Subsurface Sediment Deposits of Tanjung Berikat Coast, Bangka, Determined from GPR Interpretation

L Gustiantini1,*, U Kamiludin1, M Zulfikar1, Y Noviadi2, U Hernawan2, A F Ismayanto3

1 Marine Geological Institute, Ministry of Energy and Mineral Resources, Jl. Dr. Junjunan 236 Bandung, Indonesia
2 Centre for Geological Survey, Ministry of Energy and Mineral Resources Jl Diponegoro 57 Bandung, Indonesia
3 Research Centre for Geotechnology, Indonesian Institute of Sciences – LIPI, Komplek LIPI, JL Sangkuriang Bandung 40135 Indonesia

gustiantini@yahoo.com

Abstract. Tanjung Berikat Coast in Central Bangka, is a part of the Southeast Asian tin belt. We conducted four Ground-Penetrating Radar (GPR) survey lines and 13 hand auger coring to understand sediment deposition and composition. Two similar units were determined from GPR lines BLG 01–BLG 03: Unit A at the top part, reflected by parallel and continuous reflector configuration, weak–strong electromagnetic wave. Underneath Unit A is Unit B, characterized by subparallel configuration, not continuous–chaotic, weak–medium electromagnetic wave. Unit B is absent in BLG 04. We identify another two units from BLG 04 and BLG 03, Unit C, characterized by subparallel reflector configuration, not continuous–chaotic, weak–strong electromagnetic wave. It exhibits distinctive modulating contact with Unit D. Unit D is characterized by chaotic reflector configuration, relatively stronger electromagnetic wave that might be correlated to the granite intrusion Tanjung Klabat. Sediment deposit is composed of fine–coarse sand, consisting mostly of clastic plutonic and clastic biogenic (coral and mollusk fragments), which increase downward. This indicates marine-fluvial influence, which suggests that sea-level changes strongly influence sedimentation process. Unit A from GPR is correlated to these sediment deposits, the other three units might be correlated to weathering of older insitu deposit.

1. Introduction
Bangka area is a part of the main tin belt granite of Southeast Asia. This tin belt lies from Myanmar, Thailand, Malaysia, Riau Archipelago, Bangka Belitung Singkep to Karimata Island in the Western Kalimantan [1, 2]. Previous study also found indication of uranium, thorium, and Rare Earth Element (REE) at Bangka area contained at monazite mineral as an associated mineral in a tin [3]. Therefore, Bangka coasts are interesting in understanding the occurrence of the placer mineral. According to a previous study, at the water nearby Tanjung Berikat and surrounding found sediment that comparable to Ranggam Formation, which indicates channel filling that allows for placer mineral and accessories mineral deposition derived from granitoid source rocks [3].

In addition to that, the Bangka area has many beaches that become to be a tourist destination, leading to infrastructure development. Unfortunately, the beaches are endangered from erosion. It is
known that the coastline in Batu Beriga Beach is moving landward, particularly in the last ten years [2]. Therefore, we conducted this study to understand the subsurface Quaternary deposit related to the sedimentation process. According to the coastal characteristic mapping, which has been conducted in 2017 [3], the beach at Tanjung Berikat and surrounding are composed of 3 different beach types, are (Figure 1):

1. Sand beach, as the dominant type. This type lies along Lubuk Laut beach to the north of Tanjung Berikat beach, and southwest of Tanjung Berikat to the northeast of Batu Beriga beach. It is composed of Holocene alluvium, dominated by marine sedimentation process hence influenced by the fluvial process. This beach is relatively stable, and the process of sedimentation and abrasion is maintained balance.

2. Rocky beach (Rocks), particularly at Tanjung Berikat and Batu Beriga beaches. It is composed of Granite Klabat outcrops in 3 – 25 m in size, from Early Triassic – Early Jurassic [4], forming a medium – steep hill. Undisturbed coral characterizes the beach face. This beach type is dominated by the marine process. Although considered stable, a trace of erosion due to the oceanic current and wave is distinguished.

3. Mud flat and mangrove, formed at the southwest of Batu Beriga to the western part of the study area. This area is composed of Holocene alluvium, sandstone and claystone of Tanjung Genting Formation from Early Triassic [4]. This beach is influenced by the tide and fluvial process. It is covered by mangrove vegetation.

![Figure 1](image-url)  
**Figure 1.** Coastal Characteristic Map and lithology of the Tanjung Berikat and surrounding [3], black circles are the hand coring location for this study, rectangles are GPR lines.

