

INVESTIGATION OF SUBSURFACE STRUCTURE USING ELECTRICAL RESISTIVITY TOMOGRAPHY AND GROUND PENETRATING RADAR FOR DEVELOPMENT PLAN AT MAKASSAR INDUSTRIAL AREA, SOUTH SULAWESI

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ABSTRACT

Electrical Resistivity Tomography (ERT) and Ground Penetrating Radar (GPR) methods were applied to this research for subsurface layers and structures investigation at Makassar Industrial Area (KIMA), South Sulawesi, Indonesia. Electrical Resistivity Tomography (ERT) method can give information about rocks type but cannot represent the rock layers well, while Ground Penetrating Radar (GPR) method has better resolution to represent the rock layers but cannot give the information about rocks type so we need to combine those methods for subsurface investigation. Electrical Resistivity Tomography (ERT) method was done in 3 (three) lines, including Line 1 with length 470 m, Line 2 with length 470 m, and Line 3 with length 360 m using Dipole-dipole Array with electrode spacing at 10 m. Ground Penetrating Radar (GPR) method was done in 1 (one) line with length 140 m. The result of this research obtained a resistivity value at $1.5 - 10 \Omega\text{m}$ interpreted as Alluvial layer, resistivity value at $11 - 89 \Omega\text{m}$ interpreted as Limestone intersected with Volcanic Tuff layer, and resistivity value $>90 \Omega\text{m}$ interpreted as Limestone, whereas in GPR method obtained 1 (one) radargram section shows the subsurface with 3 (three) layers. For several cases of Horizontal Directional Drilling (HDD), information about soil and rock layers was not provided so the pilot head cannot pass through. Using those 2 (two) methods, we can get information either the layering of soil and rocks or the rocks type. So that can be interpreted the subsurface layers of this area is Alluvial, Volcanic Tuff, and Limestone.

Keywords: ERT, GPR, Subsurface, HDD.

INTRODUCTION

With the development of science and technology, geophysical methods are now intensively used for geotechnical and environmental investigations. Infrastructure development activities in Indonesia are ongoing, where the planning process requires information about the condition of surface and subsurface soil/rock. Underground utility installations often use Horizontal Directional Drilling (HDD) method because it has better flexibility compared to conventional method. This method has the advantage of allowing drilling under the forest; pool; cliff; road; and other conditions that are difficult to reach, unnecessary to restore damaged infrastructure and exposed land due to excavation,

not changing landscape conditions and have a lower risk of work. In the case of HDD done by PT XXX, the pilot head could not penetrate rock layer so the drilling was stopped and required a harder drill bit. Initial prediction is the subsurface rock layer is classified as hard rock, so that information is needed regarding the condition of subsurface layers in that area. To fulfill this information, investigation is needed by observing the condition of soil/rock exposed on the surface, while to determine the condition of soil/rock below the surface it is necessary to do a subsurface geological investigation. In this investigation, 2 (two) methods were used, ERT method and GPR method. ERT method is one of the geophysical methods that can measure the resistivity value of a medium, while GPR method utilizes reflection of

signal emitted by the transmitter and received by the receiver. This investigation aims to identify the subsurface condition in Makassar Industrial Area. This is done because each method has limitations, ERT method cannot represent the rock layers well, while the GPR method cannot obtain information about types of rocks below the surface. So that to fulfill the information needed for optimizing HDD drilling, both methods are used to describe rock layers and rock types.

Horizontal Directional Drilling (HDD)

Horizontal Directional Drilling (HDD) is a method used for the installation of underground pipes through trenchless methods involving the use of directional drilling machines and attachments. In general, Horizontal Directional Drilling (HDD) is used to overcome obstacles such as roads, rivers and other connecting roads in utility installations such as high or medium voltage electrical cables, fiber optics and gas pipes. The use of drilling using the Horizontal Directional Drilling (HDD) method has better drilling accuracy than other pipe placement methods (e.g.: open cut pipe folding method). In this Horizontal Directional Drilling (HDD) method, the determination of accuracy in conducting a drilling determines the name and age of the pipe to be used.

