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Investigation of Ground Penetrating Radar for Detection of Road Subsidence Northcoast of Jakarta, Indonesia

Penyelidikan "Ground Penetrating Radar" Untuk Menditeksi Penurunan Jalan di Pantai Utara Jakarta, Indonesia

Kris Budiono[*], **Yogi Noviadi, Godwin Latuputty and Undang Hernawan**

Marine Geological Institute, Jl. Dr Junjunan 236 Bandung-40174
Email: [*]Kris_budiono@yahoo.com

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ABSTRACT: A survey of Ground Penetrating Radar (GPR) was conducted in the coastal zone of northern part of Jakarta, Indonesia. The purpose of this survey was to provide the subsurface of coastal Quaternary sedimentary features and stratigraphy disturbances associated with induce post road subsidence 2009. The possibility of subsurface lithology disturbance shown by the GPR record. This record resulted from GPR methods using SIR system 20 GSSI, 270 MHz and 400 MHz and MLF 3200 transducer. The method is a promising tool for resolving changes of physical properties in subsurface lithology condition at the natural scale due to composition changes of physical properties.The reflection data resulted that GPR can distinguish between image the basic geometry forms such as lithology , structure geology , soil and subsurface utilities condition

Keyword: Quaternary geology, Jakarta subsidence northern road 2009, Ground Penetrating Radar

ABSTRAK: *Penyelidikan "Ground Penerating Radar" (GPR) telah dilaksanakan di kawasan pantai utara Jakarta Utara, Indonesia. Tujuan dari penyelidikan GPR ini adalah untuk melihat kondisi sedimen Kuarter bawah permukaan dan gangguan stratigrafi sehubungan dengan penurunan jalan raya pada tahun 2009. Kemungkinan gangguan terhadap litologi bawah permukaan terlihat pada rekaman GPR. Hasil rekaman metoda GPR mempergunakan model SIR 20 GSSI, transduser 270MHz, 400 MHz dan MLF 3200.Metoda GPR merupakan alat bantu yang cukup menjanjikan untuk melihat perubahan sifat fisik litologi bawah permukaan pada skala sebenarnya yang disebabkan oleh perubahan komposisi sifat fisiknya. Hasil refleksi data GPR dapat membedakan bentuk dasar geometri seperti litologi, struktur geologi, kondisi utilitas bawah permukaan.*

Kata kunci : *Geologi Kuarter, Penurunan jalan utara Jakarta 2009, Ground Penetrating Radar*

INTRODUCTION

The survey area is located along the road (300 meter) closed to the Tanjung Priok harbour.of north coastal land of Jakarta Bay, Indonesia (from 106^o 20' 00" East Longitude to 06^{o}10'00" North Latitude). A part of this road approximately 100 m was suddenly subsidence and down towards the underneath seawater in 2009.

The objective of this survey was to provide the subsurface of coastal Quaternary sedimentary features (characteristic of subbottom sediment and soil) and stratigraphy disturbances associated with induce post road subsidence 2009. The present work were also to recognized information about the sub bottom sediment and stratigraphic geometry due to the subsidence or settlement activity.

The Quaternary Geological map of the Jakarta Bay presents the properties and distribution of shallow subsurface sediments in the Jakarta Bay area by the Geological Research and Development Centre of Indonesia program for the systematic mapping of coastal zones and areas with extensive alluvial deposits. The maps provide basic geological data for regional development and information concerning natural resources and hazards.

The basis for the Quaternary geological condition is formed by the profile type legend system and sedimentary environmental units as main map legend units.

The Quatenary Geology of the Jakarta Bay shows the types and distribution of alluvial and marine sediments in the area that indicated Alluvial Fan,

Figure 1. The survey area

Beachridges, and channel deposits on geological maps, scale 1 : 100.000 (Rimbaman, 1997).

The map shows that the shallow subsurface geological conditions in Jakarta Bay very considerably from south to the north.

Sediments in the southern part mainly comprise alluvial fan clayey silt, covered by floodplain clays. The types of deposits are mainly heterogeneous in composition, and also their spatial distributions varies considerably. This is related to the morphology of the area which more higher in the southernpart. To the north, sediment deposits mainly comprise marine clay and organic clay of mangrove swamp deposits as well as fine-coarse grained and contain of shell remain of beachridges deposits (Rimbaman, 1997).

