Characteristic of Shallow Subsurface Lithology Based on Ground Probing Radar Data Interpretation at Temaju Coast, Sambas District, West Kalimantan Province

Karakteristik Litologi Bawah Permukaan Dangkal Berdasarkan Penafsiran Data "Ground Probing Radar" di Pantai Temaju, Kabupaten Sambas, Provinsi Kalimantan Barat

Yogi Noviadi

Marine Geological Institute, Jl. Dr. Djundjunan No. 236, Bandung, 40174, Email : yoginoviadi@yahoo.com

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ABSTRACT: In order to know the subsurface lithology characteristic at Temaju coast, the Ground Probing Radar (GPR) detection have been carried out. The detection was done along the coast around 11 GPR track line. The equipment which was used are SIR III with 270 MHz antenna. Based on the analysis results of GPR image data which were correlated with the exposed of surface lithology and core drilling log, show that the maximum penetration is about 10 m with the lithology composition as follow: the upper most layer is characterized by sand deposits with about 2 – 3 m width. Below the sand layer is characterized by coral limestone and sandstone.

Keywords: subsurface lithology, ground penetrating radar, Temaju Coast

ABSTRAK: *Untuk mengetahui karakteristik litologi bawah permukaan di sekitar pantai Temaju, telah dilakukan penditeksian dengan mempergunakan metoda Ground Probing Radar (GPR). Penditeksian telah dilakukan pada sekitar 11 panjang lintasan di sepanjang pantai. Peralatan yang dipergunakan terdiri dari SIR III dengan antenna 270 MHz. Berdasarkan hasil analisis data citra GPR yang dikorelasikan dengan singkapan litologi permukaan dan log pemboran inti, memperlihatkan bahwa penetrasi masimum sekitar 10 m dengan urutan litologi sebagai berikut: lapisan paling atas dicirikan oleh pasir dengan ketebalan sekitar 2-3m. Di bawah lapisan pasir dicirikan oleh batuan gamping terumbu karang dan batu pasir*

Kata kunci: *litologi bawah permukaan, "Ground Probing Radar", Pantai Temaju*

INTRODUCTION

Ground-penetrating radar (GPR) has the potential value to noninvasively investigate shallow geologic heterogeneity at high resolution over large volumes of the subsurface. The interpretation of GPR reflection data, however, is currently highly subjective and based primarily on interpreterÊs ability to recognize pattern in a radar image (Moysey, et al, 2006).

GPR is used for various applications such as aquifer and soil studies, civil engineering, glaciology, archaeology, waste disposal and geology.

The objective of this survey was to provide the subsurface of coastal sedimentary features (characteristic of sub bottom sediment and soil)

Geographically the survey area is located at 10^{o} 20^{Ê}– 10^{o} 40^{Ê}E and 2^{o}00^{Ê}– 2^{o}55^{Ê}S. and administratively belongs to Sambas District, West Kalimantan Province (Figure 1).

Based on the geological map which was produced by Geological Research and Development Centre (Rusmana and Pieters, 1993), the surface geology of Sambas area can be distinguished in to four deference rock such as : Serabang Complex, Granite Poeh, Kayan Sandstone, Littoral Deposits and Alluvium (Figure 2).

Serabang complex is exposed at northern part of Sambas and consists of ultra mafic rock, gabro, metabasalt, chert, spelite, associated as mélange with slate, phylite, schist, metasandstone and hornfels. It was reported that most of these rocks are classified as mélanges complex where some of exposed rock show as a slate. Chert which was found at Serawak consists of radiolarian from Cretaceous and Jurassic ages.

Granite Poeh as a intrusion rock was found at northern and eastern part of survey area. This rock have intruded the Serabang Complex and created the metamorphic rock.

Kayan Sandstone are characterized by very thick layer and consists of quartz sandstone, shale, siltstone, conglomerate intercalations, locally silicified wood and