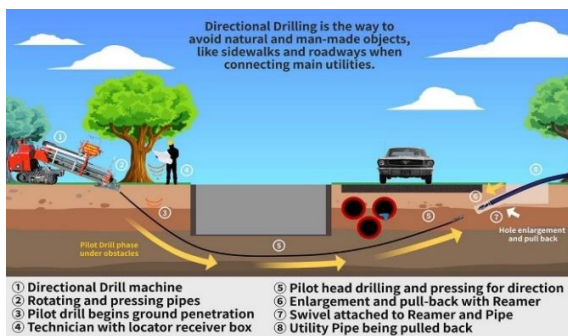


Figure 1. Construction procedure of Horizontal Directional Drilling (HDD)

Electrical Resistivity Tomography (ERT)

ERT is one of geophysical methods used to determine subsurface conditions by utilizing electrical properties of rocks. Basic principle of this method is electric current injection into the ground through a pair of electrodes (AB) and measuring the potential difference (MN) with another pair of electrodes, so that it can calculate

the resistivity value of rocks below the surface. The factors that can affect resistivity value are porosity, water content, and different constituent minerals so that the resistivity values obtained will be different.

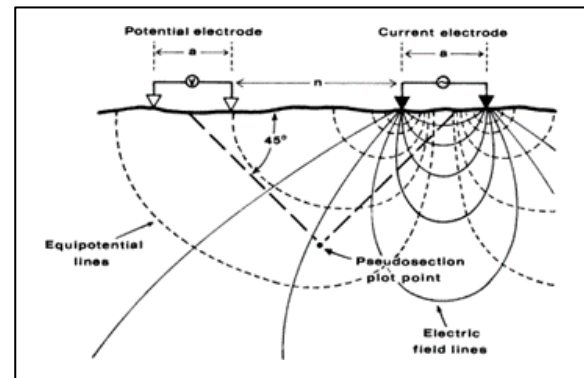


Figure 2. Electric current propagation concept in Dipole-dipole Array

Ground Penetrating Radar (GPR)

GPR is one of high-tech geophysical methods, this method is generally used for high-resolution imaging of structures beneath the surface by utilizing propagation properties of high-frequency electromagnetic (EM) waves. Basic principle of this method is transmitting a signal or EM waves by Transmitter antenna (Tx) then reflected and received by Receiver antenna (Rx). When EM waves hit an object or material below the surface that has high conductivity, amplitude of EM waves recorded on receiver will be very small. In addition to the conductivity value, GPR is also infected by the dielectric constant and magnetic permeability of a material or medium.

