

Georadar and geoelectricity method to identify the determine zone of sliding landslide

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Abstract. The aim of this research is to determine the contrast between the sliding plane by observing the parameters of rock types, fractures, and faults that could potentially land slides in Bandar Baru, Lampung Barat, Indonesia by both methods of georadar and geoelectricity. This research uses radar reflection profiling configuration for georadar and dipole-dipole configuration for geoelectricity. For georadar data processing has been done with Reflexwave software and for geoelectricity, data processing has been done with Earthimager 2DINV software to interpret subsurface section. Results of research by both methods of georadar and geoelectricity shows the area of contact between the sand stone with resistivity value of 200–1449 Ωm and clay stone with a resistivity value of 32–100 Ωm at the limit depth of 9 m as a potential zone of sliding landslides where the physical properties of clay stone easily derail massive material on it.

Keywords: fault, fracture, geoelectricity, georadar, landslide

1. Introduction

Studies of geophysical exploration in recent years have been progressing in electronics technology, producing new methods or electronic devices and affecting the development of radar equipment used in explorations. GPR method (Ground Penetrating Radar) is a new approach that is applied in this study. Tantamount to the seismic method in exploration using wave sources—either the natural wave coming from the earth itself or the artificial ones that are intentionally generated and inserted through the earth's surface to be captured by itself—the method of GPR employs radar pulses that are transmitted, reflected, and scattered by subsurface structures and anomalies. Physical parameters including magnetic permeability, electrical permittivity, and conductivity determine the characteristics of the electromagnetic wave radiation in the earth structure which will be forwarded, scattered, and reflected. The excellence of georadar method, among others, is the accuracy in detecting or mapping the subsurface structures such as ground water exploration, pipeline, fossils of ancient archaeology, exploration of minerals, and so on [4].

Geoelectric method is also a commonly used approach in geophysical exploration to investigate the subsurface structures based on the differences of rock resistivity [8]. Both of these methods are known as environmentally friendly approaches and quite good in imaging shallow layers.

West Lampung Province is an area that has a high level of mass movement hazard, traversed by Sumatra active fault lines of Semangko segments which make Sumatra island vulnerable areas of disasters, such as earthquakes and landslides) [5].



Based on these descriptions, this study takes advantage of georadar and geoelectric method to see the contrast between the sliding plane by observing the parameters of rock types, fractures, and faults that could potentially cause landslides in Bandar Baru, Lampung Barat, Indonesia.

1.1. Landslide

Landslides are formed by movements or destruction of rocks, soil, or mixture materials, shifting down or out of the slopes. The process of landslides begins with the water soaking into the soil that will add weight to the ground. If the water penetrating the soil acts as a watertight sliding plane, the ground becomes slippery, and the soil weathering on it will divert to follow the slope and eventually out of the slopes.

The soil movements that could potentially cause landslides are classified into five categories based on their mechanism and material types, i.e., falling, toppling, sliding (slump/rotational sliding and lateral sliding), spreading, and flowing [7].

1.2. Georadar

In principle, GPR method works by using signal reflection as shown in Figure 1. GPR system has a transmitter circuit connected to the pulse source and a receiver circuit linked to a signal processing unit. The transmitter circuit will generate an electrical pulse to form PRF (pulse repetition frequency), energy, and certain duration. The antenna will emit pulses into the ground, where the pulse will experience attenuation and signal defect during their propagation [1]. Homogeneous soil will reflect weak signals. If the pulse has struck inhomogeneities on the ground, then there will be reflected signals to the receiving antenna. Furthermore, these signals will be processed by the receiver circuit. By measuring the time interval between the pulse transmission and acceptance, the depth of the object can be determined. In this time interval, pulses go back and forth from the antenna to the object and back to the antenna. If t describes the interval, v represents the speed of electromagnetic wave propagation in the soil, and h denotes the depth of objects, then the equation can be written as follows:

$$h = \frac{1}{2}tv \quad (1)$$

The velocity of electromagnetic wave propagation must be known in order to determine the depth of the detected object. The propagation speed depends on the speed of light in the air and the relative dielectric constant of the propagation medium, written as follows:

$$v = \frac{c}{\sqrt{\epsilon_r}} \quad (2)$$

1.3. Geoelectricity

Geoelectricity is one of the geophysical methods that utilize the resistivity properties to investigate the circumstances under the earth's surface. This approach is carried out by injecting electric currents through two electrodes, penetrating into the earth. Subsequently, the potential difference formed between them and two additional potential electrodes in another place is observed to reflect the circumstances beneath the earth's surface. The concept of electrical current propagation in a homogeneous isotropic medium is used in this method, where equal values of electric currents move in all directions. Based on this assumption, if there is any distinguished anomaly meeting the amount of the flowing current, it is probably caused by the difference of the irregular resistivity. This anomaly will be used then to reconstruct the state of the subsurface geology.