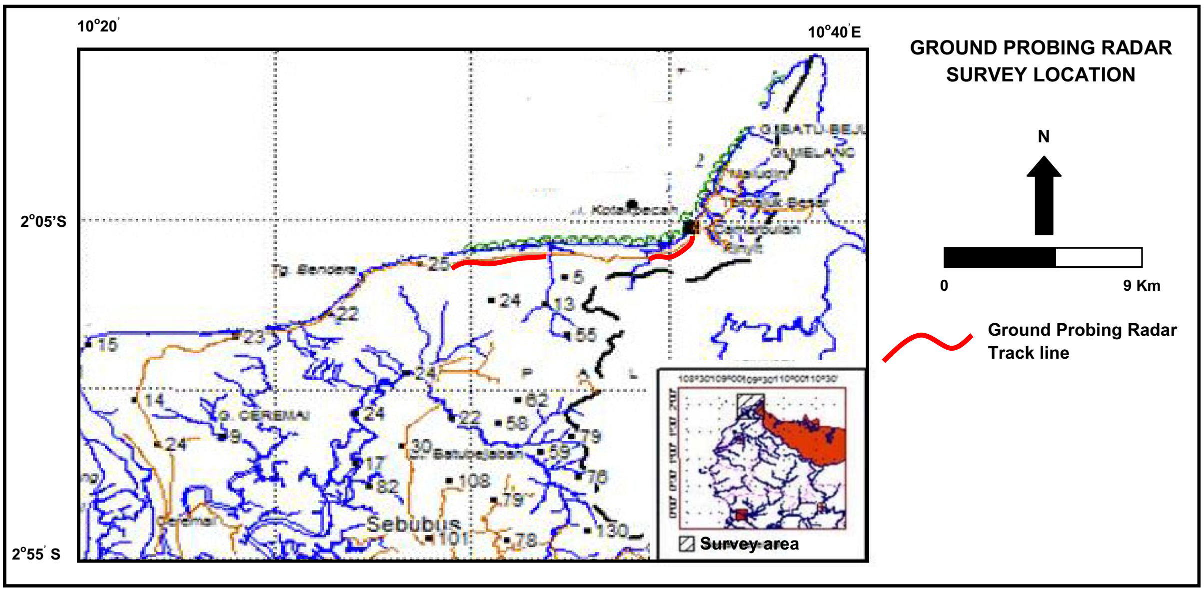


Figure 1. Location of survey area

minor coal. This layer is also characterized by syncline structure.

Littoral and alluvium deposits are classified as quaternary deposits. Littoral deposits can be found around the coast and consist of mud, sand, gravel, locally calcareous and plant matter. Alluvium deposit consists of mud, sand, gravel and plant matter, they are exposed around the coast line until coastal land.

METHODS

Field work included gathering all exposed outcrop, core drilling log data which were integrated with GPR data analyses. Ground penetrating radar (GPR) is a geophysical method that depends on the emission, transmission, reflection, and reception of an electromagnetic pulse and can produce rapidly and efficiently continuous high-resolution profiles of the subsurface (Beres and Haeni, 1991).

Radar data were collected from about 11 lines oriented parallel and perpendicular to the coast line. A Radar SIR system III was used with a 220 V transmitter. The 270 MHz transducer was selected for maximum penetration (Figure 3).

Features a cable connects the antenna with receiving and recording instruments. The radar pulses are displayed in real time on a screen and are recorded on the computer digitally. By recording a signal return every three inches a continuous profile is developed.

The subsurface strata are shown the lithology in detail profile. The graphic presentation of a vertical section of the earth is called a profile.

Profiling by GPR is similar to sonar and seismic reflection profiling. The radar produce a short pulse of high frequency Electro Magnetic energy which is transmitted into the ground. Some of the energy is reflected back to the surface due to change in bulk electrical properties of different subsurface lithology (e.g. sand and clay) and the character of the interface (Moorman et al., 1988; Davis and Annan, 1989). At the surface, a receiver monitor reflected energy versus delay time (Ekes and Hickin, 2001). The pulse delay time from the energy transmitted into the ground and reflected back to the receiver is a function of the strength of energy transmitted into the ground, the EM propagation velocity through the sediment, the depth of subsurface reflector and the character of the interface (Moorman et al., 1988; Davis and Annan, 1989; Jol, and Robert 1993).

The strong reflections of lithlogic boundaries in the subsurface is caused by the contrasts in the dielectric constants of the different sediment types, where the strength of the reflected signal is approximately proportional to the difference in dielectric constants of the sediments interface (Davis and Annan, 1989).

Electrical in homogeneities of subsurface lithology will be caused primarily by water content, dissolved mineral, expansive clay and heavy-mineral content in the subsurface material (Haeni et al, 1987). The rate of attenuation of energy which passing the ground is affected by changes in the dielectric constant. These effects enable the subsurface stratigraphy and ground – moisture conditions to be inferred from the character of the radar return signal (Jol and Robert, 1993).

The reflected signal is amplified, transformed to the audio frequency range, recorded, processed and displayed. The record shows a profile of horizontal

