Near-Surface Fault Structures of the Seulimuem Segment Based on Electrical Resistivity Model

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Abstract. The Great Sumatran Fault (GSF) system is arc-parallel strike-slip fault system along the volcanic front related to the oblique subduction of the oceanic Indo-Australian plate. Large earthquakes along the southern GSF since 1892 have been reported, but the Seulimuem segment at the northernmost Sumatra has not produced large earthquakes in the past 100 years. The 200-km-long segment is considered to be a seismic gap. Detailed geological study of the fault and thus its surface trace locations, late Quaternary slip rate, and rupture history are urgently needed for earthquake disaster mitigation in the future. However, finding a suitable area for paleoseismic trenching is an obstacle when the fault traces are not clearly shown on the surface. We have conducted geoelectrical measurement in Lamtamot area of Aceh Besar District in order to locate the fault line for paleoseismic excavation. Apparent resistivity data were collected along 40 m profile parallel to the planned trenching site. The 2D electrical resistivity model provided evidence of some resistivity anomalies by high lateral contrast. This anomaly almost coincides with the topographic scarp which is modified by agriculture on the surface at the northern part of Lamtamot. The steep dipping electrical contrast may correspond to a fault. However, the model does not resolve well evidences from minor faults that can be related to the presence of surface ruptures. A near fault paleoseismic investigation requires trenching across the fault in order to detect and analyze the geological record of the past large earthquakes along the Seulimuem segment.

1. Introduction

Aceh Province is the northern part of Sumatra passed by the Great Sumatran Fault (GSF) System. This active fault extends along 1900 km from the southern part of Sumatra to Andaman Sea. The fault is split up in several segments [1]. Most of the segments have shown their seismic activities within the last century with magnitudes above 6.0 and 7.7, except for the Aceh and Seulimuem segments in the northern part of Sumatra [2]. The seismic gap behave along these two segments for more long time could be suspected to be a silent enemy for thousands people in Aceh Province.

The slip rate of the two northern segments of the GSF are predicted 34 mm per year [3] [4] [2]. An intensive research of GPS geodetic observation crossing the Seulimuem segment suggest that the accumulated seismic moment in 170 years correspond to an earthquake of magnitude 7 [5]. Recently, in 2013 there were two events occurred close to the Seulimuem segment, i.e. Tangse (October 22nd) and Bener Meriah (July 2nd), with magnitude 5.6 and 6.2, respectively. Both events are considered small, but they caused many victims and heavy damaged.
In order to reduce risks affected by such disasters in the future, it is important to study earthquake history that has been occurred along the fault segment. By understanding the geologic structures of the fault, when the fault last displaced can be estimated and the magnitude of the earthquake that generated by the previous displacement can be predicted. By this so called paleoseismic study, it can also investigate periodicity of large earthquakes occurred along the fault.

Trenching is a common technique for investigating an active fault with a surface rupture, carefully excavating a series of trenches to reveal the structure and magnitude of the fault displacement. However, very few paleoseismic studies have been done on land in Aceh. Most of research on paleoseismic and paleotsunami studies have been reported from the coastal land in Aceh Province. The studies mostly focused on prehistoric earthquakes generated from the subduction area beneath the Indian Ocean [6] [7].

Since the Seulimuem segment is considered to be seismic gaps. An intensive geological study of the fault and thus its surface trace locations, late Quaternary slip rate, and rupture history are needed urgently. However, successful of paleoseismic investigation is influenced strongly by a proper area selection for trenching. Geophysical methods are believed to be fast and cheap method that can be used for locating the trenching site.

Based on field and geomorphic observation, we have selected Lamtamot, District of Aceh Besar for candidate paleoseismic excavation site (Figure 1). Some geological features indicated as fault traces are found in Lamtamot. At the southern part of the village we found fault trace outcrop cut perpendicular the Seulimuem segment. About 500 meter to the north from this outcrop, we also found a 7.6 meters height wall expected as fault scarp directed parallel to the Seulimuem Segment (see inset (B) in Figure 1). Although the fault features are clear, both of the sites are situated at topographic area that causes some difficulties for further excavation.