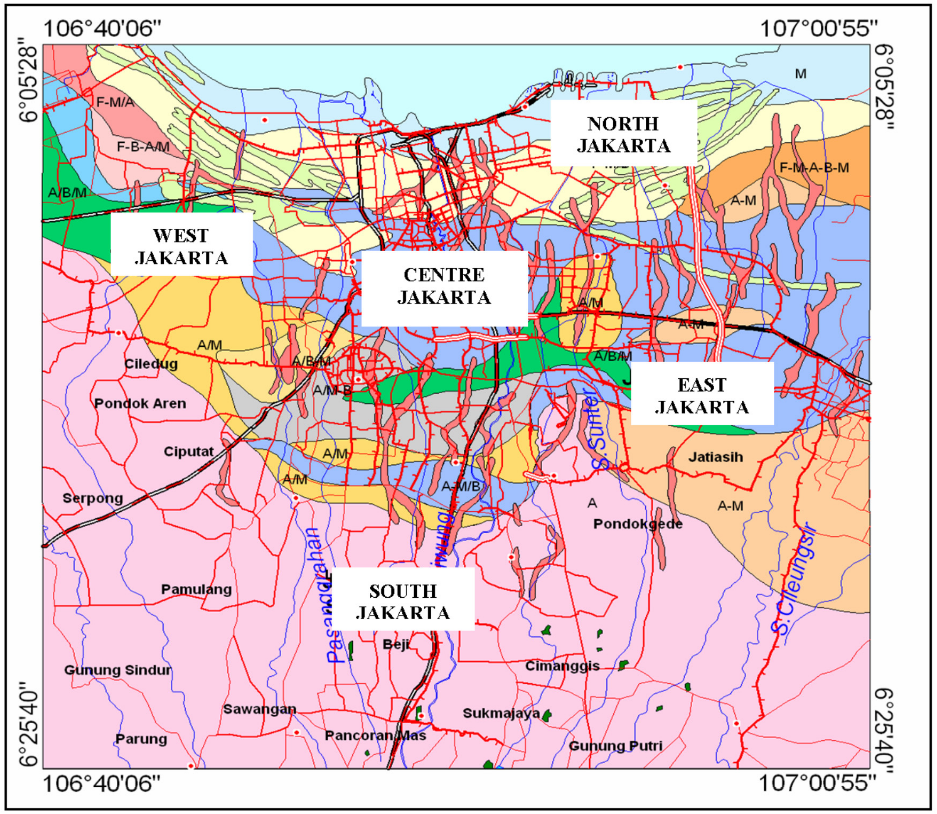
METHODS

The Ground Penetrating radar has been used to profile the position and condition of subsurface lithology below the road construction.

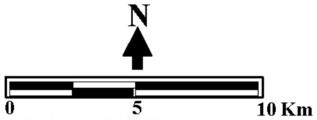
Analysis of a large data base of GPR profile from natural subsurface lithology have allowed identification of reflection configuration that characterize soil type and condition (Rossetti and Goes, 2001).

In many contamination problem, the sub bottom soil, and stratigraphic information below the road area is sparse and drill-core description only gives a limited picture of the geometry of inhomogeneties (Saarenketo, 2000).

The Ground-Probing Radar (GPR) method is a promising tool for resolving changes of physical properties in burial soil condition at the scale of natural



QUARTENARY GEOLOGIGAL MAP OF JAKARTA AREA SCALE 1:100,000



STRATIGRAPHY FRAMEWORK

AGE		SEDIMENTARY ENV
QUARTER	PLEISTOCENE	FLUVIATIL Floodplain deposits (F) Chanel deposits (C) Alluvial Fan deposits (A) Swamp deposits (S) SEA Beach and Beachridge deposits (B) Mangrove swamp Deposits (M) Nearshore and shallow marine deposits
TERTIER	PLIOCENE	FLUVIATIL Volcanic Eruptions

MAP LEGEND

🟦	M
🟩	M/B
🟨	F-M/B
🟧	F-M-A-B-M
🟥	F-M/A
🟥	F-B-A/M
🟦	F-B-A-B/M
🟩	A/B/M
🟦	A-M/B
🟧	A-M
🟨	A/M
🟥	A-M-B
⬜	A/B-M
🟪	A
🟥	F-C/M/B
🟥	A-C/M/B
🟥	A/C
🟥	A/C/M
🟥	A-C/M
🟥	A-M/C-B

Figure 2. Quartenary Geological map of Jakarta area (Rimbaman, 1997)

inhomogeneties arising from changing physical and engineering properties composition (Carrivick, 2007)

The result demonstrated that on GPR reflection image the basic geometry forms such lithology, ground water table and subsurface utilities

The method uses antennas placed near or in contact with the surface of the ground to probe the shallow subsurface.

The technique is known as Electromagnetic Subsurface Profiling (ESP) and is the electrical analog of seismic sub-bottom profiling technique used in marine geology.

