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Integrated Geophysical and Geotechnical Analysis to Subsurface Lithology Overview at ITERA Dormitory Site, Lampung, Indonesia

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Abstract

The Student Dormitory is a gathering place for most new students at ITERA. For disaster mitigation, it is necessary to conduct geophysical and geotechnical surveys. Geophysical and geotechnical surveys are conducted to describe the subsurface lithology. The purpose of this study is to identify the subsurface of the Dormitory building so that it can be determined which buildings have the potential for geological hazards. The methods used are geomagnetic, geoelectric and geotechnical methods. The results obtained are that High and low magnetic anomalies are related to the thickness of the lithology. This is also justified by the results of geoelectric using resistivity cross-sections. The thickness of this lithology is related to the level of building security. TB4 has the highest security based on magnetic and geoelectric data. Meanwhile, TB1 has the lowest security based on subsurface conditions.

Introduction

The Sumatra Institute of Technology (ITERA) is the only public technological institute on the island of Sumatra that provides student dormitory facilities. Currently, ITERA has five dormitory buildings with a capacity of approximately 1,000 new students from outside Lampung Province. Meanwhile, the number of new students from outside Lampung enrolled at ITERA each year reaches around 2,000 students. To meet the housing needs of at least 50% of the student population, an additional five dormitory buildings are required.

Before construction begins, preliminary investigations are required using geophysical [1,2,3] and geotechnical [4,5] methods such as geoelectrical [4-11], geomagnetic [12-13], and penetration tests [14-17]. The geoelectrical and geomagnetic survey aims to provide an overview of the subsurface layers to ensure the safety of the building against potential geological hazards [18-27]. On the other hand, the penetration test is used to determine the depth and characteristics of the hard soil layer, which is essential for planning the foundation of the building [28-30].

A previous study conducted by Rizka et al. [31] at the dormitory site utilized the time-lapse resistivity method (4D resistivity) to analyse subsurface fluid dynamics, particularly groundwater. The results showed variations in aquifer thickness between different seasons. However, the study focused solely on the use of geoelectrical methods for aquifer identification. The current research focuses on identifying the hard soil layer and assessing the potential geological hazards in the dormitory area. To achieve this, a combination of three methods is employed: geoelectrical, geomagnetic, and Cone Penetration Test. The geoelectrical and geomagnetic methods are used to generate subsurface images because the subsurface consists of several rock lithologies that can be identified using magnetic susceptibility and resistivity parameters. Geomagnetic is used to describe large scales while geoelectric is used to describe small scales. The CPT is specifically used to determine the presence and depth of the hard soil layer.