At the northern part, topography of the area is almost flat, where it is suitable for trenching site. However indication of fault line is still uncertain. Prior to the excavation, we have done geoelectrical measurement for near surface mapping.

![Figure 1. Area of study in Lamtamot village.](image-url)
2. Method

Area of study is paddy field of Lamtamot village situated at southern of Seulawah Agam volcano District of Aceh Besar (about 100 km to the east from Banda Aceh). The area is mostly covered by fluvial sediment, however about 50 centimeters of the uppermost layer is considered as disturbed layer by agricultural activities.

Two profiles in east-west direction crossing perpendicularly to the suspected fault line were selected for geoelectrical data measurement (Figure 1). Length of each profile is 42 meters with electrodes spacing 1.5 meters. The Wenner-Schlumberger electrodes configuration were selected for data acquisition [8]. The data collection was carried out with the help of multi-electrode electrical resistivity imaging system.

![Figure 2. Field measurements](image-url)
3. Results and Discussion

Apparent resistivity data collected from the field provides a simple image of electrical resistivity pseudo section. However it is not representing the true distribution of subsurface resistivity (the figures are not shown in this paper). True resistivity models were calculated using RES2DINV developed by Loke [8].

![Figure 3. Predicted electrical resistivity model of Profile 1](image1)

![Figure 4. Predicted electrical resistivity model of Profile 2](image2)

Figures 3 and 4 show predicted electrical resistivity model derived from Profile 1 and Profile 2, respectively. For Profile 1, the inversion process stops after 6th iteration with absolute error model of 2.0 percent. While for Profile 2, the absolute error model of 1.5 percent was reached after 6th iterations.

The inverted models obtained from both profiles show a good agreement of electrical resistivity values distribution. The models are generally made up by three resistivity layers. The uppermost layer shows a relatively thin (i.e. < 0.5 m) and low resistivity values (i.e. < 40 Ohm-m). The middle layer dominated by moderate resistivity values (i.e. 40 – 100 Ohm-m) overlain by the layer with relatively high resistivity values (i.e. above 100 Ohm-m).

The first layer with relatively high resistivity values represent as fluvial sediment made up by clay and sand as found at the surface. This sediments are considered as disturbed layer by agriculture activities. The medium resistivity layer is interpreted as sand and gravel deposits which is proved from coring information using hand Auger at the site.

Both profiles at this site shows a relatively high resistivity contrast formed vertically at distances 24 and 30 meters for Profile 1 and Profile 2, respectively. This anomaly roughly coincides with the topographic scarp of fault deduced from the southern part of the site as shown in Figure 1. However, the model does not resolve well evidences from minor faults that can be related to the presence of surface ruptures.

On the right side of the profiles, a gently dipping electric contrast could correspond to a stratigraphical discontinuity such as the erosion surface overlain by sands and gravels observed in the neighboring outcrops. The ‘U’ shape of low resistivity values may correspond to old channel situated beside the fault scarp. The channel is directed in north-south following stepping of the surface elevation from the high land in the northern part where the Seulawah Agam Volcano located (see Figure 1).

Based on the estimated resistivity models obtained from both profiles, we believe that further excavation is possible to be dug at this site. The predicted buried scarp found at the middle part along the profiles may record sequences of historical ruptures that occurred in the past.
4. Conclusion

Application of geoelectrical resistivity method for locating near surface structures of Seulimuem segment has been proven its advantages at Lamtamot area. The 2D electrical resistivity model provided evidence of some resistivity anomalies by high lateral contrast. This anomaly almost coincides with the topographic scarp which is modified by agriculture on the surface at the northern part of Lamtamot. The steep dipping electrical contrast may correspond to a fault. However, the model does not resolve well evidences from minor faults that can be related to the presence of surface ruptures. A near fault paleoseismic investigation requires trenching across the fault in order to detect and analyze the geological record of the past large earthquakes along the Seulimuem segment.

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