When the two electrodes with the current I are injected into the homogeneous isotropic soil/rock medium with a certain (finite) distance, then the potential at points near the surface will be influenced by the two electrodes of the stream, so that the equipotential generated from two point sources is the sum of the potential caused by the two electrodes.

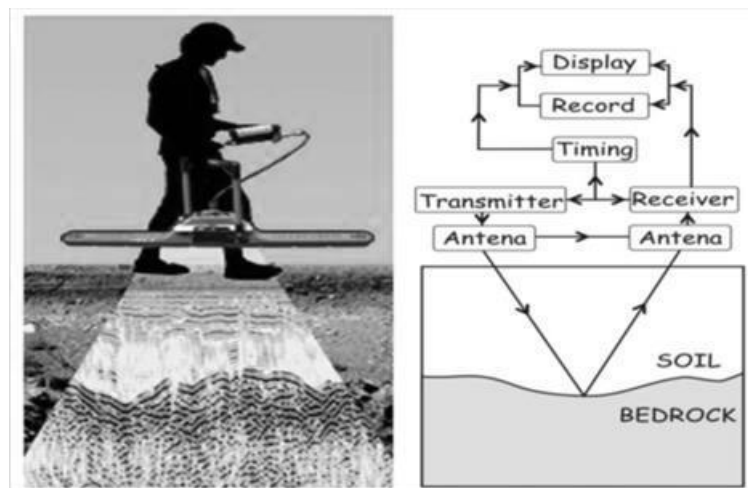


Figure 1. Working principles of GPR method [3].

If a cross section through the source C1 and C2 were made, the visible pattern of the equipotential field distribution would be as shown in Figure 2. To determine the potential difference between two points generated by two current electrodes C1 and C2, other two potential electrodes of P1 and P2 are placed near the sources as depicted in Figure 2.

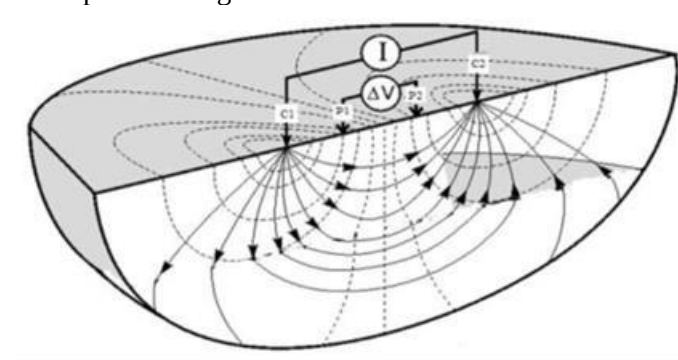


Figure 2. The configuration of the current electrodes and the potential electrodes on the surface of a homogeneous isotropic medium [6].

2. Research Method

This research was conducted in Bandar Baru, Lampung Barat, Indonesia (04°57'34.1"–04°57'36.3"S latitude and 104°03'23.6"–104°03'26.4"E longitude). A set of GSSI (*Geophysical Survey Systems Inc.*) SIR-20 georadar equipment and Geoelectricity Multichannel Supersting R8 were used to attain the objectives of this study.

Data for georadar method were acquired using an antenna with a frequency of 200 MHz along the trajectory measurements, while the geoelectricity approach was performed by dipole-dipole configuration with an interelectrode distance of six meters. The maximum line length measurement was adapted to the topography of the study area. Measurements of line and area for georadar and geoelectricity methods are the same (Figure 3).

Reflexwave software was used for georadar data processing, whereas *Earthimager 2DINV* module was used for geoelectricity data processing. For georadar, data based on the radargram analysis of subsurface rock types were interpreted through each radar facies as shown in Figure 4. Furthermore, based on Table 1, the resistivity value was adjusted for geoelectricity data.

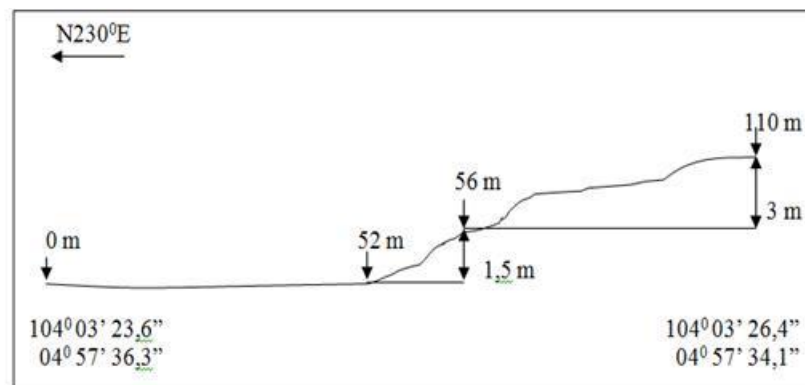


Figure 3. Line and area of georadar and geoelectricity measurements.