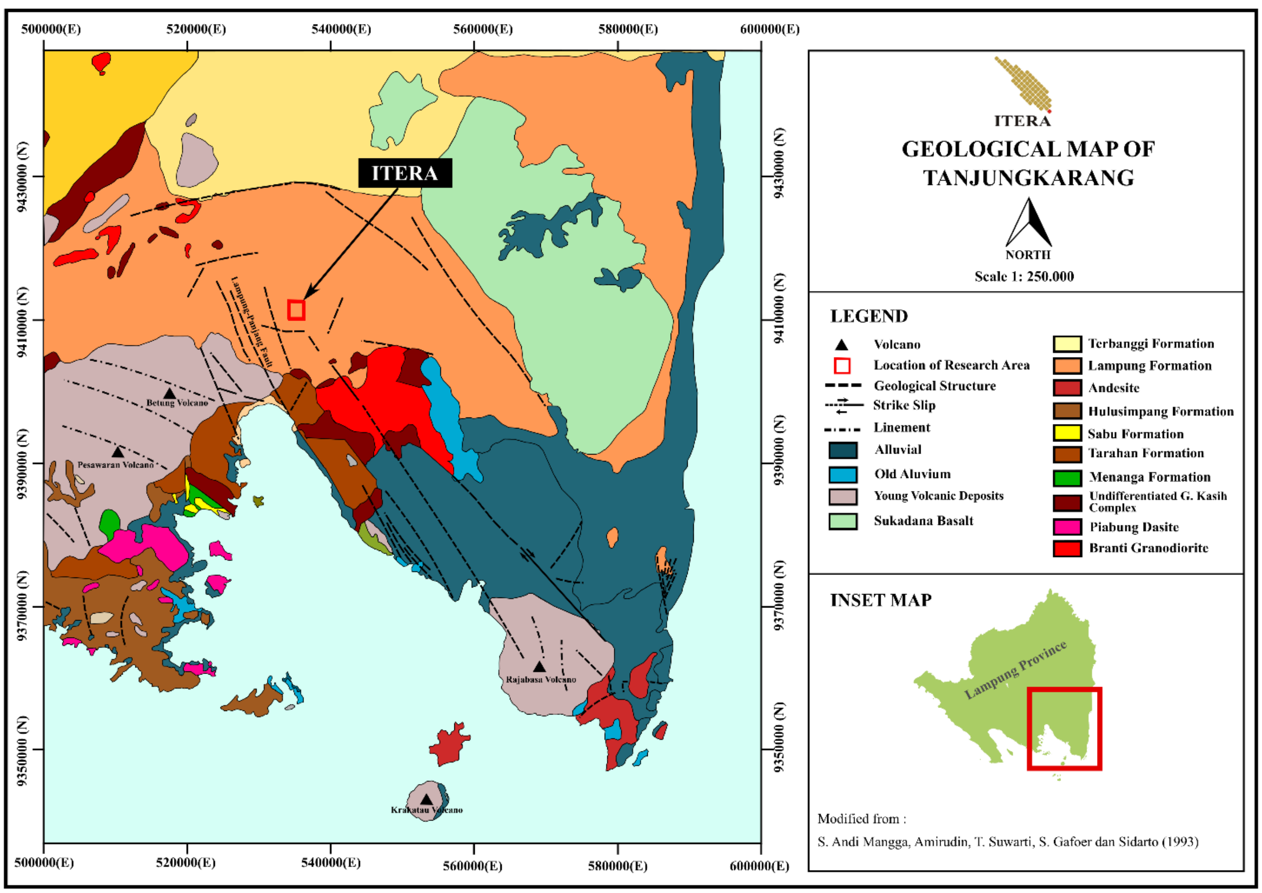

Figure 1. Geological map of the study area [32]

Geological Conditions

Based on the geological map in Figure 1 by Mangga et al., the research area is part of the Quaternary Tuff Lampung (QTL) Formation. This formation extends across the regions of Pesawaran, Bandar Lampung, South Lampung, and East Lampung. QTL covers a wide area, characteristic of a volcanic deposit. It is predominantly composed of rhyolitic tuff, tuffaceous sand, and tuffaceous clay. The tuff layer is the main focus of this research.

Basic Theory of Methods

The magnetic method is a geophysical method used to describe the subsurface lithology using magnetic parameters. Initially, this method measures the total magnetic intensity. This total magnetic intensity consists of the main magnetic field, the outer magnetic field and magnetic anomalies. This total magnetic intensity is subjected to two corrections, namely the International Geomagnetic Referee Field (IGRF) correction and the daily diurnal correction. The IGRF correction is to eliminate the main magnetic field, while the daily diurnal correction is to eliminate the outer magnetic field. The result of these two corrections is a magnetic anomaly. The anomaly is then mapped into a magnetic anomaly map. This anomaly map is a subsurface magnetization map. At the time of magnetic printing, this magnetization is converted into magnetic susceptibility using the formula:

$$\chi = \frac{M}{H} \tag{1}$$

χ: magnetic susceptibility (SI), M: magnetization (nT), H: magnetic field (nT)

The geoelectric method is a geophysical method used to describe subsurface lithology using electrical parameters. This geoelectric method begins by injecting current into the earth, after which the electrical voltage is measured. From the current and voltage, the rock resistance is obtained. This resistance still depends on the dimensions or volume. Therefore, the rock resistivity is sought using the formula:

$$R = \frac{V}{I} \tag{2}$$

$$R = \rho \frac{l}{A} \tag{3}$$

$$\rho = k \frac{V}{I} \tag{4}$$

R: rock resistance (Ω), V: electric voltage (V), I: electric current (A), ρ; rock resistivity (Ωm), k: geometric factor (m).

Cone Penetration Test produces cone pressure with or without friction resistance which is correlated with soil parameters, namely undrained shear strength, and soil compressibility so that it can estimate the type of soil layer. To classify soil there are many types of classification, one of which is from [19]. In this classification (Figure 2), the data plot between the value of qc (Conus Resistance) and FR (Friction Ratio). The plot results show the type of soil in the tested area.