The techniques are also based on the principle that high-freq. electromagnetic waves may be reflected at boundaries separating heterogeneous regions of the subsurface. They are best suited for high-resolution geophysical and subsurface concrete block investigation. The system is capable of detecting and graphically displaying subsurface interface in shallow depth (Beres and Haeni, 1991).

Most georadar surveys are conducted with the transmitter and receiver antennas very close together,practically at zero offset. An important feature of georadar antennas with beam apertures of 30^0 to 60^0, broadband, time-limited pulses of electromagnetic energy are continuously radiated into the earth from a special antenna moving along the surface.

Ground-penetrating radar (GPR) reflections often occur at boundaries between unsimilar or concrete units where the conductivity and dielectric constant changes. In many concrete setting, GPR is an effective method for imaging near surface boundaries because variations in strata and in electrical properties are closely correlated in space (Rossetti and Goes, 2001).

The system is also capable of identifying subsurface materials by analyzing the reflected pulses. The shapes of these pulses depend only on the effective dielectric constant and conductivity of the material. Ranges of values of dielectric constant and conductivity for different materials are taken from the literature.

A reflection may also be generated by a gradual change in dielectric constant caused by variable moist, dry and very dry below the concrete road unit. Capillary force produce a continous change is moisture content over a thin depth interval for sediment or soil. If the two types of reflectors-one a transition zone and the other a layer boundary are closely spaced, then their reflections may be superimposed in a radar section. Neither feature will be easily recognized, and interpretation would be difficult (Rossetti and Goes, 2001).

The GPR system is composed of video pulse transmitter, a receiver and an antenna and note boks computer

Once an area for subsurface investigation has been established, the lightweight antenna unit is towed over the ground by hand. A portion of the radar signals that have been reflected from the interface of surface and subsurface objects is received by the antenna.

Radar reflections from the interface are governed by the differential in the dielectric constant and conductivity of the materials (Van Dam and Schlager, 2000)

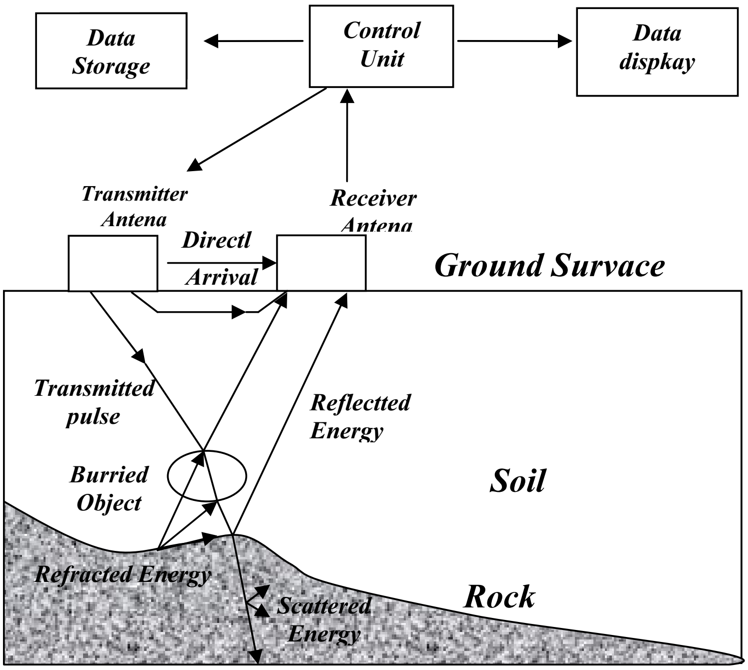


Figure 3. Operating procedure of GPR system

Figure 4. The activity of GPR Survey on the road of northern part of coastal land of Jakarta Bay

The system receives reflections of these pulses from interfaces between materials that have different electrical properties. This digital data is stored on computer and is printed out graphically after area has been scanned and analysis (Beres and Haeni, 1991).

- The equipment which was used are:
- Structure scan III
- Note book and Software Radan 5
- Transducer 400 MHz, 270 MHz and Multy Frequency 3200 MLF

After obtaining GPR data, this data must be processed. Processing GPR data involves modifying it so it is more easily visualized and interpreted. Since data obtained from GPR surveys is similar to data obtained from seismic reflection surveys, many of the same techniques used to process seismic data can be used to process GPR data. In many cases, such as that presented by GSSI, very little processing of the data is required to locate the target of interest.

Normally, processing the data involves the following steps:(Beres and Haeni, 1991).

