on the lines to find out the layer.

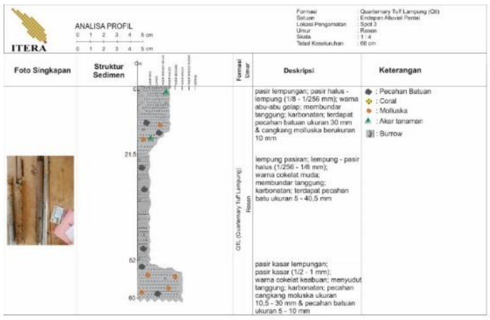


Figure 4 Result of sediment profile of core drill on grid 1

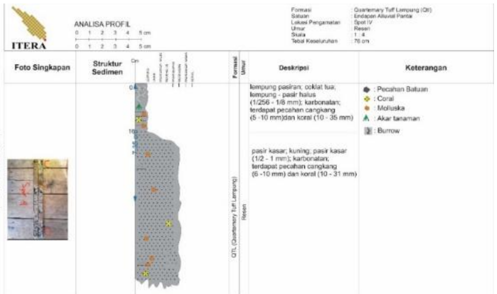


Figure 5 Result of sediment profile of core drill on grid 2

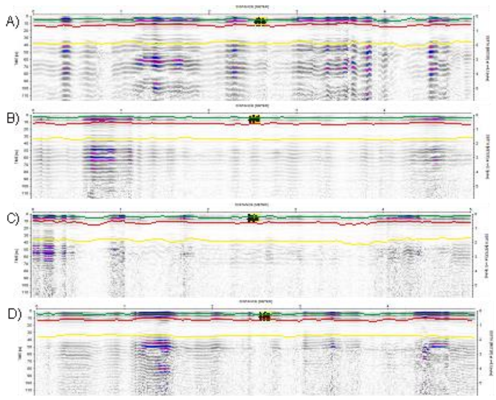
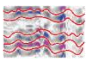


Figure 6 The result of the picking boundary layer on grid 1

Table 1 Facies ground penetrating radar from grid l 1 of each layer

No	Result Cross-Section *GPR*	Type Configuration Reflection	Description	Interpretation
1		*Parallel*	*High and low amplitude, continue reflection*	*Water table / sand*
2		*Parallel*	*High and low amplitude continue reflection*	*Water table / clay*
3		*Wavy*	*Low amplitude, continue reflection*	*Sand bedded*
4		*Wavy*	*Medium amplitude, continue reflection*	Clay, *bedded (alleged)*

Based on the outcome of the ground penetrating radar lines correlation with core drill data get 4 layers on grid 1 that is done interpretation of facies on each layer. This 1 grid path gets 4 layers of sediment sand coating and clay sediment. The variation of the amplitude is low, the measurements are killed so that the attenuation is high.

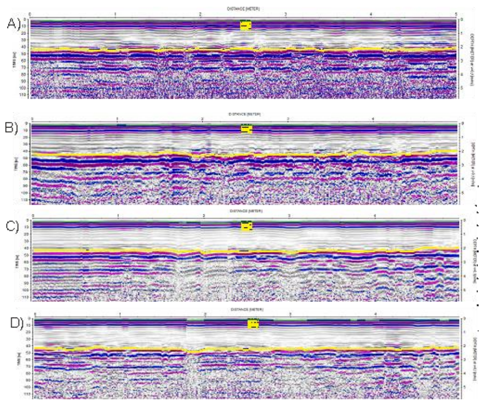
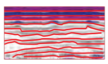
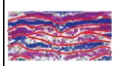


Figure 7 The result of the picking boundary layer on grid 2

Table 2 Facies ground penetrating radar from grid 2 of each layer

No	Result Cross-Section *GPR*	Type Configuration Reflection	Description	Interpretation
1		*Parallel*	*High and low amplitude continue reflection*	*Water table / sand*
2		*Parallel / wavy*	*High and low amplitude continue reflection*	*Water table / sand, bedded*
3		*Wavy*	*High amplitude*	*Cclay, bedded (alleged)*

