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Seulimeum segment characteristic indicated by 2-D resistivity imaging method

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ABSTRACT

The study conducted at Aceh (Indonesia) within Krueng Raya and Ie Seu Um vicinity with the same geology setting (Lam Teuba volcanic), to study Seulimeum Segment characteristic using 2-D resistivity imaging method. The 2-D resistivity survey applied Pole-dipole array with minimum electrode spacing of 2 and 5 m for Ie Seu Um study area, while 10 m for Krueng Raya area. Resistivity value of Ie Seu Um study area has been correlated and validated with existing outcrops and hot springs which the value used to identify overburden, saturated area and bedrock of Krueng Raya area. The resistivity value of overburden in Krueng Raya area was identify as <30 Ohm.m, bedrock is >30 Ohm.m and saturated zone is <9 Ohm.m. The imaging results used to identify the Seulimeum segment system, where the depth is increasing from southern part (20–50 m) to northern part (50–200 m) when approaching the Andaman Sea and breaks into two sections to produce horst and graben system which indicate that it produced from the moving plat.

1. Introduction

A major fault running entire length of Sumatra Island from south-east to north-west was named as Sumatran fault. The Sumatran fault accommodates mostly by strike-slip fault system which located between Indo-Australia and Eurasian plates (Sieh and Natawidjaja, 2000) and the active fault ends at the north part of Sumatera Island, just below Banda Aceh (Muztaza et al., 2014; Doust and Noble, 2008).

Seulimeum Segments is an extension from Sumatran fault which is located in Aceh and it also accommodate by strike-slip fault system (Nurhasan et al., 2011). Studies have been conducted at the segments with multidisciplinary techniques/methods, but no deep crustal studies have been investigated. After-shock event at the two segments has been identified, even though with small magnitude. Assumption can be made in the future that there is still have high possibility to rupture. Therefore detail and rapid investigation on the two segments is very important in order to understand the system and processes. 2-D resistivity survey conducted crossing predicted Seulimeum Segment starting from Krueng Raya until Ie Seu Um to identify the system.

2. Geology of study area

The study conducted including Krueng Raya and Ie Seu Um areas which covered about 9.2 km^2 (Fig. 1). On the northern part of the study area was gently flat and nearby Andaman Sea. Moving towards the southern part of the study area, the ground topography is very rough with mixture of primary/secondary jungle, villages and farms. Hot spring was identified at Ie Seu Um area which located on the south-east part of Krueng Raya.

Aceh is located at the northern part of Sumatera Island, consisting four major volcano-sedimentary sequences, separated by unconformities which are pre-Tertiary in age and the others are

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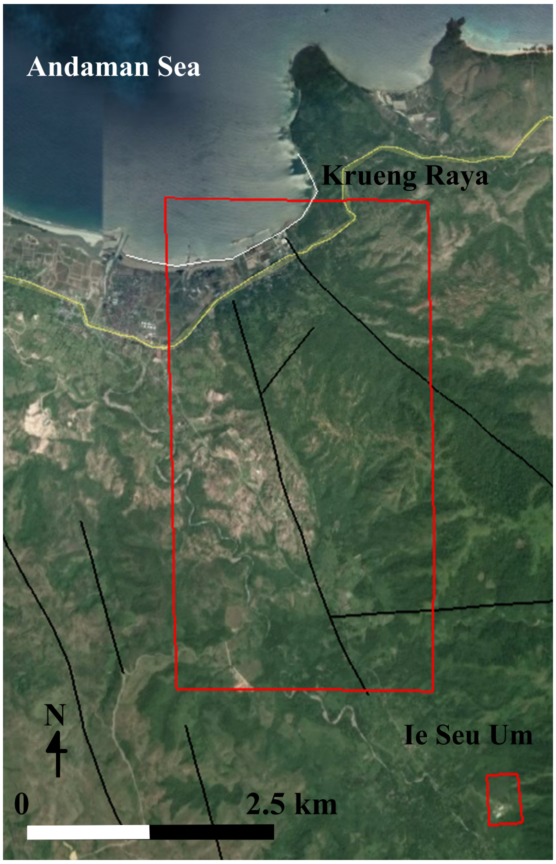

Fig. 1. Two study area; Ie Seu Um and Krueng Raya for Seulimeum Segment study. Predicted faults marked as black line (Google Earth, 2016).

