Recent Sedimentary Deposit and Dynamics Sedimentation Analysis at Teluk Betung Using GPR Interpretation and Core Data

Dicko Rizky Febriansanu1*, Angga Ahya Huseina1, Andri Yadi Paembonan2

1Geological Engineering, Institut Teknologi Sumatera, Lampung Selatan, Indonesia
2Geophysical Engineering, Institut Teknologi Sumatera, Lampung Selatan, Indonesia
Corresponding author: dicko.febriansanu@gl.itera.ac.id

Abstract. Lampung Bay is an area with a busy shipping traffic from port of Panjang and port of Teluk Betung. There are several rivers contain sediments and sedimented in Teluk Betung area. By conducting a research in this area, we can determine the sediment depositional system. The research method that will be used is the analysis of sediment deposition profiles from core data and interpretation from Ground Penetrating Radar (GPR). From sedimentary analysis, older sediments have a clay to coarse sand with relatively firm contact with coarsening upward patterns. In the top, they have a medium to clay with a fining upward pattern. The existence of a relatively thick clay layer indicates a relatively marginal depositional environment. These clay layers may form in the lower subtidal environment and gradually change to the upper intertidal environment until supratidal. This can be seen from the GPR result which show the sediment boundary. The GPR profiles confirm that the upper part mostly contains the sand or clay sand with sea water intrusion which has high conductivity and dielectric permittivity. The deeper zone could not well interpreted due to lack of the sediment information, but they show the contact of the sediment layers with different amplitude.

Keywords: ground penetrating radar, sedimentology, Lampung

1. Introduction

The process and mechanism of sediment material deposited is called sedimentation. Sedimentation process and mechanism can carried by water, wind, and glaciers; and can occur on land, river and sea. Sediment supply is a term used to express the amount of sediment material deposited in a depositional basin. Variation in the amount of sediment supply deposited in a basin is influenced by climate and tectonics [1].

Sedimentological analysis of sedimentary cores is able to provide a recorded parameters of environmental change caused from material from thousands of years ago. For example, sedimentation speed, organic material content, microfossil content and others [2]. In addition, by knowing the characteristics of sediment deposition and dynamics sedimentation, the level of active sediment deposition in the study area will be known.

Lampung Bay is an area with a busy shipping traffic from port of Panjang and port of Teluk Betung. There are several rivers contain sediments and sedimented in Teluk Betung area. This research is expected to be a preliminary research on dynamic sedimentation and process of recent sediments from the study area, because there is no publication yet about this analysis. Therefore this research is expected as a geological information and the land use in Teluk Betung area.
2. Research Method

This research is divided into 4 (four) stages which will start from a literature study by studying information related to the research area including the geology of Sumatra in general and especially around the Teluk Betung area. In the second stage, core drilling will be taken and a sediment profile will be analyzed from the data. In the third stage, a field survey and GPR data acquisition will be conducted around the study area.

Data taken from the field will be processed and analyzed and made into an interpretation of the appearance of subsurface sediments. The fourth step is the correlation between sedimentary profile data and GPR analysis, and the dynamics of sedimentation will be interpreted in the study area.

1) Sedimentary profile analysis

Sedimentary profile analysis is a method used to determine the depositional environment and to obtain paleographic images of the depositional environment. The method used is the original stratigraphic method, by recognizing the vertical sequence of the stratigraphical sequence. This analysis is very important in recognizing a depositional environment. A certain environment will have certain depositional mechanisms as well. Therefore, the vertical sequences (under normal conditions) will have their own characteristics, thus from a sedimentary profile the development of deposition and at the same time the development of the basin can be known.

2) Ground Penetrating Radar analysis

In the GPR acquisition, especially for geological investigations, a very important thing to consider is the optimum frequency used. This is related to the resolution and the depth of penetration. The first thing to do in the acquisition of GPR is to determine the path to be measured, then along the measurement path the GPR instrumentation is placed. GPR energy source is in the antenna which produces very high frequency electromagnetic pulses. The frequency range varies from several tens of MHz to GHz frequencies. Electromagnetic waves, which penetrate in ground formation, are recorded by the receiving antenna [3]. Reflective intensity waves will then be recorded through the receiving antenna on the GPR device. Different monitoring and intensity shows underground anomalies as shown in Figure 1 [4]. The initial data processing by filtering data in the time domain is done to remove very low frequency components. This is related to inductive phenomena or the possible limitations of the dynamic range of instrumentation. Automatic zero time shift correction is applied to each part of the radar to compensate for zero drift time. If needed, the data are filtered with spatial filters and average time [5]. Interpretation is largely empirical and relies on identifying GPR reflector configurations and patterns in the GPR section. Taking sediment samples directly from core drilling will be very helpful in the data interpretation.

![Figure 1. Anomaly in GPR measurement. Red lines show traces of faults and fractures on deflected radar signals [4]](image-url)
3. Result and Discussion

Sampling of core drilling data is carried out using the manual hand drill method. We use is PVC pipe which was designed so that it can gather the existing sediments. With this method, we obtain sediment samples in the study area as thick as 20 - 45 cm per sample. From this sediment sample, we can analyses the sediment profile. Sediment samples were taken at 10 different spots in a relatively calm beach environment (Figure 2). The results of observations on sediment samples are then used to create a sediment profile. Succession on the sediment profile is analysed to determine dynamics sedimentation such as sediment type and depositional environment.