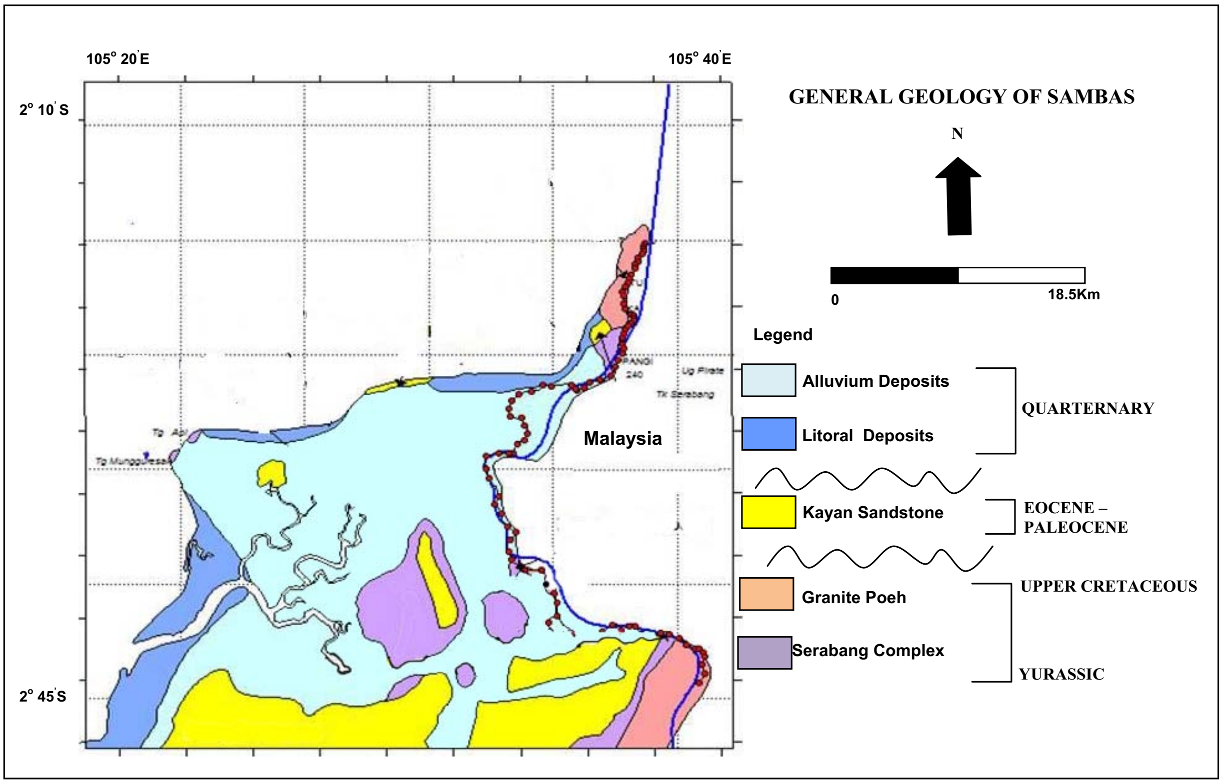


Figure 2. General geological conditions of survey area (Rusmana and Pieters, 1993)

Figure 3. Operating of GPR survey

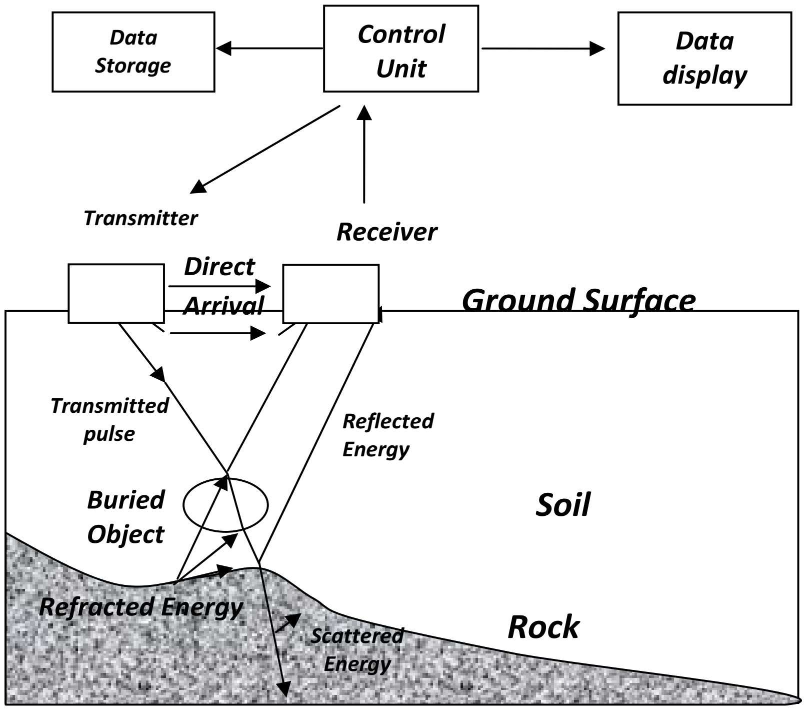


Figure 4. Operating procedure of GPR Survey (Modified from Budiono et al, 2012)

survey distance in meters versus two way travel time in nanoseconds.

Data were processed using the RADAN 5.5 software package. For presentation, gain Control was applied. The number of stacks normally was kept 60 per trace and Spatial temporal filtering was applied to reduce random noise.

GPR interpretation is based on the identification of reflection configuration and is verified by stratigraphic information from outcrop data and core drilling data log. Interpretation of GPR profile involves the deciphering of interference patterns rather than discrete reflections and diffraction that are characteristic of reflection seismic profile (Gawathorpe et al., 1993).