The lithology of the waters surrounding Tanjung Berikat revealed from seismic profile [3] indicated the oldest sequence that resembles Tanjung Genting Formation. This formation is composed of intercalating between sandstone and claystone. It was deposited during Early Triassic in shallow marine environment [4]. The formation was infiltrated by Granite Klabat intrusion during Early Triassic – Early Jurassic. Then sequence above was correlated to Ranggam Formation, intercalating
between sandstone, claystone and conglomerate. This formation was deposited during Late Miocene – Early Pliocene, in fluvial environment. The youngest sequence was correlated to Holocene Alluvium, composed of a loose grain of clay, mud, sand, and gravel, as fluvial, swamp, and beach deposit (Table 1).

Table 1. Seismic stratigraphy [3] correlated to the regional stratigraphy [4] of Tanjung Berikat waters

| ERA     | PERIODS | EPOCH | Surface Deposits and Sedimentary rocks | Metamorphic Rocks | Intrusive Rocks | Tanjung Berikat and Surrounding [5] |
|---------|---------|-------|--------------------------------------|-------------------|----------------|-------------------------------------|
| CENOZOIC| QUATERNARY | Holocene | Alluvium (Qa) | - | - | Sequence A |
|         | TERTIARY | Pleistocene | Ranjamin Formation (TQr) | - | - | Sequence B |
|         |         | Pliocene | Miocene | - | - | Intrusion Sequence C |
|         |         | Oligocene | Eocene | - | - | |
| MESOZOIC |        | Cretaceous | | - | Pemali Metamorof (CPm) | |
| PALEOZOIC |        | Jurassic | | - | Granite Klabat intrusion (TRKg) | |
|         |        | Triassic | | - | | |
|         |        | Permian | | - | | |
|         |        | Carboniferous | | - | | |

Ground Penetrating Radar (GPR) is a non-invasive method for a subsurface geological investigation that relatively shallow and detail, according to the changes of its geological material properties and physical characteristic composition [5], [6], [7] and [8]. The principle of GPR application is similar to the reflection seismic as facies identification and subsurface layer sequence [6]. The GPR signal can be influenced by dielectric constant material properties [9]. Interpretation of sediment type and facies are based on the concept of seismic stratigraphy, notably configuration identification and reflection termination, a configuration of internal reflection and external geometry [6], [10]. The result of GPR image will exhibit geometrical basic form as lithology, freshwater, and subsurface utilization [11].

2. Methods
We conducted Ground Penetrating Radar (GPR) by using SIRVeyor 20 model of GSSI product. It has 40 MHz MLF (Multi-Level Frequency) antenna as separated transmitter, and receiver antenna. Depth penetration optimum of the equipment unit approximately down to 30 m. Supporting equipment, including accumulator survey wheel, GPS, and measurement type, were also used.

GPR method is based on the emission of electromagnetic wave to the ground and the capture of electromagnetic waves that are transmitted, reflected and scattered by subsurface structure and anomalies beneath the earth surface. Reflected and scattered electromagnetic wave is then received by receiving antenna on the earth surface [12]. An electromagnetic pulse will be transmitted through the ground, and the return time of the reflected pulse will be recorded. The velocity of electromagnetic wave transmission and backscattering is swift and stated in the nanosecond time unit [13].

The resolution of penetration depth of radar signal relies on the transmitted pulse and antenna choices, mostly between 10 and 1000 MHz. Higher frequencies will result in higher resolution but shallower penetration depth. However, the depth of penetration will also according to the dielectric and the properties of conductive ground material [7].

In general, georadar data processing consist of several steps: data conversion to digital format, eliminating or reducing direct wave from air to the surface, setting and adjustment of amplitude and gain, static data adjustment for removing elevation distinction, data filtering, and velocity analysis [10]. To process the data, we used Radar 5 software of GSSI product. The first step of processing data was time zero correction. This step removes direct wave between antenna and land surface.
Afterwards, were spatial filter process, deconvolution, migration, and adjustment of amplitude and gain. The last step was interpretation of GPR data.

GPR data interpretation was based on interpretation of radar facies. The concept is similar to the methodology applied to seismic stratigraphy surveys [14]. The characteristics of radar facies were interpreted according to the internal configuration, reflection continuity, and the pattern of reflection termination [15]. It is generally characterized by the basic of shape, amplitude, continuity, and internal reflection configuration and external form [16], [17].