Sediment samples in spot 1, spot 2, spot 5 and spot 9 (Figure 3) are dominated by sand grain size. The abundance of shell and coral fragments in the sample, shows that the sedimentation currents originated from ocean waves. Sediment samples have a poor sorting that shows the smooth and coarse grain sediment mixing. The dominant grain shape in sediment samples is angular. The shape of the angled grains indicates sediment transport in the depositional environment relatively close to the source. This shows that the study area is affected by low ocean waves, in a tidal flat environment.
Figure 3. Sediment samples in spot 1 (top) and spot 9 (bottom) shows sand grain size domination
The appearance of current ripple sedimentary structures at the beach surface also strengthen the hypothesis (Figure 4). Tidal flat's morphology and sedimentology are largely controlled by sediment type, influx sediment, and tidal and wave interactions [6]. The sedimentary structure in a tidal flat environment is strongly influenced by the direction of current flow. The waves and tides can become main controls during tidal level in a minimum condition (shear velocity decreases), wind pressure and surface water decline on the surface [7].

![Figure 4. Appearance of current ripple sedimentary structures (marks with the black box) ](image)

In several studies of the tidal environment, differences in wave energy levels and currents will be influenced by tidal zones and contact with the open sea. This became the main control on the ripple pattern that will develop on the surface, such as the sinuous ripple pattern found at the research area that will develop in a tidal flat environment [7].

At spot 11 (Figure 6) samples in the succession of older sediments have different texture characteristics than samples in younger successions. The most different texture is the color. The relatively older samples had black color while the younger samples were brown. Older sediments have a grain size from clay to coarse sand with relatively firm contact limits with coarsening upward patterns. Relatively young sediments have a grain size from medium sand to clay with a fining upward patterns.

This shows the occurrence of changes in the depositional environment. The existence of a relatively thick clay layer indicates a relatively marginal environment. These clay layers may form in the lower subtidal environment and gradually change into the upper intertidal environment to marsh / supratidal [6].

Changes in the depositional environment were strengthened by the succession of sediments in samples at spot 3, spot 4 and spot 8 (Figure 7). The sediment profiles results indicate changes in grain size from bottom to upper succession. Bottom samples have a clayey grain size while in upper samples have a sandy grain size. In a tidal flat environment, changes in the dominant clay deposition to the dominant sand with a coarsening upward pattern indicate a subtidal flat zone [6].
Figure 5. Morphology and type of sediment from the tidal flat environment (left); succession models of sediment deposits in intertidal-subtidal flat environments (right) [6]

Figure 6. Sediment samples in spot 11 shows coarsening upward succession in the bottom, and fining upward succession in the top
Figure 7. Sediment samples in spot 4 and spot 8 shows changes in a grain size from bottom to upper succession.
At spot 10 (Figure 8) the grain size changes from sandy to clayey. In a tidal flat environment, sand dominance with a fining upward pattern indicates an intertidal zone while clay dominance indicates a supratidal zone [6]. The sample at spot 10 shows an environmental change in tidal flats.

Figure 8. Sediment sample in spot 10 shows changes in grain size, from sandy to clayey

Figure 9. Correlation between the results of sedimentary profiles. It shows a change in tidal flat environment
The GSSI system has been used to measure the GPR data for the present study. The GPR data is compared with the coring data. The high-frequency electromagnetic waves (270 megahertz) are transmitted through the subsurface. The reflections occur due to the heterogeneities and then the reflected energy is measured at the receiver. The physical property measured depend on the dielectric permittivity and electrical conductivity of the material. The maximum depth of penetration can be a few meters until several tens of meter under the surface depend on the frequency. The field data is then processed using Reflexw software by applying filtering, static correction and removing the background. We also apply some gain to increase the amplitude of signal.

The GPR profiles were collected from the Teluk Betung Beach complex. Several profiles were taken continuously along the beach and we also measured the five-meter profile on the coring location. Because the bad ground conditions, some GPR acquisition results are not in a decent quality. It is not possible to showing all the GPR acquisition results due to its monotonous nature. The finest GPR profiles with length of 36 meters and approximately 6 meters depth, is described with the radar facies general characteristics.

![Figure 10](image)

**Figure 10.** The GPR processed data showing the three-layer of sediment.

The result for the GPR survey (Figure 9) shows three different sediment layers. The upper layer, recent sediment, confirms that materials mostly consist of the sand or clay. It can be seen that the 1st layer (recent sediment) forming a horizontal radar facies (Figure 10). This pattern is typically found in salt water intrusion, in the delta plain system; and when GPR acquisition running on the active beach. In this condition, salt water exist and GPR signal in a bad condition [8].

This can be seen clearly and it may also affect the sea water intrusion as we can see the water table from the data. The data indicates the contact between the recent sediment and the second layer of sediment in the depth of 0.5 meter. This is indicated from the different reflection factor of material between the layers. The sand or clay sand with sea water intrusion has high dielectric permittivity and high conductivity while the deeper zone could not be well interpreted due to the lack of the sediment information. The third layer below 2-meter depth is also seen from the profile. Unfortunately, the material from this layer could not be recognized due to the lack of information.
4. Conclusions

This paper explain characteristic and dynamics sedimentation in the research area from sedimentary profiles and Ground Penetrating Radar (GPR) analysis. From sedimentary profiles analysis, three facies associations were initialized: intertidal flat, supratidal flat and subtidal flat, and shows that the depositional environment of the study area is a tidal flat and influenced by tidal currents.

GPR analysis shows there are three different sediment layers; the upper part mostly contains the sand or clay sand. The second layer may also affected the sea water intrusion. The data indicates the contact between the upper sediment and the second layer of sediment in the depth of 0.5 meter and we can see the sand or clay with sea water intrusion which is very conductive and has high dielectric permitivity. The deeper zone or third layer could not well interpreted due to lack of the sediment information, but they show the contact of the sediment layers with different signal amplitude.

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