Tertiary to Recent. Banda Aceh Quadrangle and Krueng Raya lithology is dominated by Lam Tuba volcanic (Fig. 2). It composed of andesitic to dacitic volcanics, pumiceous breccia, tuffs, agglomerate and ash flows. The intruded ash into the Seulimeum formation composed of tuffaceous and calcareous sandstones, conglomerates and minor mudstones (Bennett et al., 1981). The flat and low alluvial including flat-topped hills, within Barisan range, runs along the entire western edge of the Sumatera Island. A continuous axial valleys system follow closely the Barisan range crest, marks an outcrop of the main fault line (Sumatran fault system) with right lateral fracture system. Two main faults system controlled the area with orientation of NW to SE. The topographic morphology of the Krueng Raya is subdued because the rocks are strongly fractured and altered (Katili and Hehuwet, 1967; Page et al., 1979).

3. Methodology

2-D resistivity imaging method conducted by injecting direct current into the ground through a pair of current electrode and

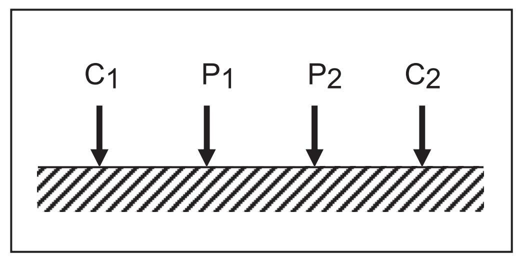

Fig. 3. Electrode arrangement for 2-D resistivity imaging.

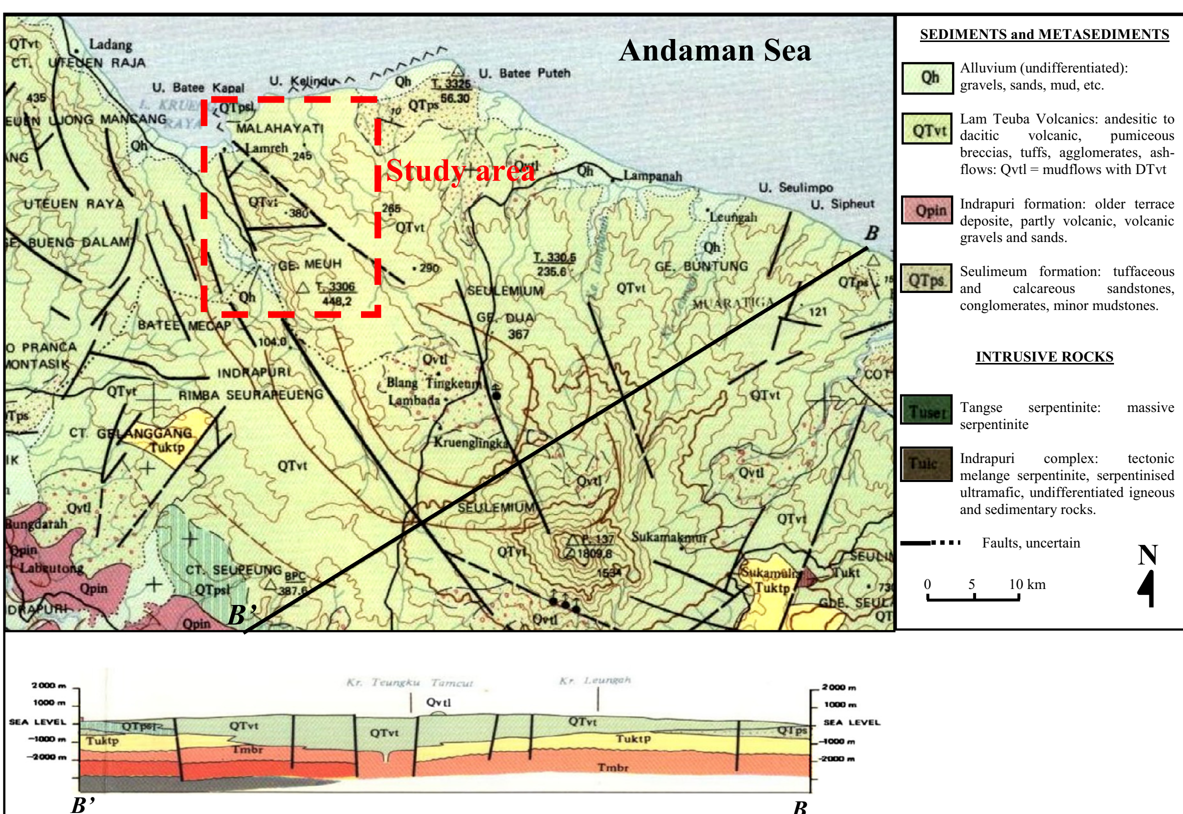

Fig. 2. Geology of the study area (Modified from Bennett et al., 1981).