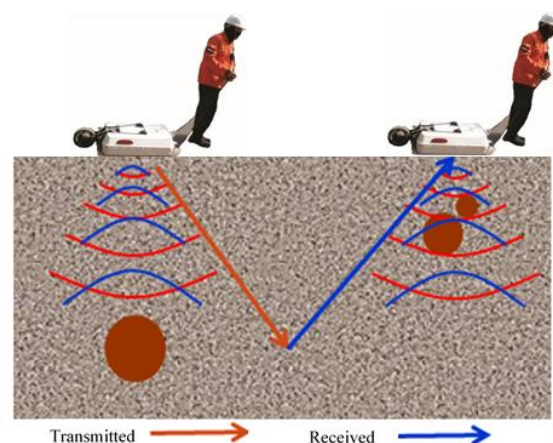


Figure 3. Electromagnetic waves propagation in GPR method

Geological Overview

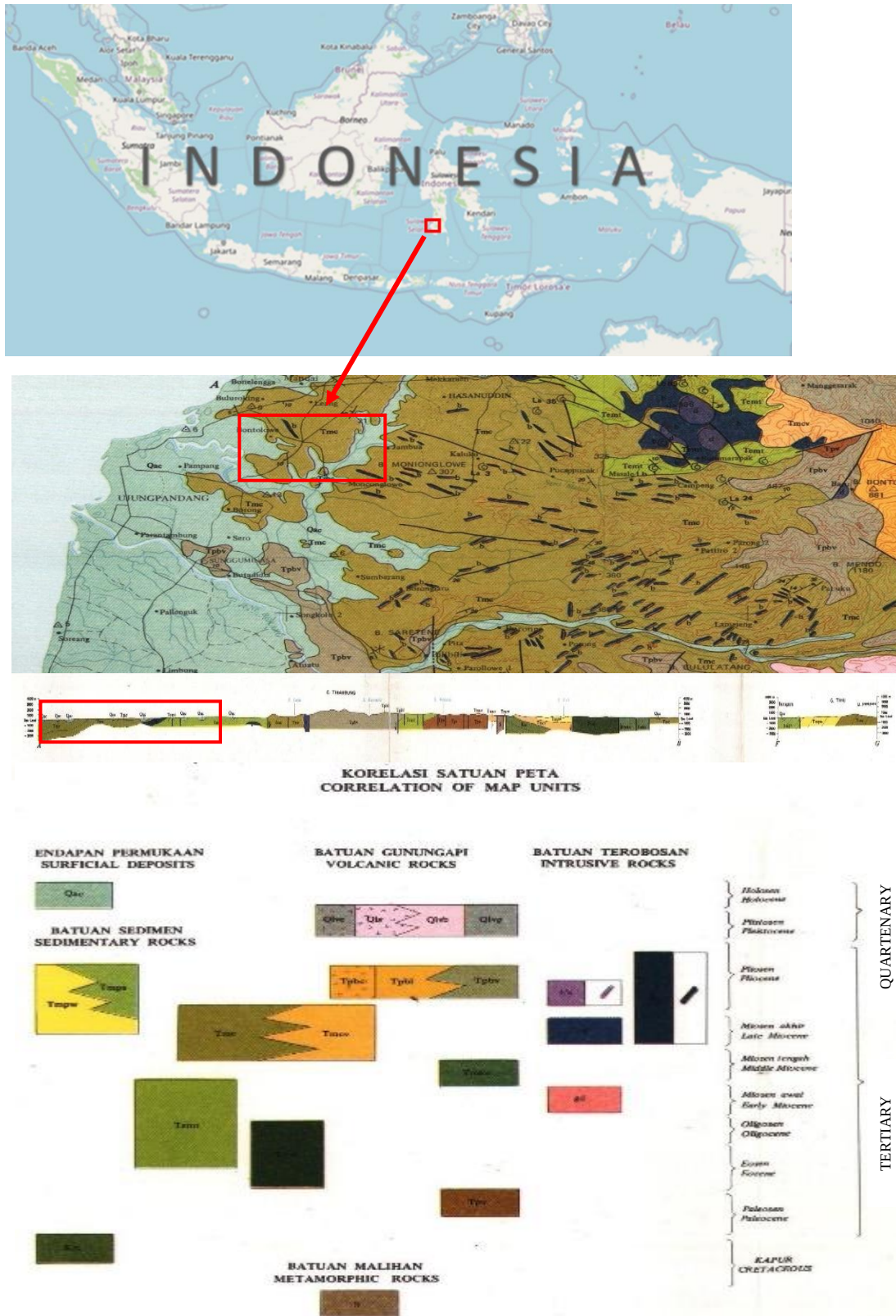


Figure 4. Geological Map at work area (Sukamto and Supriatna, 1982)

Work area was included in Geological Map of the Ujung Pandang, Benteng, and Sinjai sheet, Sulawesi. Scale 1: 250,000. Based on information from geological map (Figure 3), the rocks that form

Makassar City consist of 3 (three) rock units, namely: Camba Formation, Baturape – Cikuto Formation, and alluvial and coastal units.