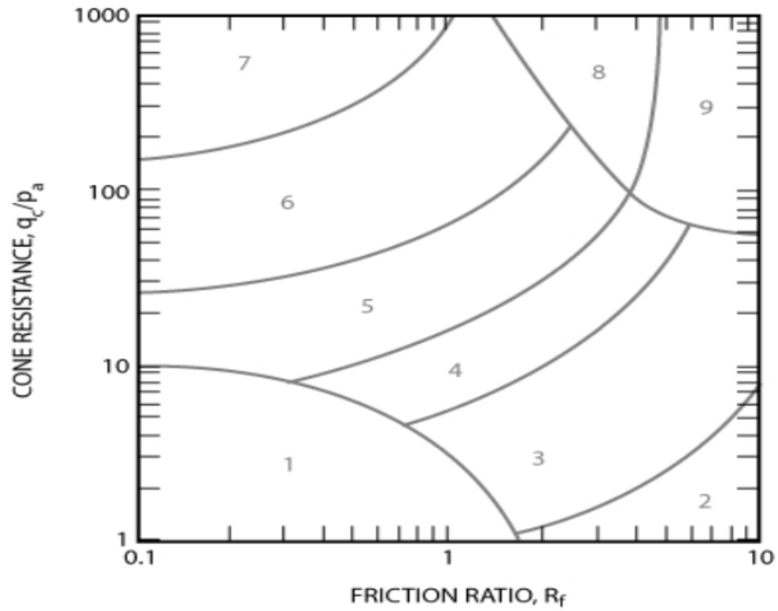

Figure 2. Graph of soil type classification based on the relationship qc and Fr [33]

Based on the type of soil classification each zone on the graph can be identified as the soil type as described in Table 1.

Table 1. Soil type zone based on qc and Fr relationship [33]

Zone	Soil Behavior Type
1	Sensitive, fine-grained
2	Organic soils – clay
3	Clay – silty clay to clay
4	Silt mixtures – clayey silt to silty clay
5	Sand mixtures – silty sand to sandy silt
6	Sands – clean sand to silty sand
7	Gravelly sand to dense sand
8	Very stiff sand to clayey sand
9	Very stiff fine-grained

Experimental Method

The research location is located in the Sumatran Institute of Technology Student Dormitory, Ryacudu Canal Street, Wayhui, Jati Agung, South Lampung (Figure 3). Geomagnetic measurements were carried out using a Precision Proton Magnetometer GEM GSM-19T made in Canada. The parameter measured on the device is the total magnetic intensity (nT). When measuring using this tool it is required to be away from motorized vehicles, electric poles and materials containing iron such as bridges and buildings. The magnetic measurements were carried out at as many as 30 points with a measurement space of 50 meters for each point. Magnetic point measurements cover TB1, TB2, TB3, TB4, and TB5 dormitories.

Geoelectric measurements use two tools, namely the Naniura NRD-300 made in Indonesia for VES measurements and the ARES-GF Instrument made by Ceczh for ERT measurements. ERT is used to justify VES results. For geoelectrical measurements, VES uses the Schlumberger configuration and ERT uses the Wenner-Schlumberger configuration. For the VES method, the track length is 300 meters while the ERT method uses a track length of 235 meters with an electrode spacing of 5 meters. In addition, there are also CPT measurements at as many as 3 test points in the TB5 Dormitory development area. The geomagnetic survey design was made as in Figure 3 because it covered the entire Dormitory area and the ERT geoelectric measurements were placed in the middle of the Dormitory.