measuring potential difference using a different pair of potential electrode planted on the ground surface. The method use to investigate electrical properties of subsurface by calculating apparent resistivity distribution of the materials (ρ_a) from data measuring on ground surface (Fig. 3).

The measured apparent resistivity (ρ_a) mostly depends on a combination of resistance and dielectric related to lithology and geology of the subsurface (Edwin and Cahit, 1988). Rock types such as igneous and metamorphic; typically having high resistivity values depending on degree of fractures. Since water table in Malaysia is generally shallow, the fractures are commonly filled with ground water (Muztaza et al., 2014). High fracturing rocks will result a lower resistivity values. Table 1 shows the resistivity values of rocks and soil types (Keller and Frischknecht, 1996).

Table 1
Resistivity value of rocks and soil (Keller and Frischknecht, 1996).

Material	Resistivity (Ωm)
Alluvium	10–800
Sand	60–1000
Clay	1–100
Groundwater (fresh)	10–100
Sandstone	8 - $4x10^3$
Shale	20 - $2x10^3$
Limestone	50 - $4x10^3$
Granite	$5x10^3$ - $1x10^6$

Table 2
ABEM SAS4000 Terrameter data acquisition setting.

Function	Setting	Value
Current	Maximum	50 mA
	Minimum	1 mA
Mode	Auto	–
Acquisition delay	–	0.3 s
Acquisition time	–	0.3 s
Total cycle time	–	3 s
Stack	Maximum	3
	Minimum	1
Power line frequency	–	50 Hz

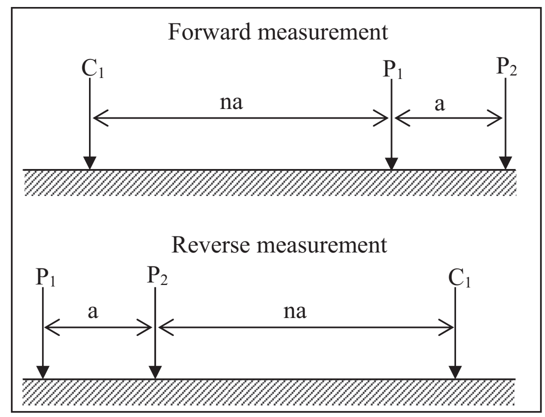

Fig. 5. Forward and reverse measurement of pole-dipole array (Loke, 1999).