Camba Formation (Tmc) overlapping older rocks. Camba Formation is a marine sedimentary rock that intersects with volcanic rocks, spreading from North to South, eastern part of Makassar City. Camba volcanic rock is rock consisting of fine tuff, sand tuff, and intersects with lapilli, and volcanic breccias also in several place limestone fragments are found.

Baturape – Cikuto Formation is rocks from volcanic eruptions, both effusive and explosive. This unit is a volcanic rock unit that is Quaternary (Pliocene) and spread over at southern part of Makassar City, which consists of melted lava and insertion of fine to coarse tuff, volcanic breccia with orientation of Northeast – Southwest rock layer.

Alluvial and Coastal Units are rocks resulting from marine sedimentation. This unit spread across eastern part of Makassar City, consisting of gravel, sand, clay, mud, and coral limestone.

METHODS

ERT and GPR data acquisition was carried out at Makassar Industrial Area (KIMA), Biringkanaya, Makassar City, South Sulawesi. This research was done in 3 (three) ERT lines, 1 (one) GPR line, and field observation to find some outcrops. ERT method used to obtain information about rocks type, although GPR method used to identify rock layers. GPR method has done only in 1 (one) line because it represents all ERT lines.

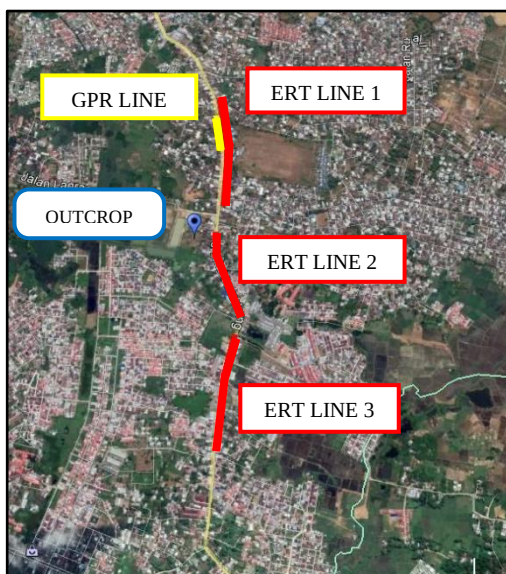


Figure 5. Work area of ERT and GPR survey

ERT Method

Data acquisition of ERT method using GD-10 Resistivity and Imaging System from Geomatics. Length of Line 1 and 3 respectively is 470 m with number of electrodes used is 48, electrode spacing is 10 m, while for line 2 is 360 m with number of electrodes used is 36, electrode spacing is 10 m. Electrode configuration used is Dipole-dipole Array. Result obtained from data acquisition is apparent resistivity value. Data processing was done with inversion method using software RES2DINV. Final result from data processing is 2D resistivity section from ERT lines.



Figure 6. ERT Data Acquisition

GPR Method

Data acquisition of GPR method using GroundVue 100 from UTSI Electronics with frequency 100 MHz. Length of the GPR line is 140 m which represents ERT lines. Obtained depth is ± 35 m. Result from GPR data acquisition is radargram raw data. Data processing was done with software Reflexw to remove static effect, increase signal energy (gain), and remove the recorded data noise. Final result from data processing is 2D radargram section from GPR line.



Figure 7. GPR Data Acquisition

RESULT

Interpretation of subsurface layer using ERT method at Makassar Industrial Area (KIMA) is refers to Resistivity of Rocks and Materials Table (Telford, 1990). Identification results of the cross section are as follows:

Table 1. Resistivity of Rocks and Materials

Material	Resistivitas (Ω m)
Udara (Air)	~
Pirit (Pyrite)	0.01-100
Kwarsa (Quartz)	500-800000
Kalsit (Calcite)	1×10^{12} - 1×10^{13}
Garam Batu (Rock salt)	$30 \cdot 1 \times 10^{13}$
Granit (Granite)	200-10000
Andesit (Andesite)	1.7×10^2 - 45×10^4
Basal (Basalt)	200-10.0000
Gamping (Limestone)	500-10000
Batu pasir (Sandstone)	200-8000
Batu tulis (Shales)	20-2000
Pasir (Sand)	1-1000
Lempung (Clay)	1-100
Air tanah (Ground water)	0.5-300
Air asin (Sea water)	0.2
Magnetit (Magnetite)	0.01-1000
Kerikil kering (Dry gravel)	600-10000
Aluvium (Alluvium)	10-800
Kerikil (Gravel)	100-600