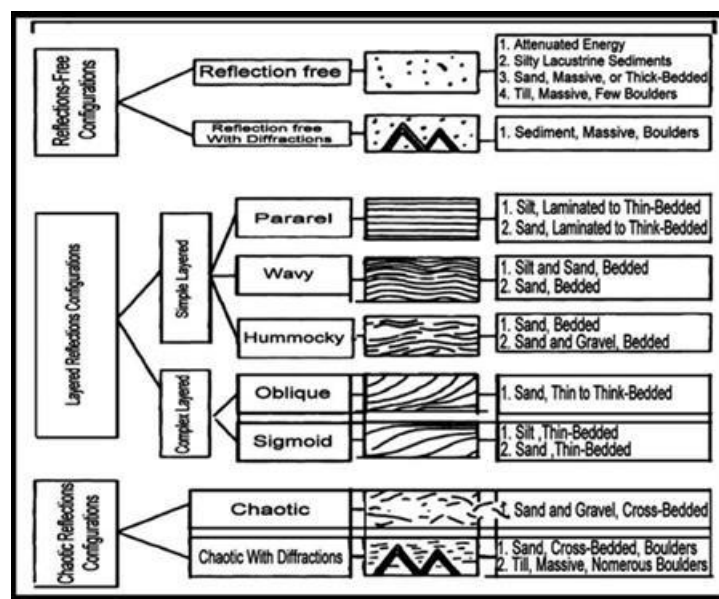


Figure 4. Determination of subsurface sediment types [2].

3. Results and Discussion

Georadar data measurements with 200 MHz frequency transducer were carried out by passing the Semangko segment of Sumatra fault, and the measurement position was determined using GPS Garmin 76 CSX. The results are shown in Figure 5. Measurements with geoelectric method were performed on the same trajectory with the georadar approach using dipole-dipole configuration type on an interelectrode of upto six meters. The results are depicted in Figure 6.

3.1. Georadar

Topographic measurements on track 2 generate the form of low undulating hills with a lithological condition of sandy loam surface. This trajectory is the main fault lineament of Semangko segment. At varying depths of 0–9 m, layered reflections in the form of simple layered configurations of hummocky/subparallel were found, instead of constantly intermediate to high possibilities such as sand and gravel. At a depth of 9–12 m, reflection-free configurations were obtained in the form of low-amplitude possibilities of clay, sand, fine to coarse-grained sediments (chewy to solid level).

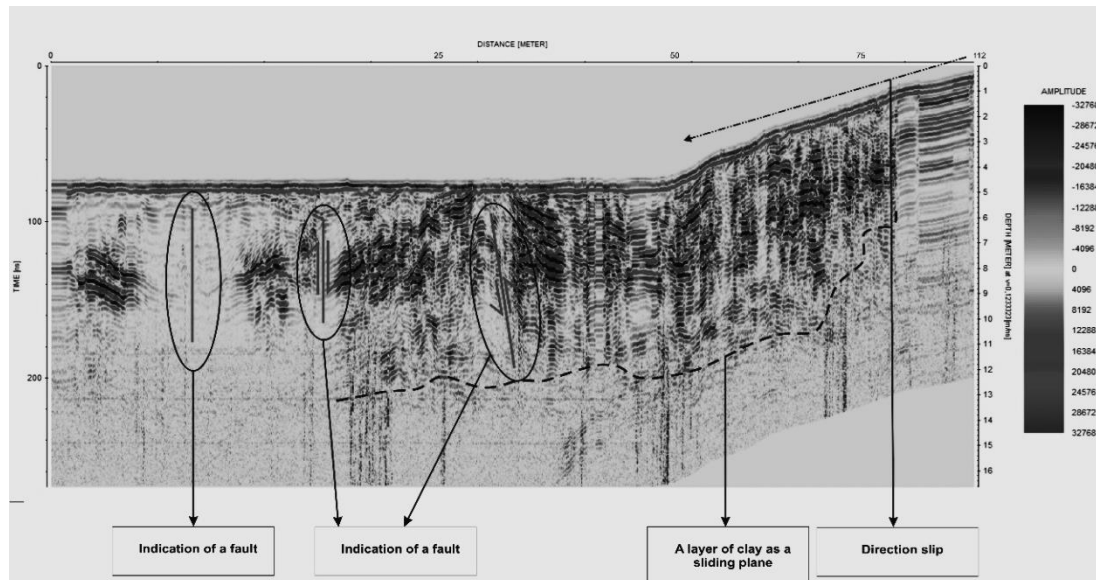


Figure 5. The results of georadar data processing on line and their interpretation.