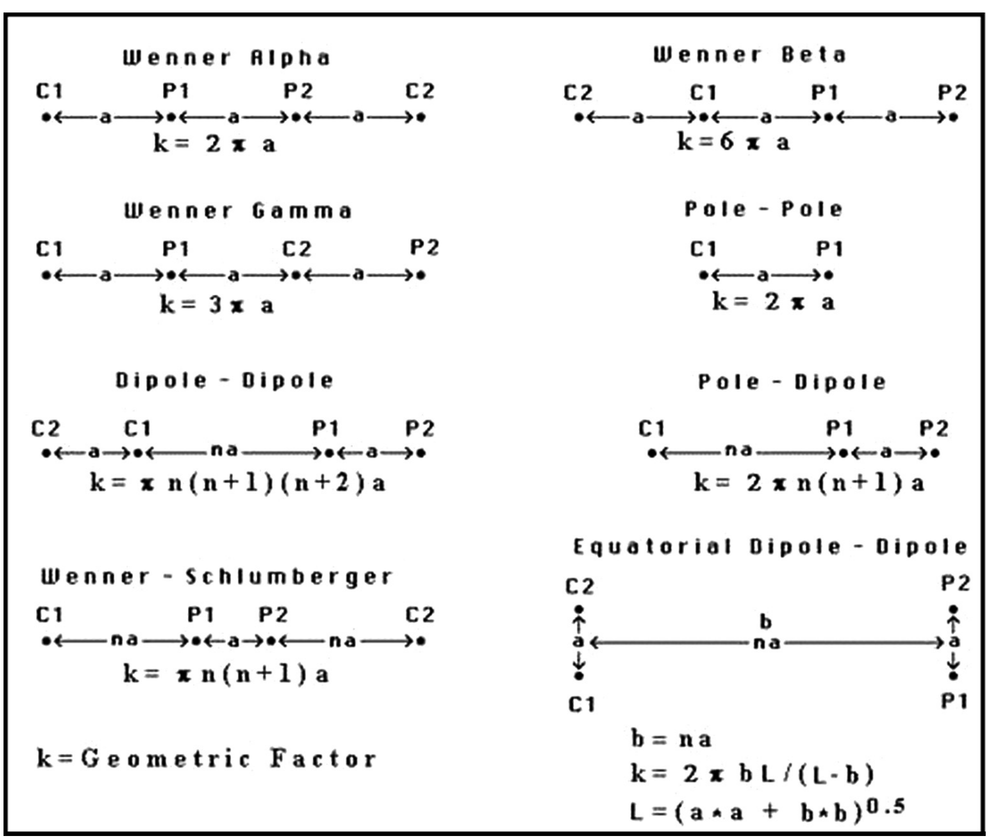

Fig. 4. 2-D resistivity imaging electrode array and their geometric factor, k (Loke, 2011).

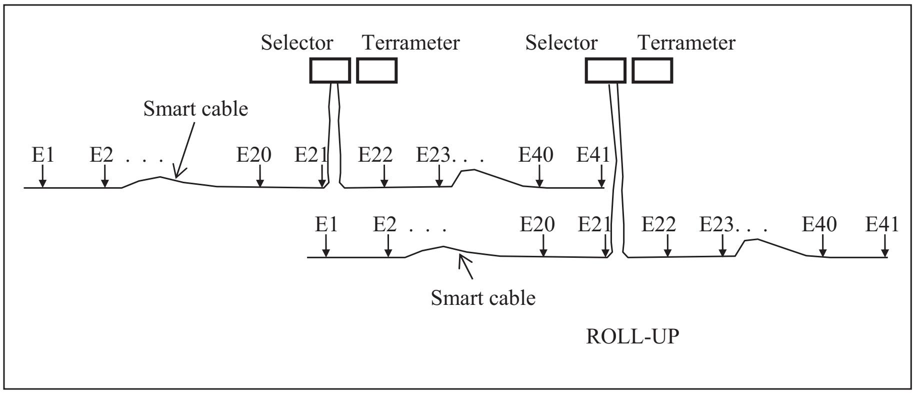

Fig. 6. Roll-up techniques.

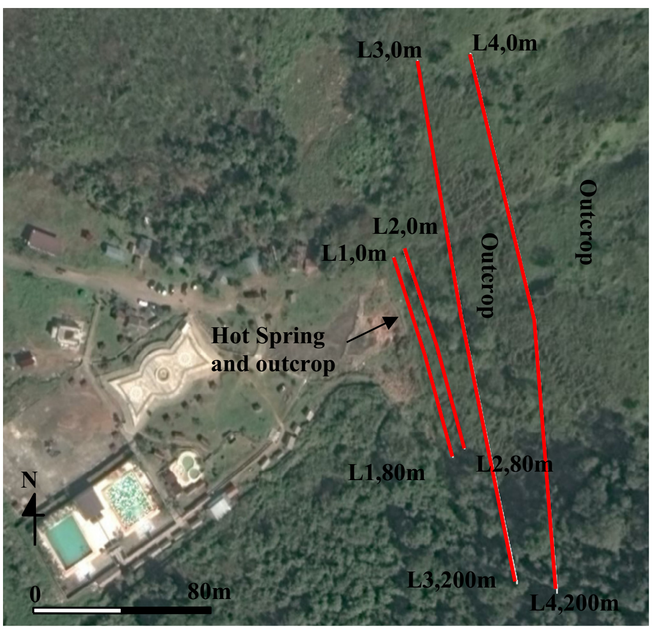

Fig. 7. 2-D resistivity survey lines at Ie Seu Um (Google Earth, 2016).