ERT Method Results

Line 1

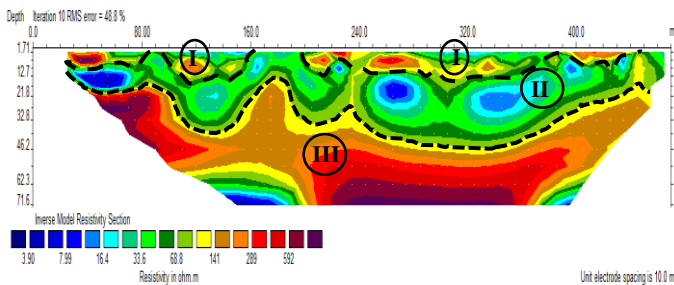


Figure 8. Line 1 ERT 2D Section

Figure 8 is 2D section obtained from RES2DINV. Lower resistivity range (II) given at $1.5 - 10 \Omega$ m with depth of $\pm 0 - 20$ m interpreted as alluvial layer. Middle resistivity range (I) given at $11 - 89 \Omega$ m interpreted as limestone intersects with volcanic tuff with depth $\pm 0 - 30$ m. Higher resistivity range (III) given at $> 90 \Omega$ m with depth range $\pm 0 - 6$ m and $\pm 20 - 70$ m interpreted as limestone which has hard physical properties.

Line 2

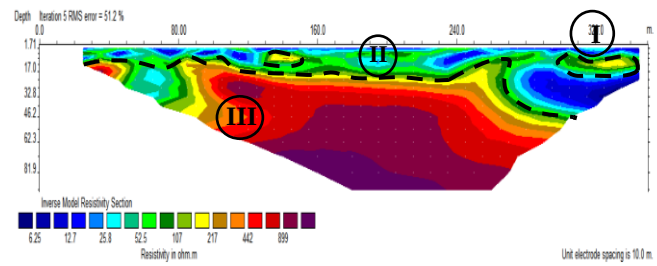


Figure 9. Line 2 ERT 2D Section

Figure 9 is 2D section obtained from RES2DINV. Lower resistivity range (II) given at $1.5 - 10 \Omega$ m with depth of $\pm 0 - 10$ m and $\pm 0 - 30$ m interpreted as alluvial layer. Middle resistivity range (I) given at $11 - 89 \Omega$ m interpreted as limestone intersects with volcanic tuff with depth $\pm 2 - 30$ m. Higher resistivity range (III) given at $> 90 \Omega$ m with depth range $\pm 3 - 81$ m interpreted as limestone. Limestone which intersect to volcanic tuff is from Camba Formation (Tmc).

Line 3

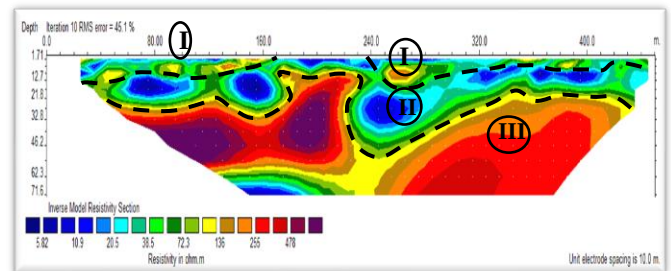


Figure 10. Line 3 ERT 2D Section

Figure 10 is 2D section obtained from RES2DINV. Lower resistivity range (II) given at $1.5 - 10 \Omega$ m with depth of $\pm 0 - 15$ m and $\pm 10 - 35$ m interpreted as alluvial layer. Middle resistivity range (I) given at $11 - 89 \Omega$ m interpreted as limestone intersects with volcanic tuff with depth $\pm 0 - 30$ m. Higher resistivity range (III) given at $> 90 \Omega$ m with depth range $\pm 0 - 10$ m and $\pm 10 - 70$ m interpreted as limestone.