The reliability of the interpretation is dependent on the experience of the interpreter and their ability to use reference material (Ekes and Hickin, 2001)

RESULT

The interpretation of Ground Probing Radar image was correlated with the lithology that distributed along the coast and core drilling data that was carried out at -3 m bellow sea water.

Surface Lithology

The lithology which is exposed around the study area can be summarized as follow:

Sand

Sand can be found along the coast and characterized by grey to yellow color, fine to coarse grained, consists of shell remain, unconsolidated sediments, they are classified as Quaternary alluvium deposit (Figure 4)

Limestone

Limestone outcrop are exposed along the coast, characterized by coral reef limestone which some of them are still growing. They are mainly found in some part of Temaju coast line especially during low tide.

Sandstone

Sandstone are also very good exposured at south and northern part of Temaju coast. Sandstone are grey to yellowish grey coloured, fine to medium grained, consists of quartz and feldspar mineral, massive and very consolidated, medium to hard (Figure 5).

Core drilling data

Core drilling has been carried out at about -3 m of sea water depth with about 30 m total depth penetration. Stratigraphically the lithology is characterized by sand, limestone and sandstone. Sand is the uppermost layer, characterized by yellowish white colour, medium to coarse grained, loose, consist of 90 % of quartz mineral and small amount of shell remain. The thickness of sand is about 11 m. Below sand deposits is limestone which

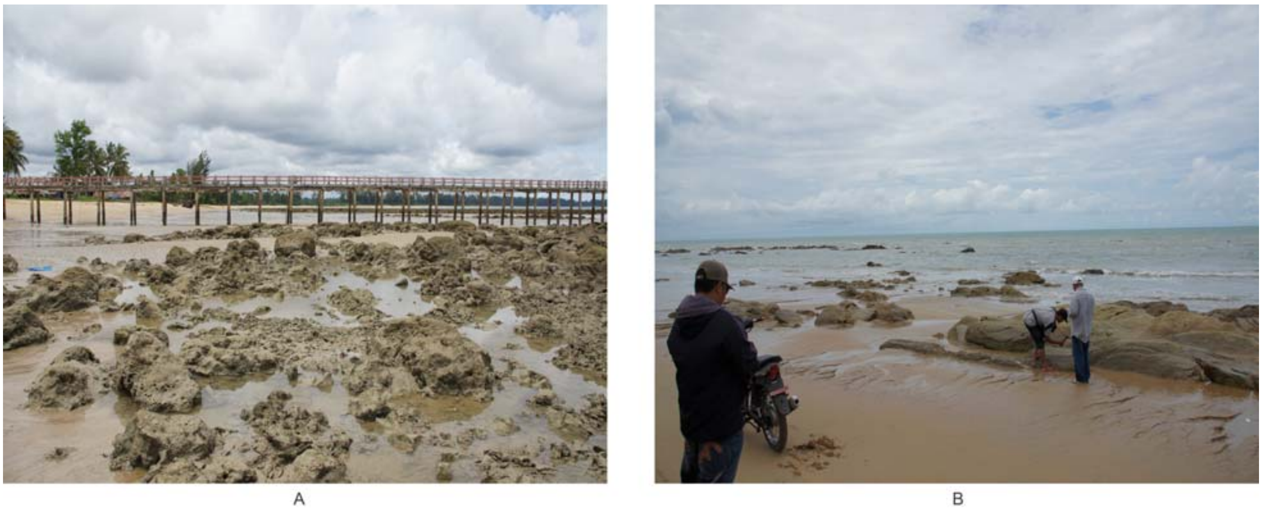


Figure 5. Outcrop of coral limestone (A) and outcrop of sandstone (B)

is interpreted derived from coral reef, dirty white colour, hard to very hard and the thickness about 7 m. The lowermost layer is sandstone, brown colour, coarse grained, consists of gravel, very hard. It is found from 18 – 30 m depth.

Analysis Radar Facies

The procedure to analyze the radar facies is the same with the sedimentological facies analysis.

The radar facies is resulted from analyze of the GPR data set is consisted in the identification of individual radar facies, were grouped into radar unit (Budiono et al, 2012).

The full length of all GPR image data were analyzed and interpreted, but only selected profiles are presented in this paper. The GPR facies is described in term of reflection characteristic and continuity, shape, amplitude, internal reflection configuration and external form using the approach applied by Beres and Haeni (1991); Van Heteren et al. (1998).