Converting the data to a usable digital format, removal or minimization of direct and air waves from the data, amplitude adjustments to the data, gain adjustments to the data, static adjustments to the data this involves removing the effects of changes in elevation and effects from leveling the GPR, filtering the data, velocity analysis.

In many cases, it is possible to use the results from a GPR survey with very little processing. In these cases, the only adjustments that need to be made are to convert the data to a usable digital format, to make gain adjustments to the data, and to determine the depth to each reflector (such as the water table) in the subsurface (Johnson, 1987).

The interpretation of GPR-reflections presented in this paper is based on correlation of the GPR signal with the core drilling data. and key surfaces observed along the road area. The direct comparison and detailed correlation with the radar sections made throughout the study area enabled to calibrate the GPR data with the local sedimentology, providing a reliable geological interpretation for individual reflections and leading to a more precise stratigraphic framework for Quaternary deposits at Jakarta area. The GPR signal can be affected by sediment type and its facies interpretation relies on the principles of seismic stratigraphy, which mostly include the identification of reflection configurations and terminations, internal reflection configuration and external geometry (Van Heteren et al, 1998, Beres Jr. and Haeni, 1991). Radar stratigraphic procedure identifies radar sequences which are defined by packages of genetically related strata bounded by

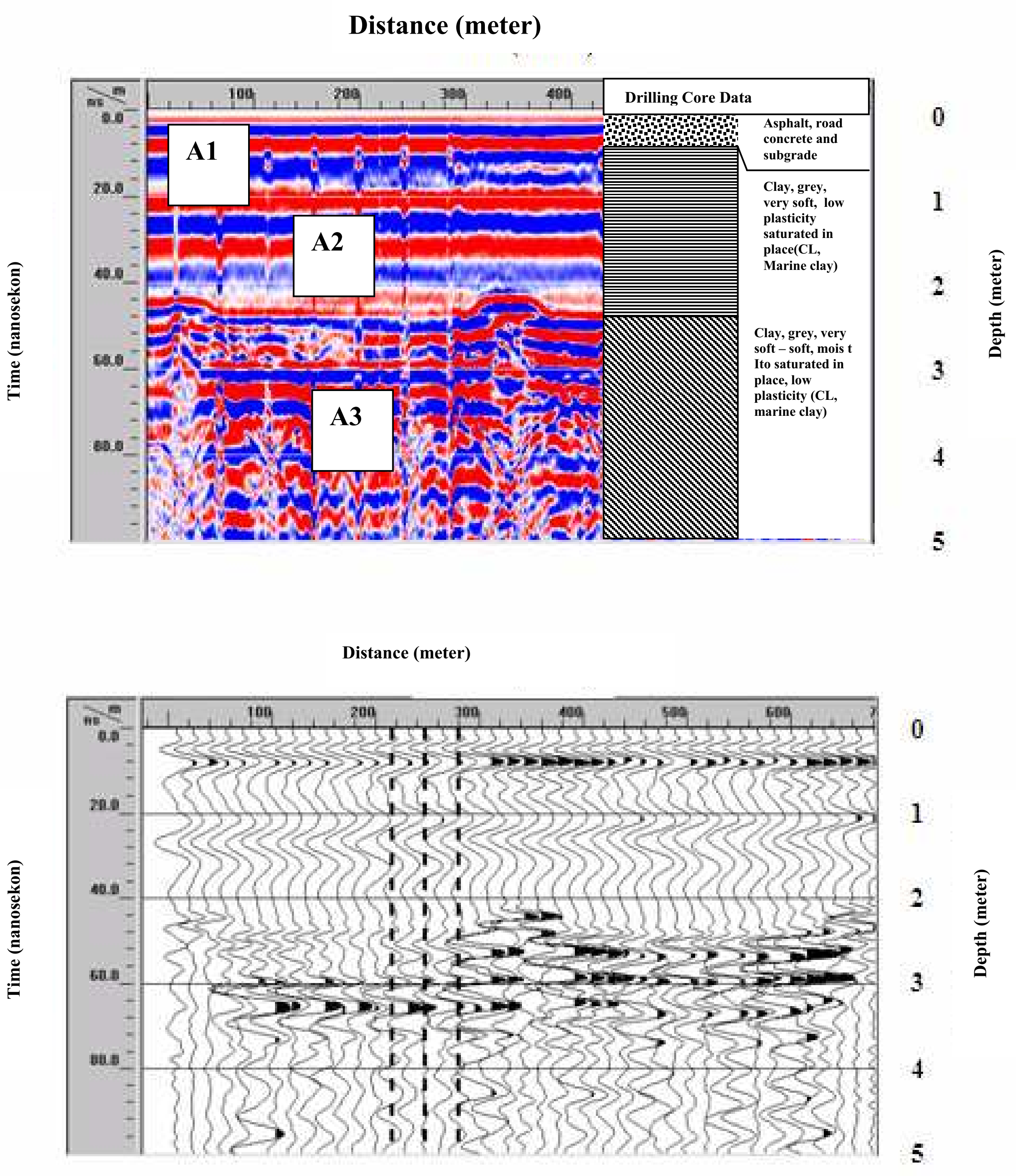


Figure 5. GPR records of line 231

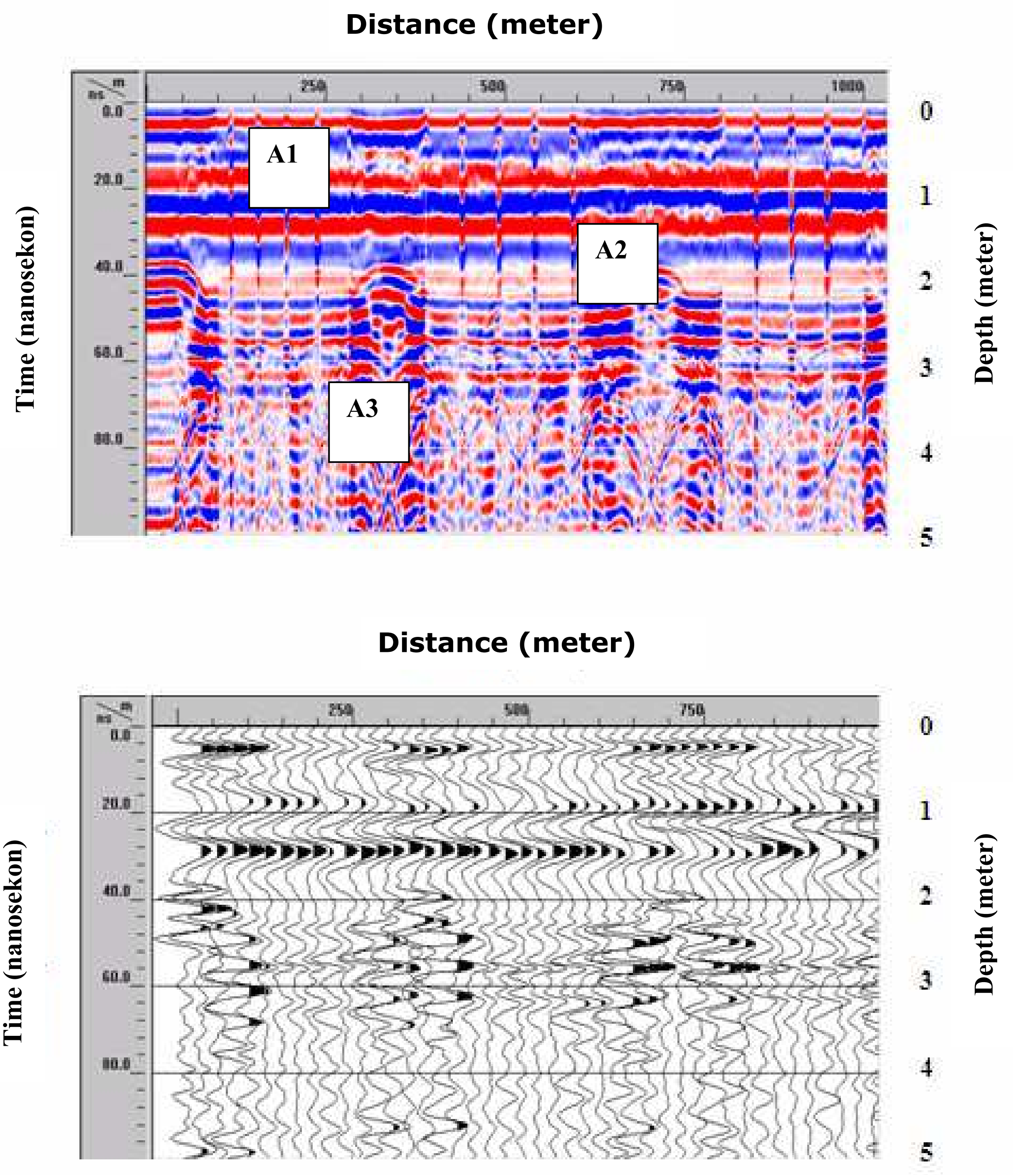


Figure 6. GPR records of line 235