GPR Method

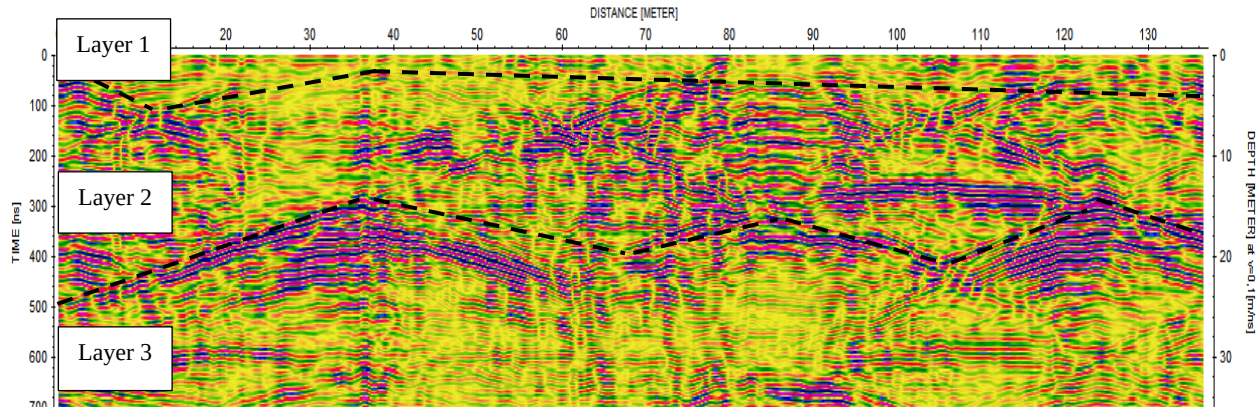


Figure 11. GPR 2D Section (Radargram)

Figure 11 is GPR 2D result that represent rock layers. From the result above, there are 3 (three) layers. Based on GPR result that represent subsurface conditions at ERT Line 1 – 3 obtained 3 (three) layers based on amplitude variation. After integration with ERT data, layer 1 with depth $\pm 0 - 6$ m interpreted as limestone intersects with volcanic tuff, layer 2 with depth $\pm 6 - 16$ m interpreted as alluvial layer, and layer 3 with depth $\pm 16 - 35$ m interpreted as limestone.

Outcrop Identification

Based on our field observation at work area, we found outcrop at excavated zone. That outcrop identified as soil at first layer and limestone at second layer with depth ± 60 cm and estimated continue to ± 6 m. This limestone outcrop indicated as the limestone layer which intersects with volcanic tuff. This outcrop validates ERT and GPR result that the limestone layer was found at top layer of the rock layers. Based on all those results above, subsurface conditions can be described as 3 (three) layers (Table 2).