The activity of GPR survey have been done for 5 and 10 m depth penetration, where both of these activity have used 270 MHz transducer (Figure 6, 7 and 8)

The facies configuration of GPR image data can be described as follow:

Unit 1

Both of 5 and 10 m penetration depth are characterized by weak to medium reflector, moderately amplitude, sub parallel – parallel, transparent and continuous. The thickness of this unit is about 2 m (Figure 5)

Unit 2

Unit 2 is located below unit 1 with the thickness about 5 m. They are the differences of facies configuration of 5 m and 10 m depth penetration. The facies configuration of 5 m depth penetration is characterized by strong reflector, high amplitude, sub parallel to parallel, wavy and hummocky and continuous. The dipping layer at the bottom part is characterized by divergent reflector configuration. The GPR image data of 10 m depth penetration is characterized by medium reflector, moderately amplitude, sub parallel to parallel and continuous. At uppermost layer there is dipping layer which is characterized by divergent reflector configuration.

Unit 3

Unit 3 is the lower most layer and just can be recognized from the line with 10 m depth penetration. This unit is dominated by strong reflector, high amplitude, parallel and continuous reflector.

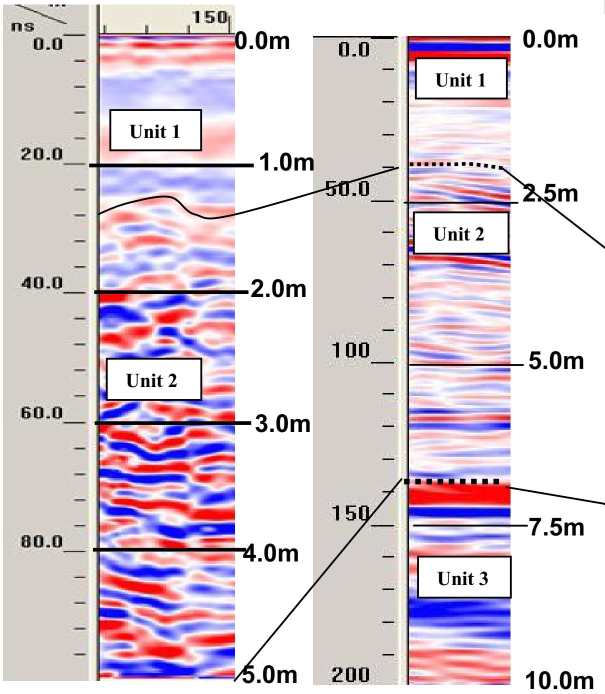
Interpretation of GPR Image

Radar discontinuities were recognized by the analysis of different styles of reflection terminations. These discontinuities show good correlation with the surface geological condition and drilling data log of Temaju coast. Three radar unit from top to bottom were recognized in the study area and each unit is characterized by one or more facies which have been discussed previously.

Line 1

Line 1 was imaged by using 270 MHz antenna and maximum penetration is about 5 m. The radar unit can be divided into 2 unit mainly unit 1 and 2 (Figure 6 and 7).

Unit 1 is the uppermost layer, characterized by weak reflector, low to moderately amplitude, transparent, sub parallel – parallel and continuous.



Radar Facies	Interpretation
Weak reflector, low amplitude, parallel, sub parallel transparent	Sand
Strong reflector, high amplitude, sub parallel, wavy, hummocky, divergent, continuous	Limestone (coral riff)
Medium- strong reflector,moderately amplitude, parallel – sub parallel, continuous	Sandstone