GPR survey was conducted on four traverse lines, with seaward direction, perpendicular to the beach line. Two lines were conducted at Pantai Lubuk Laut (BLG-01 and BLG-02) at S-N direction, 50 m each in length. One line (BLG-03) is located at Pantai Gusung Tanjung Berikat (S-N) along 175 m. The last one is located at Batu Beriga (BLG-4) aligned from NW-SE along 200 m (Figure 2). In order to understand the texture and characteristic of sediment in horizontal distribution, 13 Hand coring (shallow coring) was also performed on the sand beach by using Eijkelkamp hand auger. Due to sand texture and shallow seawater, it is known that coring on sand beach barely reaches 100% recovery. Part of the sediment will escape once the barrel core is lifted to the surface.

3. Result and Discussion
From shallow hand coring, we obtained sediment core varied between 20 to 260 cm in length (Table 2). Core sediment recovery indicates relatively thicker sediment along the beach of Lubuk Laut to Tanjung Berikat sediment profile (NW – SE) compared to that of Tanjung Berikat to Batu Beriga (SW – NE) (Figure 2 and 3). The sediment length from the first sediment profile indicates more than 1 m lengths, relatively longer at the NW side (> 1.5 m). The size of core sediment at the second profile exhibits shorter (mostly < 1 m). The most extended sediment core is BHT 11 at the northeast of Batu Beriga (1.6 m), and BHT 13 at Batu Beriga (1 m length). The other sediment cores are less than 1 m. seawater contents might be the significant factors that lead to various sediment core recovery, as mentioned above. Particularly along the beach Batu Beriga to the southwest part is characterized by mudflat and mangrove, thus, its sediment is composed of relatively higher water content. The NW beach, at Lubuk Laut is marked by accretion due to more elevated sedimentation, lead to thicker sand deposits, particularly from the marine side transported by a wave that forming berms as beach ridge [3]. While nearby Tanjung Berikat and at Batu Beriga are more characterized by abrasion process lead to lower sediment deposit.

| Sample  | Coordinate         | lengths (cm) |
|---------|--------------------|--------------|
|         | Longitude          | Latitude      |
| BHT-01  | 106°040'40.98"    | 2°32'21.624" | 160 |
| BHT-02  | 106°041'18.816"   | 2°32'26.052" | 220 |
| BHT-03  | 106°041'52.26"    | 2°32'32.444" | 170 |
| BHT-04  | 106°042'24.264"   | 2°32'42"     | 210 |
| BHT-05  | 106°043'17.508"   | 2°32'55.32"  | 260 |
| BHT-06  | 106°045'5.688"    | 2°33'20.916" | 160 |
| BHT-07  | 106°047'3.768"    | 2°33'42.12"  | 130 |
| BHT-08  | 106°049'41.268"   | 2°34'9.948"  | 120 |
| BHT-09  | 106°043'58.728"   | 2°37'23.916" | 60  |
| BHT-10  | 106°044'50.892"   | 2°36'28.44"  | 20  |
| BHT-11  | 106°047'27.096"   | 2°35'7.116"  | 160 |
| BHT-12  | 106°049'1.02"     | 2°34'41.088" | 20  |
| BHT-13  | 106°049'1.02"     | 2°34'41.088" | 100 |
Furthermore, from 13 coring, the sediment composition are rather similar, characterized by sand deposit, brownish yellow wet color, whitish brown for dry color, fine – coarse in size, rounded to subangular, medium - bad shorting, composed mainly by clastic plutonic and partly by carbonaceous biogenic clastic. Plutonic material is particularly composed of quartz, feldspar, mafic mineral, and rock fragment. Bioclastic material is composed of rock fragments and biogenic material, which increase downward.

GPR record from BLG-01 and BLG-02 at Pantai Lubuk Laut indicate similar characteristics, and each line penetrates down to ± 25 m, exhibit 2 different unit characteristics. Unit A at the top part down to 14 m, indicated by parallel reflector configuration, continuous with a weak – strong electromagnetic wave. Below Unit A, separated by a parallel unconformity, is Unit B, characterized by subparallel reflector configuration, not continuous – chaotic, with a weak – medium electromagnetic wave (Figure 4 and 5). This finding indicates that these areas composed of at least two different facies that might be resulted from 2 different sedimentation processes.