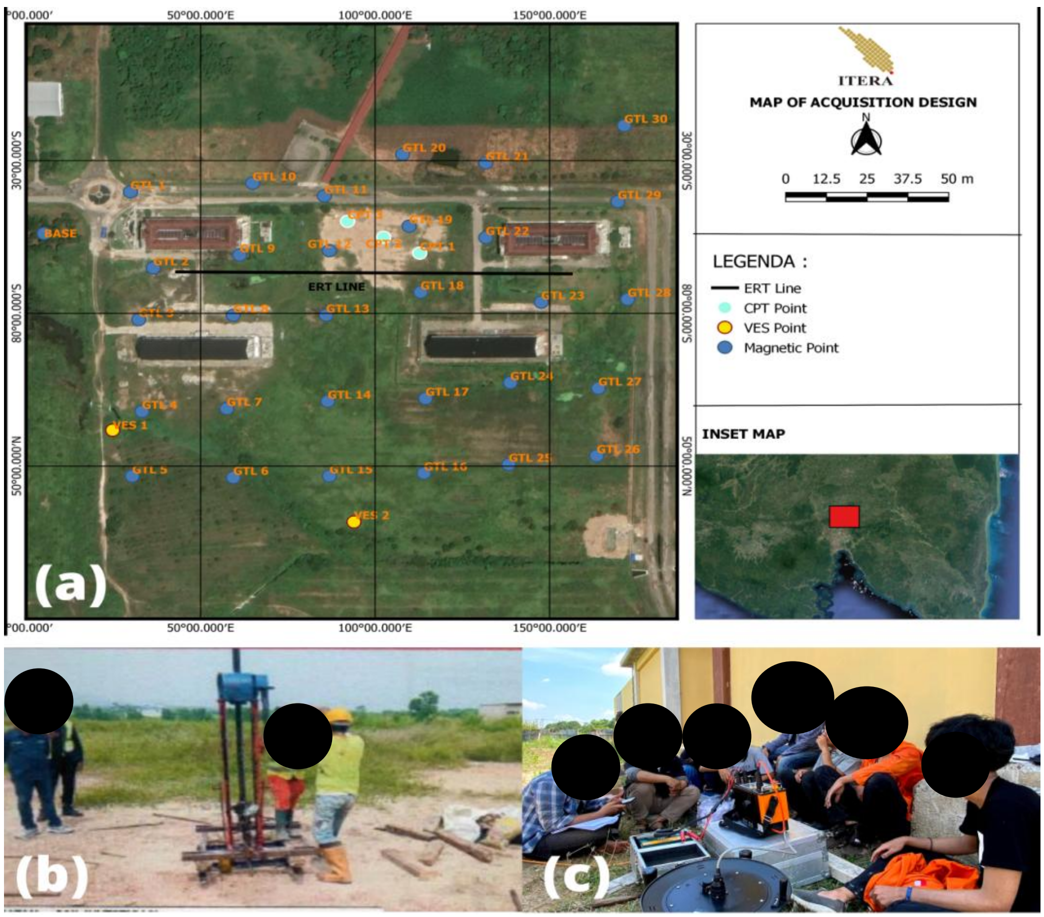

Figure 3. (a) Research data acquisition survey design (b) The process of CPT data probing (c) ERT Acquisition with Automatic Resistivity (Ares) Equipment

Results and Discussion

The TMI Map results can be seen in Figure 4a. The TMI map was then Reduced to Pole to obtain the map in Figure 4b. It can be seen in Figure 4b, the highest subsurface magnetization value is in TB4, then the lowest value is in TB1. This magnetization value is related to the density level of magnetic minerals below the surface [34,35].