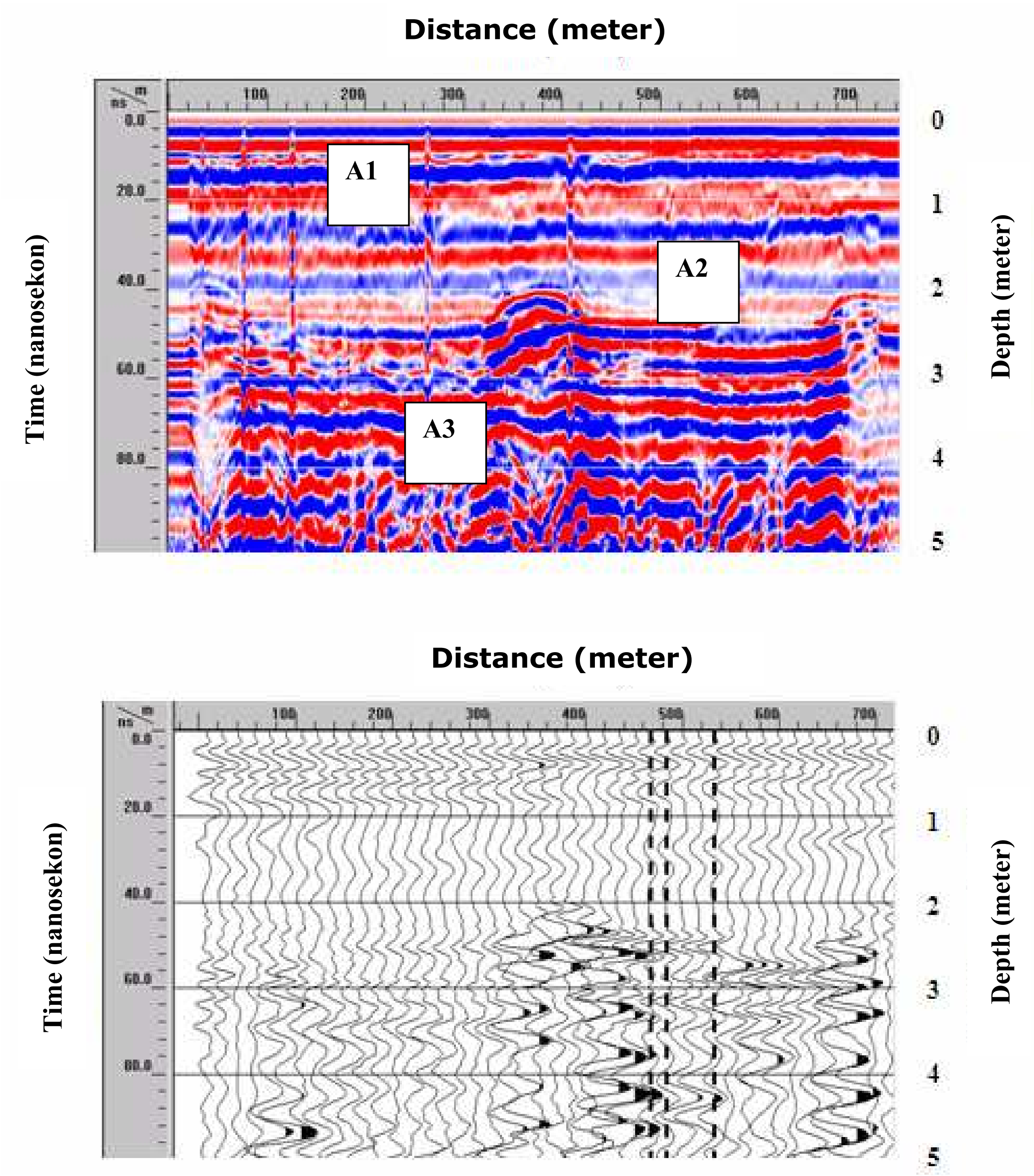


Figure 7. GPR records of line 232

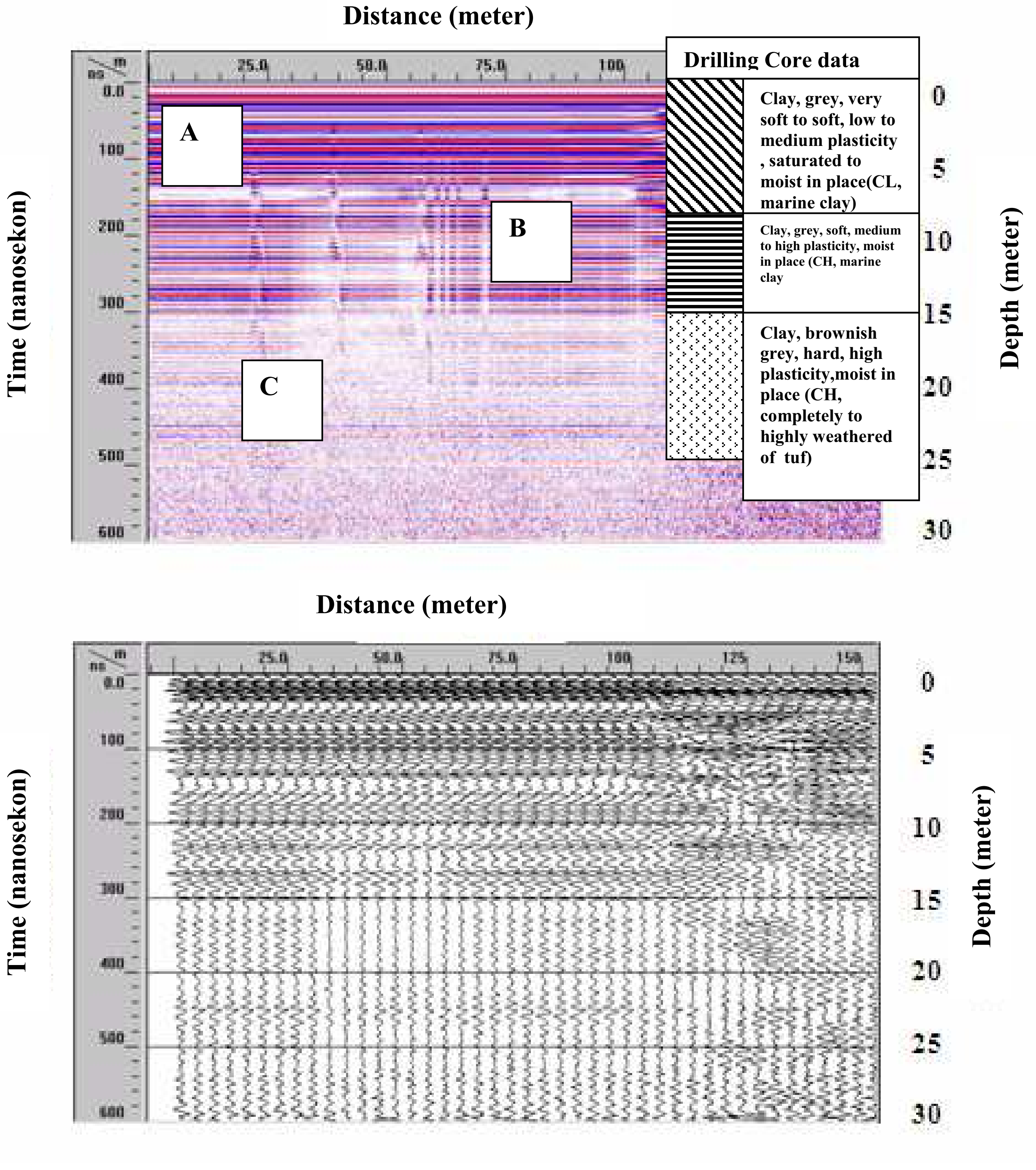


Figure 8. GPR records of line 232

unconformities and their correlative conformities (i.e., radar boundaries), as well as to analyze the sedimentary facies and facies architecture in order to understand the lithology, depositional environments and stratigraphic evolution of this sedimentary succession (Rosseti and Goes, 2001a).

RESULTS

The antenna or transducer used during survey were 270 MHz and Multy Level Frequency 3200 MLF.

The transducer 270 MHz was used to detect the relatively shallow and detail soil condition, where as the MLF 3200 was used to detect the dipper subsurface soil condition.

Similarly to sedimentological facies analysis, the procedure used herein to analyze the GPR data set consisted in the identification of individual radar facies, which were grouped into radar units, interpreted to be representative of the depositional environments.

Three radar facies were recognized in the study area based on distinctive reflection configurations. Comparisons with radar signals obtained from other areas documented in the literature, enabled one to interpret each individual radar facies.

Generally the image of subsurface soil or sediment condition that used transducer 270 Mhz can be explained as follow:

Generally the GPR image can be divided into three units of electromagnetic reflector namely A, B and C, where unit A can be divided into unit A1, A2 and A3.

Unit A1, from 0.00 – 0.50 m is characterized by parallel, hyperbolic and strong reflector configuration and more dipper became transparent. From top to bottom, this unit is interpreted as asphalt , road iron concrete and mix of clay, sand and gravel (subgrade?) respectively.