Figure 6. Radar facies

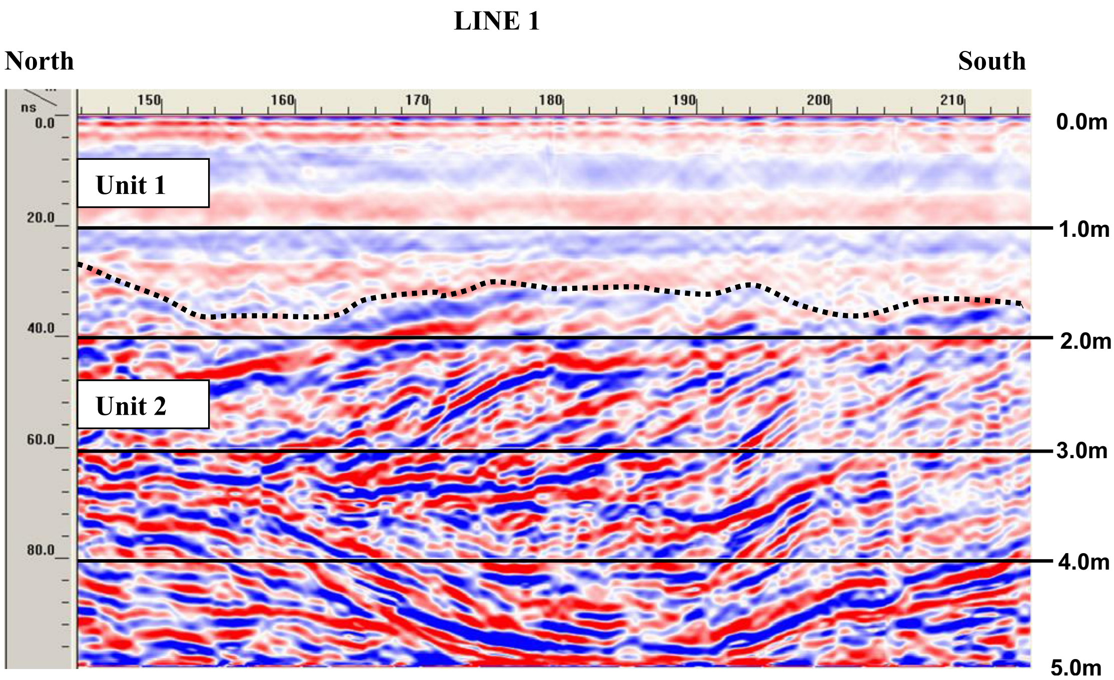


Figure 7. The GPR image of line 1

Based on the surface lithology and core drilling observation, the upper most layer is dominated by alluvium deposits which consists of sand, fine to coarse grained. The GPR image show that the thickness of sand deposits is about 2 m whereas based on the core drilling data which was carried out at -3m below sea water have a sand thickness about 11 m. Below the unit 1 is unit 2. On line 1, it shows that this unit is characterized by strong reflector, high amplitude, wavy, hyperbolic, hummocky and divergent. The detail of the reflection patterns of unit 2 appears that the divergent reflector to the north part (Figure 6) is terminated by concave reflector. Based on the surface geological data and core drilling observation, both divergent and concave reflector is interpreted as coral reef limestone. The thickness of unit 2 at line 1 is about 3m.

Line 2.

The GPR survey which have been carried out at line 2 were recorded by using 270 MHz antenna and maximum penetration is about 200 nano second or about 10 m depth (Figure 8).

They are 3 radar units that can be recognized from line 2 mainly unit 1, 2 and 3.

Unit 1 is uppermost layer, characterized by continuous parallel facies, weak reflector and low amplitude. This unit has an approximate thickness about 2.5 m and interpreted as alluvium which consists of sand. Compare to the sediments facies, the continuous parallel facies indicate that the texture of sediment deposits probably is characterized by medium to coarse grained sediments that was deposited through high energy (strong wave and current).

Below unit 1 is unit 2 which is dominated by strong reflector, moderately to high amplitude, continuous sub parallel- parallel, hummocky, mound ore hyperbolic and divergent facies. Unit 2 is interpreted as coral reef limestone which have dipping to the sea ward.

Unit 3 is the lowest layer, characterized by strong reflector, high amplitude continuous parallel and wavy facies. This unit is found from about 7.5 to 10 m depth (Figure 7 and 8). By comparing to the lithology which is exposed around the study area, this unit can be interpreted as a Kayan Sandstone. The core drilling data shows that the sandstone is characterized by yellowish white colour , moderately to coarse grained, consists of 90% quartz mineral and small amount of gravel , it is found from -21.0 – -33.0 m below sea water.

DISCUSSION

Ground penetrating radar image proved to be a useful survey tool that allowed the collection of about 11 line subsurface data on the Temaju coast. The interpretation of GPR image data is the very interesting challenging component of GPR survey.

The feasibility of using GPR for investigation of coastal geology is demonstrated. The data show structures of the expected scales and spatial relationship. Correlation of GPR data record with