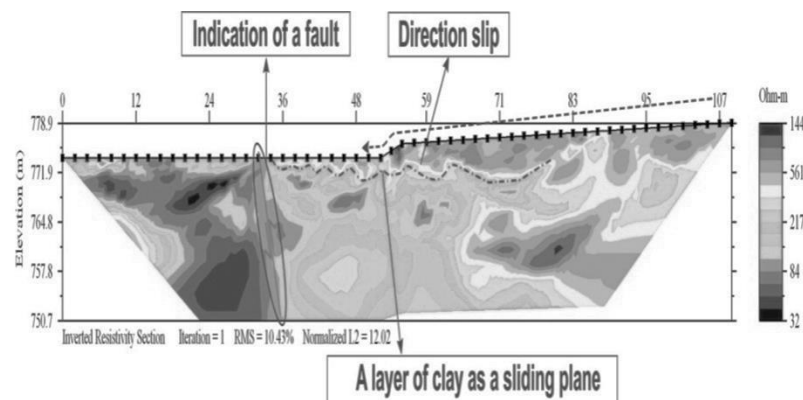


Figure 6. The results of geoelectricity data processing on line and their interpretation.

3.2. Geoelectricity

In this layer, the dark–light blue range with a resistivity value of 32–100 Ωm were estimated to consist of clay, while green–red line with a resistivity value of 200–1449 Ωm were estimated to consist of sandy and igneous rocks. Data processing of geoelectric and georadar indicate a boundary between the sandstone and clay. This clay layer under the sand structure can function as a sliding plane where the sandstone rock absorbs water so that the weight increases, especially during the rainy season. Besides, the trajectory profile sketch shows the angle of 4.45° , indicating that the soil easily shifts from its original position. Georadar and geoelectric data processing also indicate the presence of a fault, and in case of rain, the rocks and sand can be slipped into the area by cesarean formed clays.

Based on the results, discussion, as well as the geological maps, this area is prone to ground movements. On account of the ground motion trajectory profile, this region can be included on the type of soil translational movement with a characteristic of flatly or gently sloping corrugated ramps.

4. Conclusion

Georadar measurement results state that at varying depths of 0–9 m, layered reflections in the form of simple layered configurations of hummocky/subparallel were found, instead of constantly intermediate to high possibilities such as sand and gravel. Mean while, at a depth of 9–12 m, reflection-free configurations were obtained in the form of low-amplitude possibilities of clay, sand, fine to coarse-

grained sediments (chewy to solid level). The regional subsurface structure of Bandar Baru, Lampung Barat, Indonesia, is composed of clay stone with resistivity values of 32–100 Ωm , as well as sandy rocks and igneous rocks (200–1449 Ωm), according to the measurement by geoelectricity method. Some indications of a weak zone or fault were encountered at the red line on the data interpretation. The depth limit of 9 m is considered as a potential zone of sliding landslides where the physical properties of clay stone easily derail massive materials on it.

Acknowledgment

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References

- [1] Annan A P. 2003. Ground Penetrating Radar Principles, Procedures & Applications, Sensor & Software Inc., 1040 Stacey Court, Mississauga, ON L4W 2x8 (Canada).
- [2] Beres M, and Haeni F P. 1991. Application of Ground Penetrating Radar Methods in Hydrogeologic Studies, *Ground Water*. 3(29):375–386.
- [3] Ervan M. 2013. The Basic Theory of Ground Penetrating Radar, Puslitbang (Bandung).
- [4] Deniyatno. 2014. Sliding Field Identification Zone Landslide with Georadar Method. *Journal of Physics Applications*. 7(2).
- [5] Khairani Y, Sismanto, Ervan M, and Januar. 2014. Identification of Mass Movement Area in Liwa, Lampung Barat by Using Georadar and Geoelectricity Method. *International Conference on Physics (ICP 2014)*.
- [6] Knödel K, Krummel, H, and Lange G. 1997. Handbuch zur Erkundung des Untergrundes von Deponien und Altlasten, Band 3—Geophysik, Bundesanstalt für Geowissenschaften und Rohstoffe (Springer Verlag, 1063 S).
- [7] Vernes DJ. 1978. Slope Movement Types and Processes, in Schuster, R L , and Krizek, R J, eds., Landslides. Analysis and Control: National Research Council, Washington, D.C., Transportation Research Board, Special Report. 176:11–33.
- [8] Waluyo, 2012. Free Workshop Exploration Geophysics. Theory and Applications. The Geophysical Laboratory, Faculty of Mathematics and Natural Sciences UGM, Yogyakarta.
- [9] <http://www.subsurfacesurveys.com/pdf/Methods.pdf>.