Grid 2 performed the interpretation of facies on each layer. This 2 grid lines has 4 layers of sediment sand coating and clay sediment. The variation of amplitude the first layer is being dropped to low, and at the last layer of the signal strengthened, a significant change occurred indicating the change in sedimentary material. From the results of the data that has been done picking on the coating, done plotting 3D model to see the correlation on grid measurements on line 1 and 2 Data Acquisition The field in addition to the

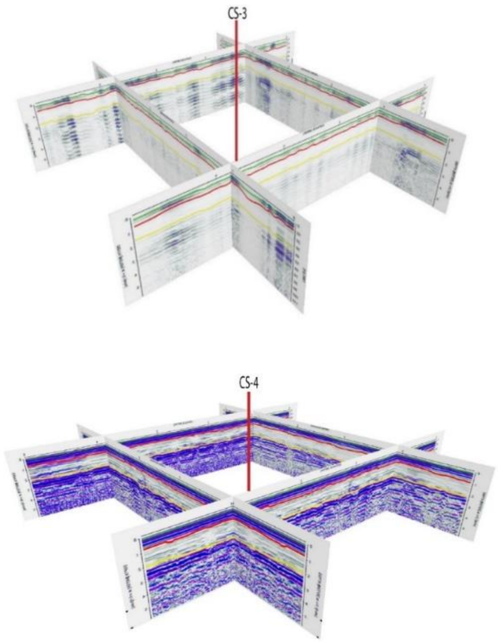


Figure 8 Visualisasi 2.5D model from grid 1 and 2

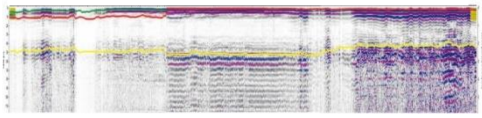
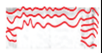
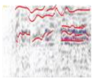


Figure 9 All three straight measuring lines are or associated to see sedimentation changes

grid measurement carried out straight measurements (profiling) to connect grids 1 and 2. This measurement gets 3 lines connecting grids 1 and 2. In this connective line also performed interpretation of facies on each layer for the facies Connective line 2 and 3 get almost as much results just different coating on the value of Amplitude.

Table 3 Facies ground penetrating radar line 1 and 3, linked grids 1 and 2 of each layer

No	Result Cross-Section GPR Lines 3 link grid 1 and 2	Type Configuration Reflection	Description	Interpretation
1		*Wavy*	*Low amplitude* *continue reflection*	*Water table / sand*
2		*Wavy*	*Low amplitude* *continue reflection*	*Water table / clay*
3		*Wavy*	*Low amplitude* *continue reflection*	*Sand dan bedded*
4		*Wavy*	*Low amplitude*	*Clay, bedded (alleged)*

No	Result Cross-Section GPR Lines 3 link grid 1 and 2	Type Configuration Reflection	Description	Interpretation
1		*Parallel*	High Amplitude	*Water table / clay*
2		*Wavy*	High and Low Amplitude	*Sand bedded*
3		*Wavy*	High Amplitude	*clay, bedded (alleged)*

Conclusions

From the core drill correlation results with GPR data correlation is done boundary determination (horizon) of each different layer. A 6-metre deep GPR data with core drill data as 60 – 76 meters. Each correlation is done facies analysis for each layer, on facies analysis acquired 2 forms of GPR signal namely wavy and parallel. This facies shows the sediment layer by looking at the amplitude and the result of the core drill data. The result of the correlation between the core drill data and the GPR indicating the subsurface layer in the transitional deposition in Teluk Betung, Data on grid 1 is difficult to interpret due to the high saturation effect of seawater as it is measured in areas Beach, seawater has high conductivity. This high conductivity will be influential with the attenuation of the signal. With sedimentary material and the driver is estimated that this area is an environment of tidal flat Teluk Betung is a resent environment. And from the GPR seen changes from the clay and sand which is the classification of the environmental Deposition sedimentation is tidal flat.

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