The apparent resistivity (ρ_a) is calculated based on Eq. (1.1).

$$\rho_a = k\frac{V}{I} \quad (1.1)$$

where
V = voltage
I = current
k = geometric factor

The geometric factor (k) is identified by electrodes arrangement (Fig. 4) and it is a key factor in identifying depth of penetration.

The study conducted at two study area; Ie Seu Um and Krueng Raya (Fig. 1), using 2-D resistivity imaging survey with ABEM SAS4000 Terrameter system including ES10-64C electrode selector, smart cables, 41 stainless steel electrodes and jumpers. The surveys were performed using Pole-dipole array with remote electrode located at distance of 5 times of maximum electrode spacing from each survey line and perpendicular to it. Table 2 shows ABEM SAS4000 Terrameter data acquisition setting used for all survey lines.

Pole-dipole array was used based on the deepest depth penetration beside provide a good resolution. Pole-dipole array is an asymmetrical arrangement which influence the anomalies by giving asymmetrical apparent resistivity. To eliminate the asymmetry affect, reverse measurement also taken (Fig. 5).

Roll-along techniques was applied to complete the total length of each survey line if the total length of the survey line exceeding more then one spread. The overlapped applied was at the centre of the previous spread (Fig. 6).

Ie Seu Um is a hot spring area with outcrop identified at the western and eastern part of the area. Four resistivity survey lines; L1–L4 were conducted at the area (Fig. 7). L1 and L2 conducted using two smart cables with 2 m minimum electrode spacing, while L3 and L4 using two smart cables with 5 m minimum electrode spacing. The 2-D resistivity data was processed to identify resistivity value of overburden and bedrock, and the values will be use for correlation and validation of Krueng Raya study area.

Fig. 8 shows Krueng Raya study area with six resistivity survey lines; L5–L10. The survey lines were conducted using four smart cables with 10 m minimum electrode spacing. Roll-up techniques was applied for survey line L5, L6, L8 and L10. The 2-D resistivity data was processed, correlated and validated with the value identified from Ie Seu Um result for Seulimeum Segment identification.

The 2-D resistivity data were processed using Res2Dinv (ver.3.56.70) to produce inverse model resistivity section. The inversion model converted to surfer8 format for validation, correlation and interpretation. The overburden and bedrock resistivity value of Ie Seu Um area are used as a bench mark to delineate Seulimeum Segment of Krueng Raya.

4. Results

Fig. 9 shows 2-D resistivity inversion model of L1-L4 at Ie Seu Um, with resistivity values of 0–2000 Ohm.m. The area divided into two main zones; overburden with resistivity value of < 30 Ohm.m and bedrock with resistivity value of >30 Ohm.m. The hot spring identified onsite flowing from the ground surface was indicate by resistivity value of <9 Ohm.m.

Fig. 10 shows 2-D resistivity inversion model of L5–L10 conducted at Krueng Raya. The results were correlated with resistivity