**Figure 2.** Sediment profile of the hand coring along the beach of Lubuk Laut – Tanjung Berikat (northern part of the study area, NW – SE)

**Figure 3.** Sediment profile of the hand coring along beach of Bakung – Batu Beriga - Tanjung Berikat (SW – NE)
Figure 4. GPR Record of BLG-01 (Pantai Lubuk Laut)

Figure 5. GPR Record of BLG-02 (Pantai Lubuk Laut)

BLG-03 and BLG-04 are located at Pantai Gusung Tanjung Berikat, and Batu Beriga also indicates similar characteristics, each line penetrates down to ± 40 m. Subsurface geological condition reveals three different characters. The top part of these two lines is identical to that of BLG-01 and BLG-02, characterized by parallel reflector configuration, continuous with a weak – strong electromagnetic wave, hence marked as Unit A. The thickness of this configuration is ± 16 m. Below Unit A from BLG-03 is Unit B, characterized by subparallel reflector configuration, not continuous – chaotic, with a weak – medium electromagnetic wave, comprised for approximately 2 m. While at BLG-04, Unit B is absent. Afterwards, confined with parallel unconformity below, is Unit C, determined by subparallel reflector configuration, not continuous – chaotic, with a weak – strong electromagnetic wave. This unit’s bottom part is undulated, resulting in various thickness between 3 and 20 m from BLG-03. The bottom part of BLG-03 and BLG-04 is Unit D, characterized by chaotic reflector configuration with stronger electromagnetic waves (Figure 6 and 7). At BLG-03, Unit D is distinguished from 20 m to 36 m, while at BLG-04, the configuration is found from 20 – 25 m depth.
Correlating GPR record to the shallow core profile, the first horizon of radar (Unit A) indicating parallel reflector. It can be correlated to the sandy sediment deposit, which is characterized by a parallel layer with fine – coarse grain size, deposited by marine-fluvial process related to the sea level changes, or the Unit Holocene Alluvium of regional stratigraphy [4] (Table 3).

Figure 6. GPR Record of BLG-03 (Pantai Tanjung Berikat)

Unit B that characterized by subparallel reflector configuration, not continuous – chaotic, with a weak – medium electromagnetic wave, clearly represents different facies than Unit A, we assumed that this profile is comparable to stratigraphy below the alluvium, which is Ranggam Formation. And we correlated Unit C to Tanjung Genting Formation, below the Ranggam Formation. The shape of chaotic reflector configuration with stronger electromagnetic wave (D) that infiltrate Unit C is

Figure 7. GPR Record of BLG-04 (Pantai Batu Beriga)
comparable to granite intrusion. The intrusion is also distinguished from the seismic profile from waters surrounding the area [2]. This granite is also found at the beach outcrop, particularly at Tanjung Berikat and Batu Beriga, where the Line BLG-03 and BLG-04 of GPR were performed. Ranggam Formation, according to [2], indicates channel filling that allows for placer mineral and accessories mineral deposition derived from granitoid source rocks. Therefore, the presence of this formation revealed from the GPR profile might evidence the occurrence of placer minerals in the study area.

Table 3. Stratigraphy of Tanjung Berikat and surrounding from GPR data compared to the regional stratigraphy

| Era | Periods | Epoch | Surface Deposits and Sedimentary rocks | Metamorphic Rocks | Intrusive Rocks | GPR |
|-----|---------|-------|----------------------------------------|-------------------|----------------|-----|
| Cenozoic | Quaternary | Holocene | Alluvium (Qa) | Ranggam Formation (Tqr) | | Unit A |
| Tertiary | Pleistocene | Pliocene | | | | Unit B |
| | Miocene | Oligocene | | | | |
| | Eocene | Eocene | | | | |
| | Paleogene | Paleogene | | | | |
| Mesozoic | Cretaceous | Jurassic | | | Granite Klabat Intrusion (TRJkg) | Unit D |
| | | Triassic | | | | Unit C |
| Paleozoic | Permian | Carboniferous | Tanjung Genting Formation (TNGkg) | Pemali Metamorf (CPp) | | |

4. Conclusion
The GPR interpretation indicates that the lithology of the area surrounding Tanjung Berikat is composed of 4 deposit types: Holocene Alluvium, Ranggam Formation, Tanjung Genting Formation, and the granite intrusion of Klabat. The beach sediment is composed of particularly plutonic and clastic biogenic, which indicates marine-fluvial influence, suggesting that sea-level changes strongly influence the sedimentation process. Ranggam Formation’s presence indicates a possibility of the placer mineral deposit occurrence, although the form of channel filling was not found.