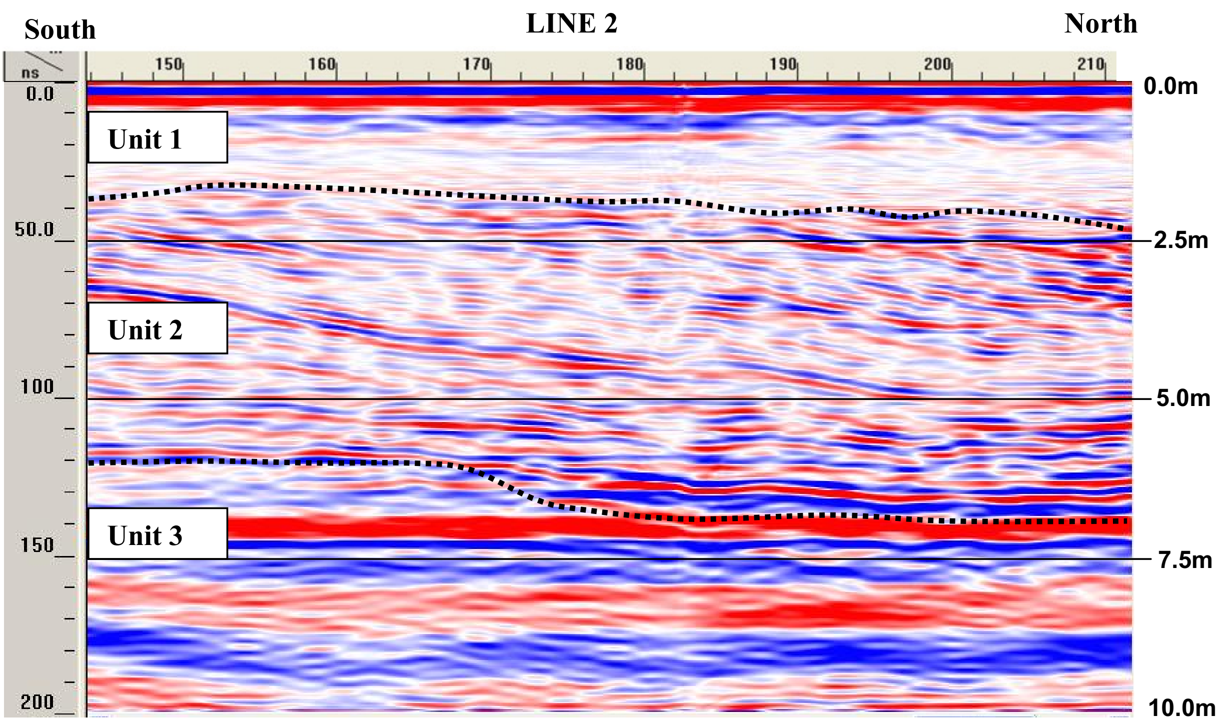


Figure 8. The GPR image of line 2

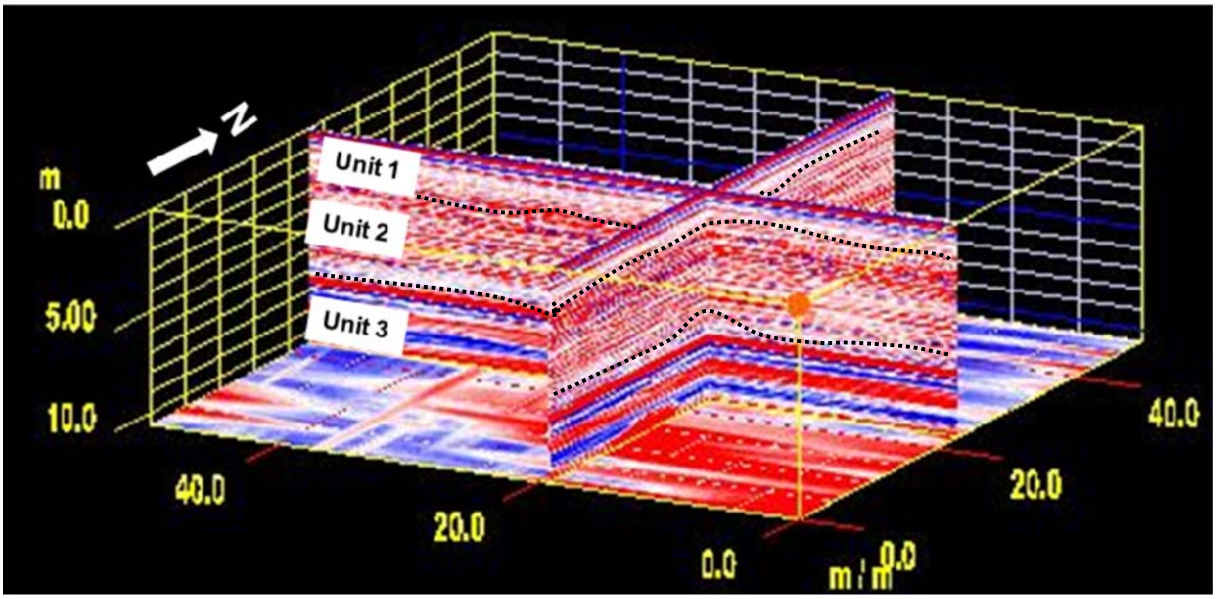


Figure 9. The 3 dimension of GPR image

borehole data is seen on the scale of the main stratigraphic boundaries.

GPR data can be used to analyse the dynamics of coastal processes and resulting barrier response and it is frequently possible to distinguish coast sediments formed by onshore, offshore and longshore accretion.

In view of the limitation in present data with regard to scales of loose and massive rock sediment stratigraphic features, it will be useful to do additional data acquisition both at finer sampling intervals and over larger areas.

It relies largely on the availability of reliable subsurface information such as core drilling data information and accurate of exposed outcrop. Interpretation can be greatly aided by calibration. Based on the experiences, the reflection configuration of Radar from different lithology types can be similar in appearance, therefore the interpreters understanding of local and regional geology is of very importance.

The differentiation between loose alluvium sediments and sedimentary rock will be briefly explained below.

The GPR image data were calibrated and showed some promise to distinguish loose sediment and massive sedimentary rock (Figure 5, 6 and 7), but sometimes, the results is not consistent. This condition is shown by facies coral reef limestone at GPR image of 5 m and 10 m depth penetration (Figure 6, 7 and 8). Although the type of sedimentary rock is similar but the internal and external facies is completely different.