Unit A1 is underlying by unit A2 (0.50 – 2.00 depth) which is characterized by parallel , continuous, strong reflector and high conductivity. Based on correlation with core drilling data, this unit is characterized by grey, very soft clay, low plasticity, saturated in place and derived from Quaternary marine clay sediment (Figures 5, 6 and 7)

Bellow Unit A2 is unit A3 which occupied 2.00 - 5.00m depth, characterized by parallel to sub parallel, hyperbolic and strong reflector. Based on the core drilling data, this unit is dominated by clay, grey coloured, soft, low plasticity and derived from Quaternary marine clay. The hyperbolic reflector configuration might be interpreted as a result of heavy load of the road and caused the disturbed of subsurface stratigraphic.

Based on the GPR image which was resulted by using the transducer 40 MHz (3200 MLF), the maximum penetration is about 25.00m (figure 8) . The subsurface lithology can be explained as follow:

The upper most layer is unit A (0.00 – 15.00 m) which can be divided into Unit A1, A2 and A3 (figure 5,6 and 7).

In general the reflector configuration are characterized by parallel and strong reflector. The core drilling data shows that this reflector can be interpreted as marine clay sediment, very soft to soft, moist to saturated in place (Figure 8)

Below the unit A is unit B,itt is characterized by continuous subparallel, strong reflector, high conductivity. Based on correlated with core drilling data the unit B show as clay, wet, soft to medium hard and stiff. The total thickness of this unit is about 7m.

Unit C is found bellow unit B and is interpreted as the lowest unit. It is characterized by sub parallel and chaotic reflector, medium to high conductivity. The core drilling data show that this unit is characterized by clay stone or volcanic tuff.

The results obtained from GPR surveys, show that the subsurface geological conditions of study area is occupied by the Quaternary and Pliocene sediments . The Quaternary sediments which is characterized by very soft to soft clay is interpreted as marine sediment. This marine sediment is influenced by very shallow ground water table (1-2 m).

The subsurface marine Quaternary sediments is underlain by Pliocene sediments which consists of clay stone or volcanic tuff.

DISCCUSSION

The study of using GPR for investigation of road subsidence is demonstrated. The data show the geometry of the expected scales of subsurface geological conditions and spatial relationship. Correlation of GPR data record with borehole data is seen on the scale of the main subsurface stratigraphic, and lithology physical properties boundaries.

GPR data can be used to analyse the dynamics of subsurface Quaternary sediments processes and resulting barrier response and it is frequently possible to distinguish the marine clay sediments formed by progradation processes

In view of the limitation in present data with regard to scales of Quaternary and Pra Quaternary stratigraphic features, it will be useful to do additional data acquisition both at detail sampling intervals and over larger areas

The subsurface very saturated soft clay in GPR image records, is exposed by very strong and high amplitude of electromagnetic reflector.

Mapping of Quartenary marine clay formations can be performed with a combination of laboratory tests, soundings and Ground Probing Radar (GPR) measurements. There is no field test for measuring the remoulded shear strength with sufficient accuracy and resolution for a detailed classification of the sensitivity in highly sensitive and marine clays. Therefore, it is advisible has to be measured in the laboratory. The undrained shear strength can be measured in the field by field vane tests or CPT tests, or by laboratory tests on undisturbed samples.

Ground Probing Radar measurements can also be a useful aid in areas where the marine clay formation has originated from leaching of salts. The method provides information on how far the leaching process has proceeded in different parts of the investigated sections, and by combining several measuring sections. The method can only be used in combination with the other test methods, but provides a continuous picture of the subsurface soil mass in contrast to the point information obtained by the others.

It can be concluded that the very soft marine clay sediments which have shallow ground water table is one of the reason why the slide or settlement of the road was occurred in the north of Jakarta coast.

CONCLUSIONS

The GPR survey by using Surveyor III/20 and transducer 270 MHz and MLF 3200, shows that the subsurface lithology below the road can be summarized as follow:

Unit A is the upper most layer, which is characterized by very soft to soft marine clay, very saturated layer with the thickness about 10 m

Below this layer is unit B which is characterized by soft to medium hard clay and tend to became very stiff clay and to more deeper is found also clay stone or volcanic tuff. The thickness of this unit is about 5 m.

Unit C is the lowest layer and characterized by clay stone or volcanic tuff, very hard and is found from 15 m to 22 m depth.

Based on the GPR survey and core drilling data, the subsidence or settlement at one of the high way at north Jakarta city is due to the condition of very soft marine clay of unit A.

Finally, it can be concluded that more data and further investigation are required to understand the detail and comprehensive relationship between road subsidence and the Quaternary marine clay sediments conditions.

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