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References
[1] Cobbing E J, Mallick D I J, Pitfield P E J and Teoh L H 1986 The granites of the Southeast Asia tin belt, J. Geol. Soc. London., pp. 537–550
[2] Kamiludin U, Aryanto N C D, Pertala A W and Zulfikar M 2018 Paleo channel indication as place of placer minerals and rare earth elements in Tanjung Berikat waters and surrounding, Central Bangka, Bangka Belitung (in bahasa Indonesia), Jurnal Geologi Kelautan, 16(2): 115-123
[3] Kamiludin U, Noviadi Y, Setyanto A, Pertala A W, Zulfikar M, Astawa I N, Mustofa M A, Surachman M, Piranti S A, Sampurno P, Saputro E, Hutabarat Y, Aryanto N C D, Setiady D, Widiatmoko H C, 2017 Penelitian Mineral Plaser dan Unsur Tanah Jarang di Perairan Tanjung Berikat dan Sekitarnya, Project Report, Pusat Penelitian dan Pengembangan Geologi Kelautan, unpublished
[4] Margono U, Supandjono R J B and Partoyo E 1995 Peta Geologi Lembar Bangka Selatan, Sumatera, skala 1 : 250.000. *Pusat Penelitian dan Pengembangan Geologi, Bandung*

[5] Moysey S, Rosemary J K and Hary M 2006 Texture – based on classification of ground-penetrating radar images. *Geophysics* **71**: k111-k118

[6] van Heteren S, Fitzgerald D M, Mckinlay P A and Buynevich I V 1998 Radar fasies of paraglacial barrier systems: coastal New England, USA. *Sedimentology* **45**:181-200

[7] Sjöberg Y, Marklund P, Pettersson R and Lyon S W 2015 Geophysical Mapping of Palsa Peatland Permafrost. *The Cryosphere* **9**: 465-478

[8] Carrivick J L 2007 GPR-Derived Sedimentary Architecture and Stratigraphy of Outburst Flood Sedimentation Within a Bedrock Valley System, Hraundalur, Iceland. *Journal of Environmental and Engineering Geophysics* **12** (1): 127-143

[9] van Dam R L and Schlager W 2000 Identifying Causes of Ground Penetrating Radar Reflection Using Time-Domain Reflectometry and Sedimentological Analyses. *Sedimentology* **47**: 435-449

[10] Beres Jr M and Haeni F P 1991 Application of Ground Penetrating Radar Methods in Hydrogeologic Studies, *Ground Water* **29** (3):375-386

[11] Budiono K, Noviadi Y, Latuputty G and Hernawan U 2012 Investigation of Ground Penetrating Radar for Detection od Road Subsidence Northeast of Jakarta, Indonesia. *Bulletin of the Marine Geol*ogi **27** (2):87-97

[12] Busby J P, Cuss R J, Raines M G and Beamish D 2004 Application of ground penetrating radar to geological investigations, *British Geological Survey Internal report, IR/04/21*, 33pp

[13] Allen R L 1979 Studies In Fluviatile Sedimentation: Anelementary Geometric Model For The Connectedness Of Avulsion-Related Channel Sand Bodies. *Sedimentary Geology* **24**:253-267

[14] Tamura L N, de Almeida R P, Taioli F, Marconato A and Janikian L 2016 Ground penetrating radar investigation of depositional architecture: the São Sebastião and Marzial Formations in the Cretaceous Tucano Basin (Northeastern Brazil), *Brazilian Journal of Geology* **46** (1): 15-27

[15] Shan X, Yu X, Clift P D, Tan C, Jin L, Li M and Li W 2015 The Ground Penetrating Radar Facies and Architecture of a Paleo-spit from Huangqihae Lake, North China: Implication for genesis and evolution, *Sedimentary Geology* **323**: 1-14

[16] Chowksey V, Joshi P, Maurya D M and Chamyal L S 2011 Ground penetrating radar characterization of fault-generated Quaternary colluvio-fluvial deposits along the seismicity active Kachchh Mainland Faults,Western India, Research communication, *Current Science* **100** (6): 915-921

[17] Ekes C and Hickin E J 2001 Ground penetrating radar facies of the paraglacial Cheekye Fan, southwestern British Columbia, Canada, *Sedimentary Geology* **143**: 199-217