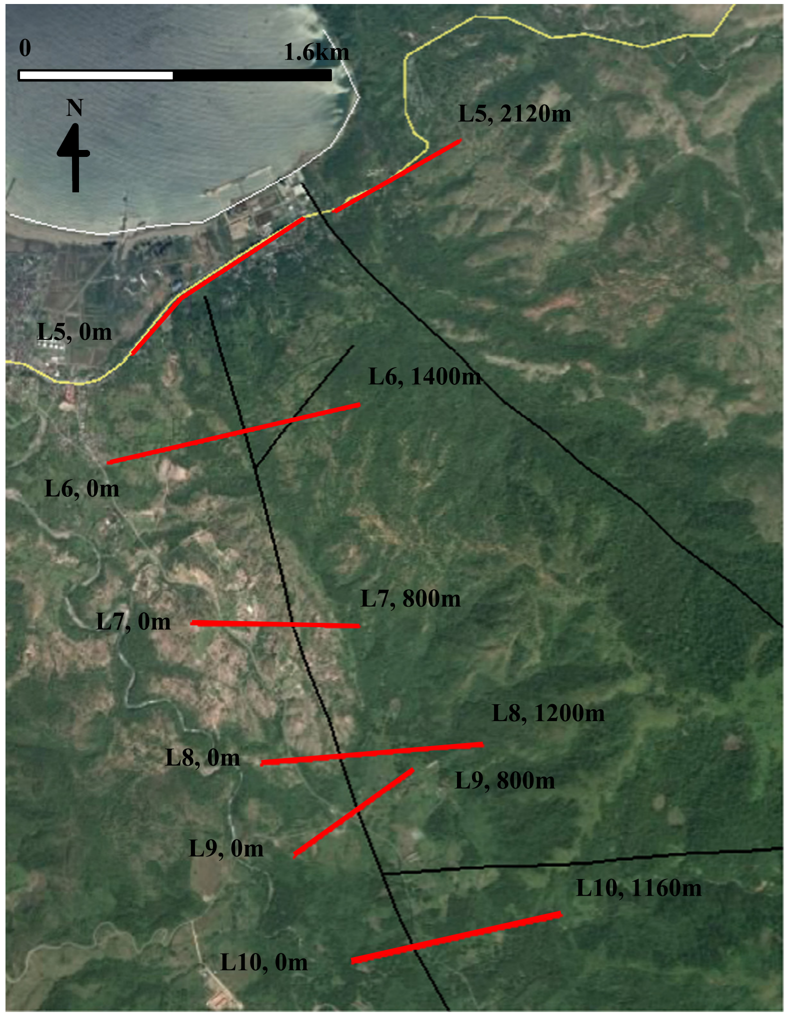

Fig. 8. 2-D resistivity survey lines at Krueng Raya (Google Earth, 2016).

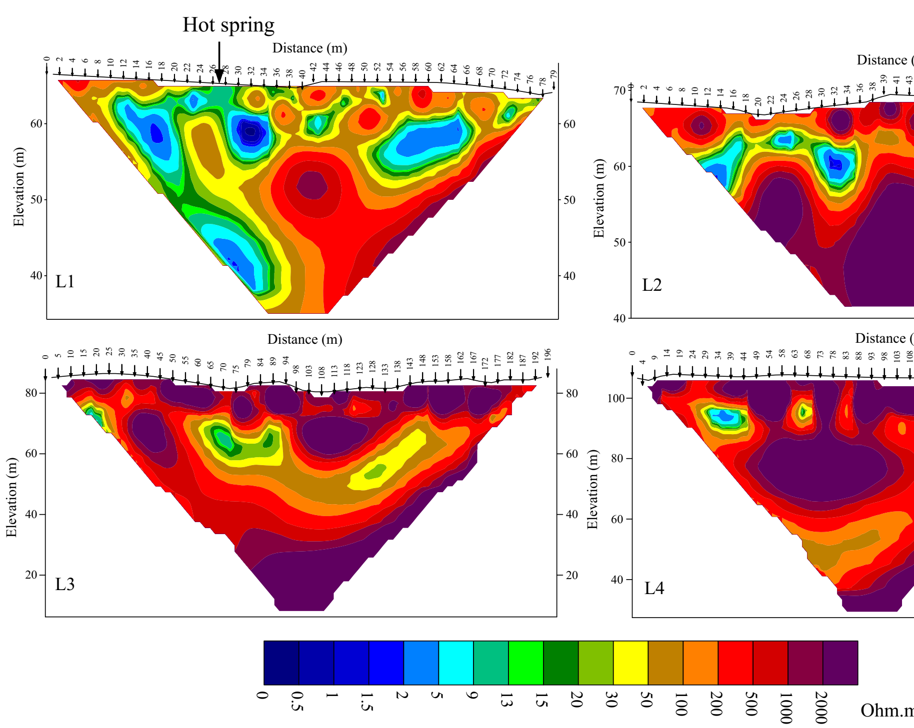

Fig. 9. 2-D resistivity inversion model of line L1-L4 at Ie Seu Um.