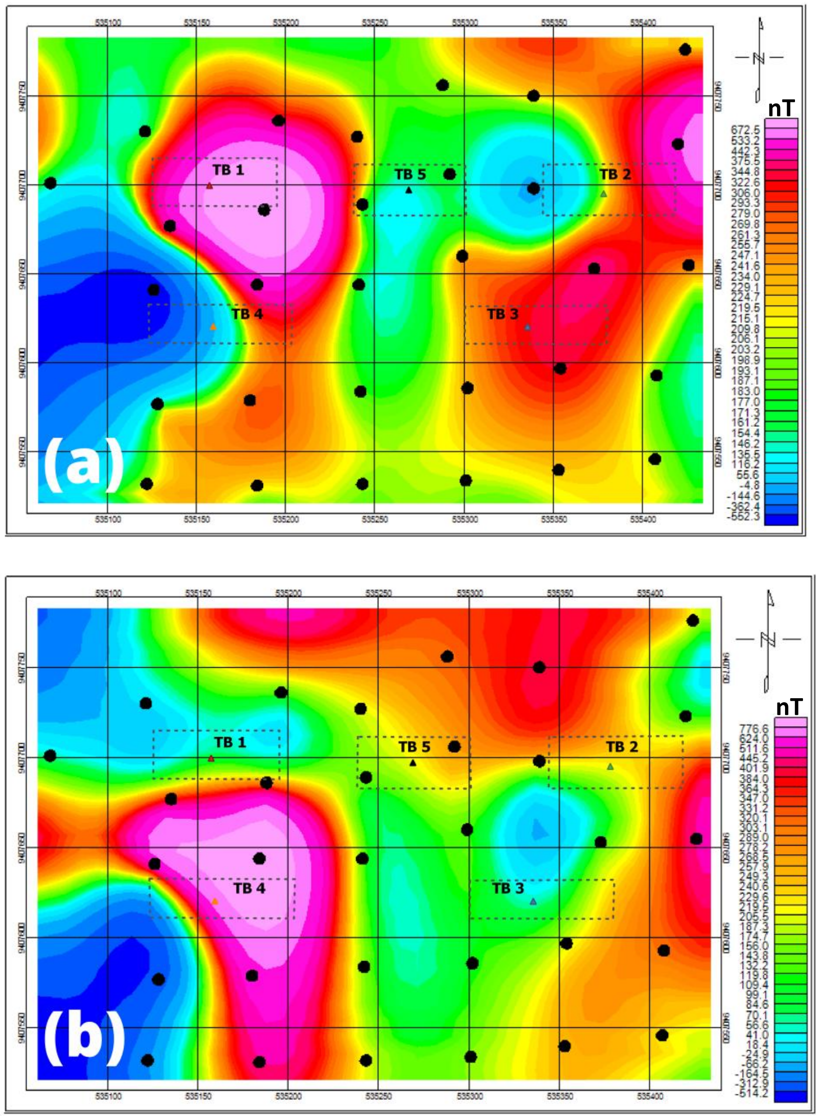

Figure 4. (a) TMI Map (b) RTP Map. Color bar is value of anomaly magnetic (nT)

After being clarified using anomaly separation, the residual anomaly map is obtained in Figure 5. If the low and high anomalies are associated with variations in subsurface rock density, then the low anomaly area indicates a zone of subsidence due to unconsolidated subsurface materials. Therefore, TB1 is considered the most unsafe structure, while TB4 is the safest.

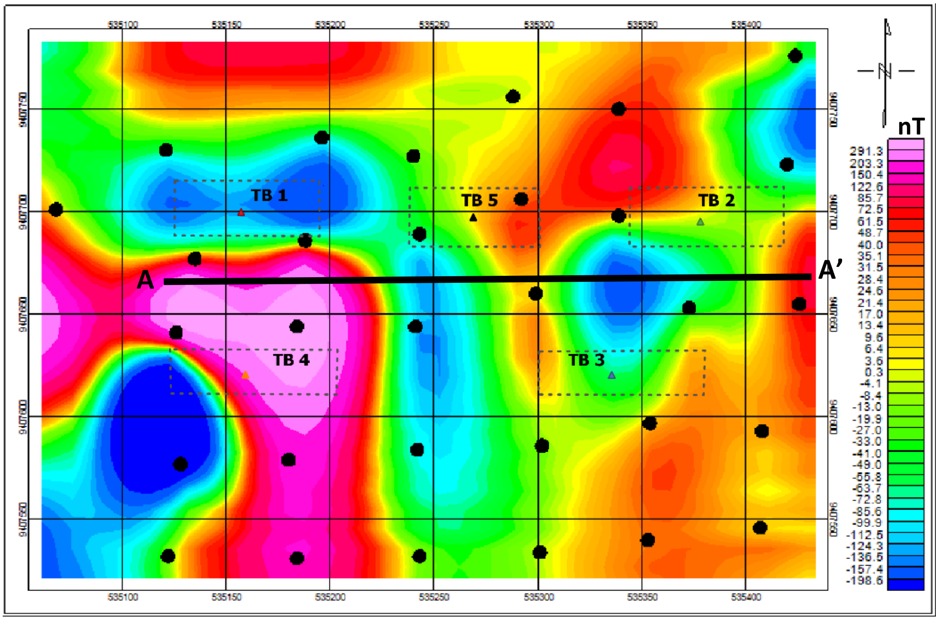

Figure 5. Residual Anomaly Map

To clarify the subsurface under the Student Dormitory building, forward modelling was performed on the residual magnetic data. The cross-section in Figure 5 was then modelled. The results of the subsurface model can be seen in Figure 6. It can be seen in Figure 6 that high magnetization values correlate with the thickness of the sandy tuff layer and low magnetization values correlate with the thickness of the clayey tuff layer. The lithology produced in Figure 6 is reinforced by the results of VES 1. While the results of VES 2 are different. The results of Electrical Resistivity Tomography (ERT) in Figure 7 also show that thick clay tuff is found in the central zone.