GPR image distinguished reliably between loose sediment and massive sedimentary rock. There is a clear separation between loose sand and underlying massive hard limestone.

The correlation between GPR image facies and lithology from surface outcrop and core drilling result, shows that the coastal sediment is continuous extend to the sea ward.

CONCLUSSION

Ground-penetrating radar (GPR) has the potential to noninvasively investigate shallow geologic heterogeneity at high resolution over large volumes of the sub surface, therefore the GPR technique is gaining popularity among earth scientist interested in sub surface shallow depth. The survey carried out under this study could recognition of various sedimentary reflectors. The study indicates major radar surfaces that delineate sediment facies, reflecting the dynamic nature of coastal sediment system.

GPR can distinguish reliably between unconsolidated alluvium deposits and consolidated massive sedimentary rock. There is a clear separation between unconsolidated alluvium sand deposits and underlying hard massive sedimentary rock (limestone and sandstone)

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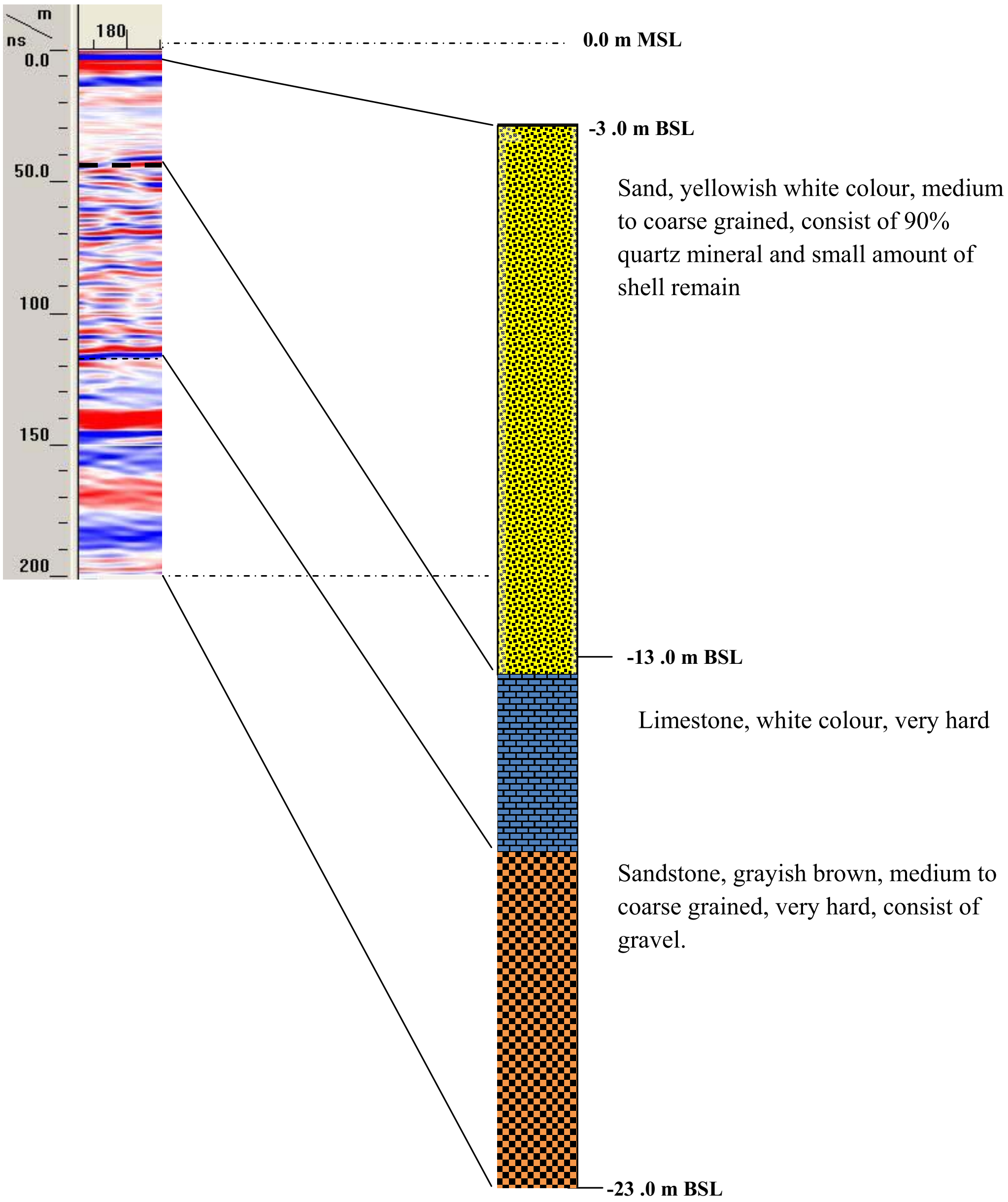

Figure 10. The correlation between radar facies and core drilling data

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