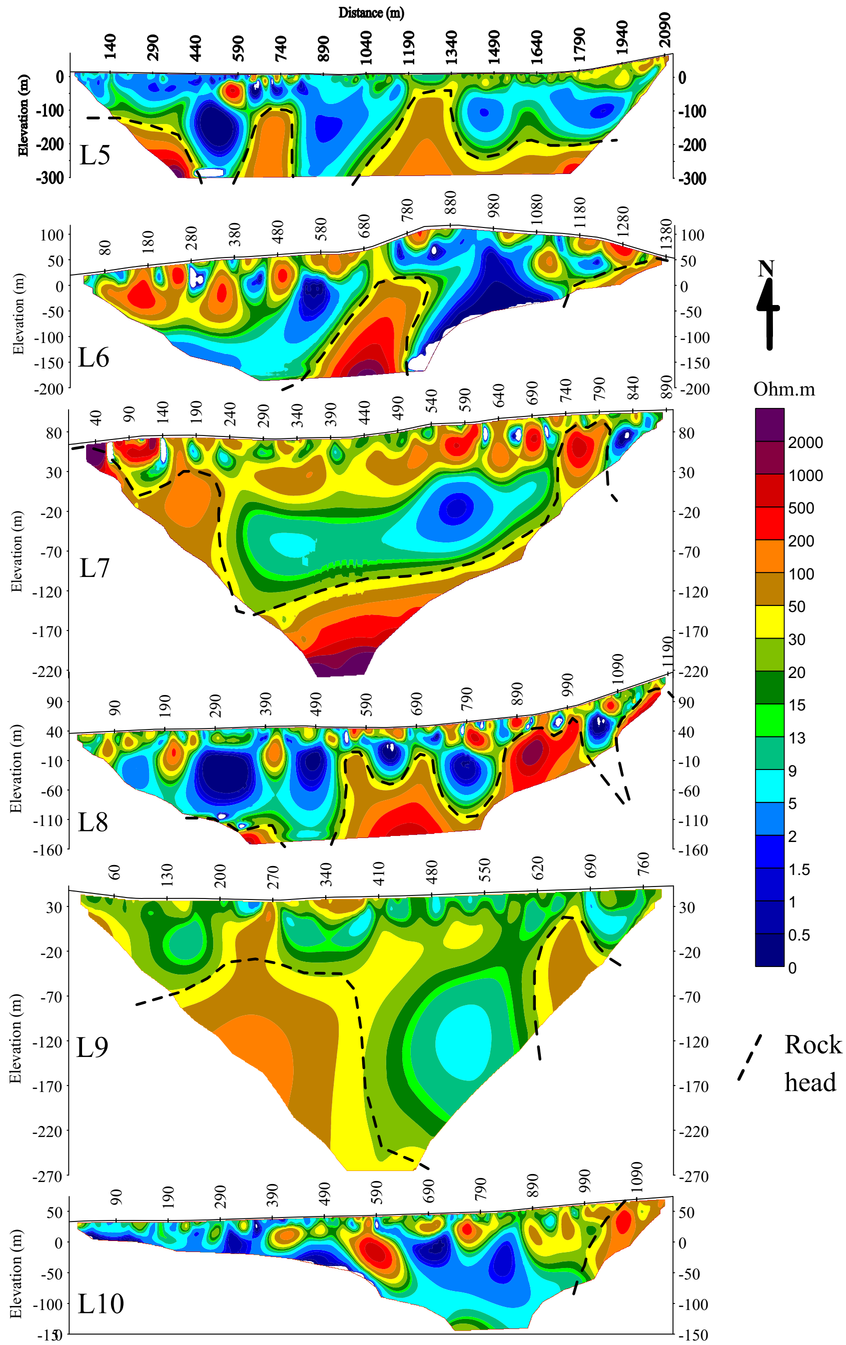

Fig. 10. 2-D resistivity inversion model of line L5-L10 at Krueng Raya.

value identified at Ie Seu Um area for geology subsurface information. Generally 2-D resistivity inversion model show the Krueng Raya was divided into two main zones; overburden with resistivity value of <30 Ohm.m and bedrock with resistivity value of >30 Ohm.m with undulating rock head.

5. Discussion and conclusion

The overburden and bedrock resistivity value of Krueng Raya area were identified referring to the value identified at Ie Seu Um study area which has been correlated and validated with the existence of outcrops and hot spring. Generally, the resistivity value of Krueng Raya bedrock was identified with a value of >30 Ohm.m and interpreted as Lam Teuba volcanic. The bedrock was overlaid by overburden with resistivity value of <30 Ohm.m. Fig. 11 shows the depth to bedrock of Krueng Raya area after processing and interpretation. It was identified that the bedrock is undulating shape with depth is increasing from southern part (20–50 m) to northern part (50–200 m) when approaching the Andaman Sea. Line L5–L9 show that the bedrock breaks into two sections to produce horst and graben system. The study shows that Seulimeum Segment consists of horst and graben system and the depth is increasing when approaching Andaman Sea, which indicate that it produced from the moving plat.