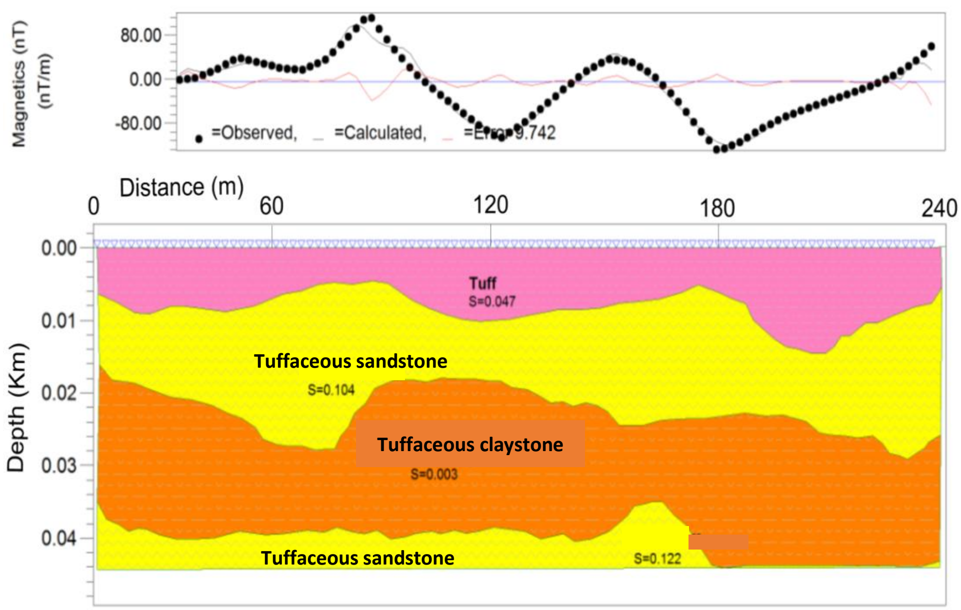

Figure 6. Profile 2D slice. Position A = 0 m to A'=240m

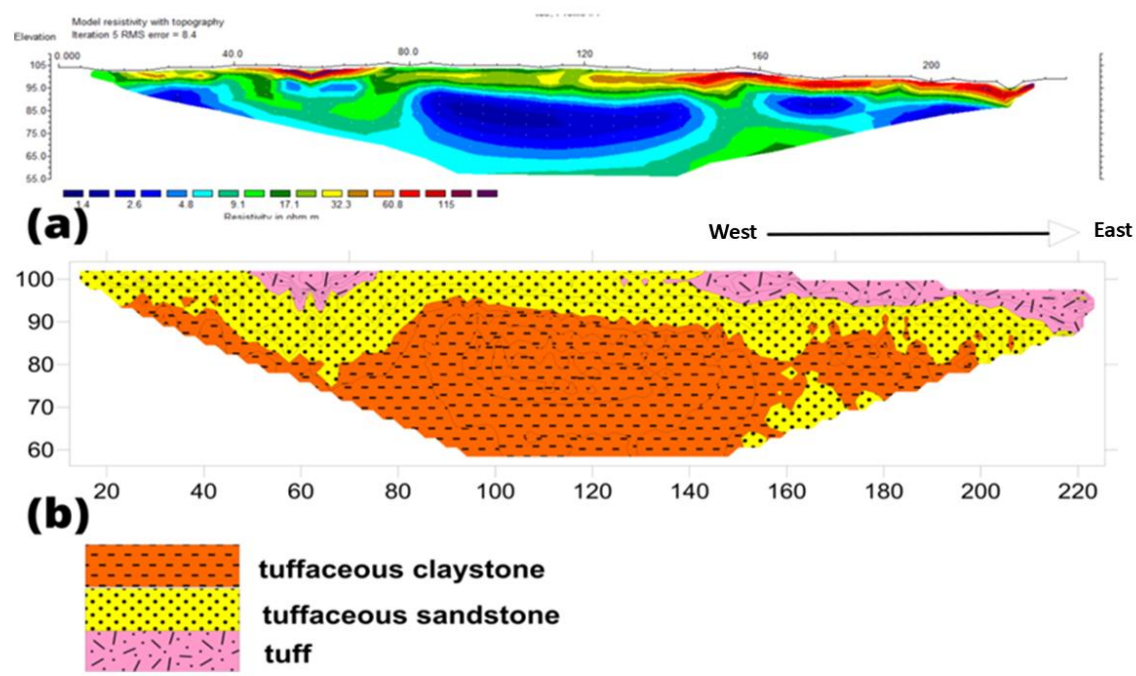

Figure 7. ERT cross section

After that, CPT is used to determine the hard soil layer. The hard soil layer is detected with a cone resistance (qc) of 200 kg/cm2. Based on the CPT results, it was found that the hard soil layer at CPT1 was around 2.6m, CPT2 was around 3.2 m and CPT 3 was around 4.8 m. From the three CPTs, it is estimated that the hard soil layer starts to be the same for each CPT at a depth of 5 meters.

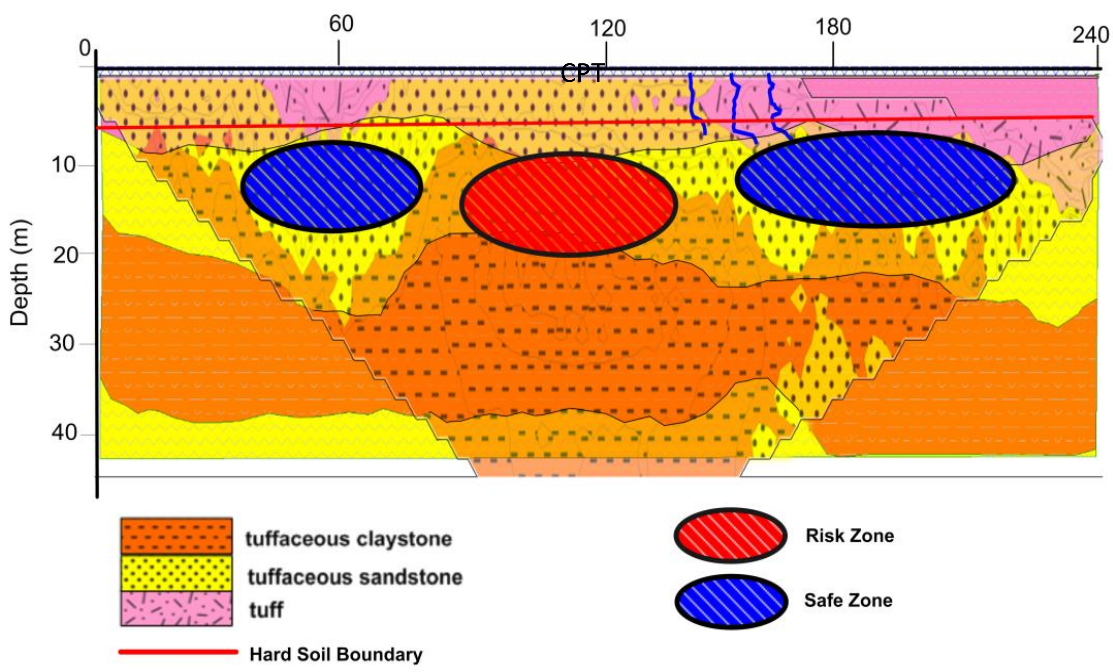

Figure 8. Magnetic Modelling Slice 1 AA', ERT, and CPT Correlation

Next, the determination of the subsurface zone is carried out, the results of Magnetic Forward Modelling, ERT cross-section and CPT results are combined and can be seen in Figure 8. Based on CPT after 5 meters is a hard layer. However, if analysed with geophysical data, namely magnetic and geoelectric, it can be seen that below the hard soil layer is a layer of sandy tuff and clay tuff. From the combination of the cross-section, it can be identified that if below the hard soil layer is sandy tuff, then the zone is safe. However, if below the hard soil layer is clay tuff, then the zone is dangerous. The clay tuff zone is considered hazardous due to its low soil bearing capacity and tendency to collapse easily when exposed to water. This zone is located near the Lampung Panjang Fault, as shown on the geological map (Figure 1), so it poses a significant geological hazard in the event of an earthquake.

Conclusion

Based on the results of magnetic and geoelectric analysis, the subsurface lithology of the Dormitory building is generally tuff, sandy tuff and clayey tuff. When viewed from the potential geological hazards that occur, the TB 1 building is the most dangerous building because its subsurface has a thick layer of clayey tuff compared to other buildings. The safest building is TB4 which has thicker sandy tuff than other TB.

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