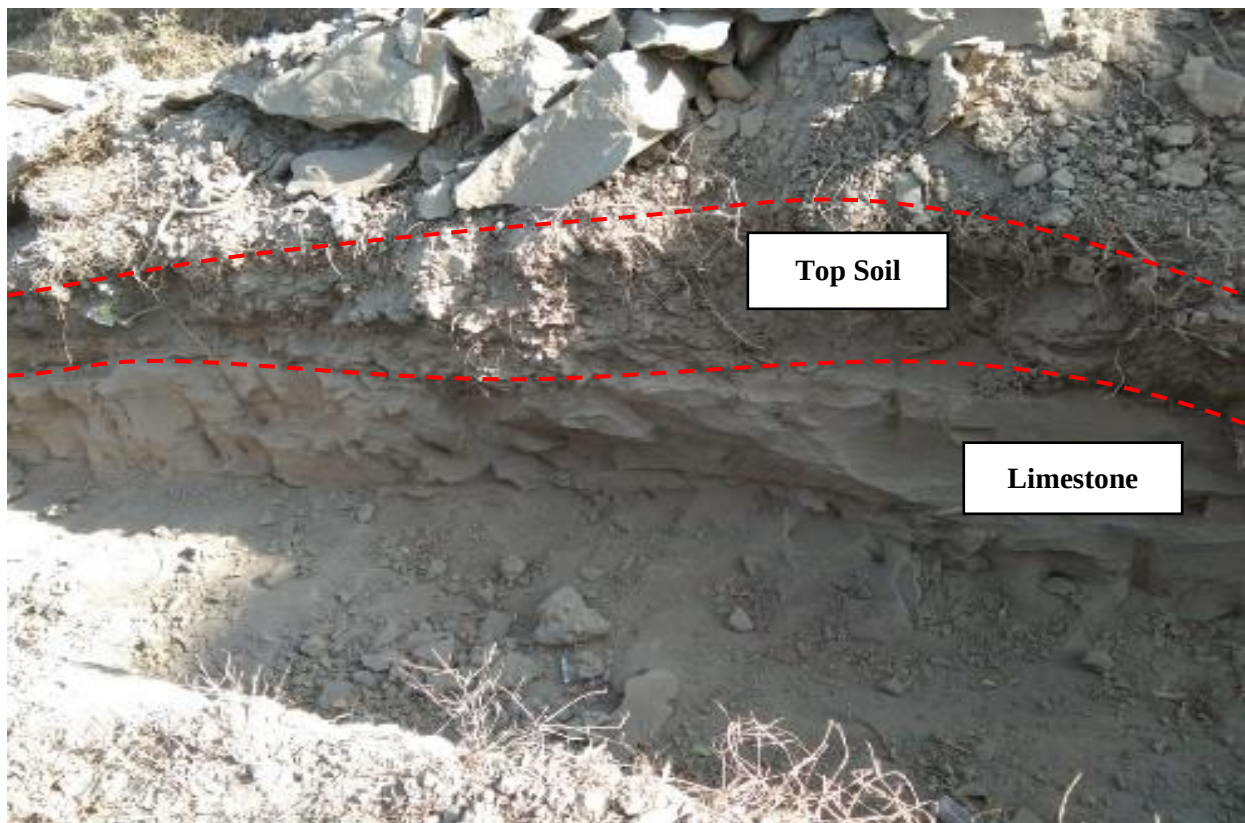


Figure 12. Limestone Outcrop

Table 2. Final Result

Layer	Depth (m)	Resistivity (Ωm)	Interpreted Rocks
1.	0 – 6	11 – 89	Limestone and Volcanic Tuff
2.	6 – 16	1.5 – 10	Alluvial
3.	16 – 35	> 90	Limestone

CONCLUSION

From the results of ERT and GPR methods, we can conclude that:

1. Material contained in work area is indicated as alluvial layer in the form of sandy clay with depth $\pm 6 - 16$ m and resistivity value $\pm 1.5 - 10 \Omega\text{m}$, marine sediment deposits in the form of limestone intersect with volcanic rocks with depth $\pm 0 - 6$ m and resistivity value $\pm 11 - 89 \Omega\text{m}$, limestone with depth $\pm 16 - 35$ m and resistivity value $> 90 \Omega\text{m}$.
2. Limestone outcrop was found in work area. Based on that outcrop, limestone was found at depth of ± 60 cm and estimated continue to ± 6 m depth. This indicates that ERT and GPR results are suitable with the field conditions.
3. Based on the result of ERT and GPR methods that can represent the subsurface rock layers and rocks type well, HDD planning and activities will be optimal.
4. This combination of ERT and GPR methods purposed to produce a more detailed imaging of a layer.

REFERENCE

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