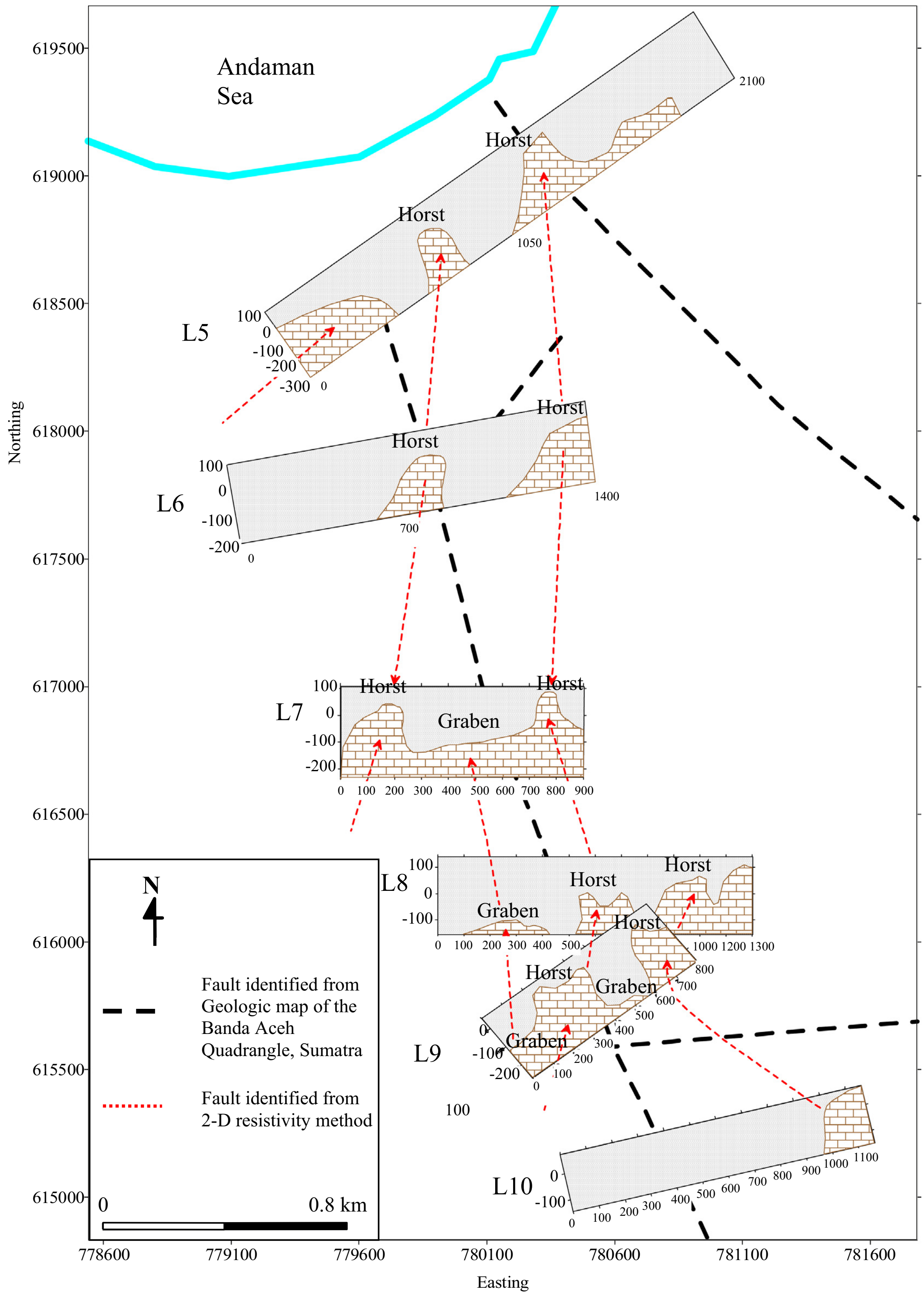

Fig. 11. Bedrock and fault system of study area 'B' identified by 2-D resistivity imaging method.

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