The Application of Induced Polarization and Chargeability for Geothermal Fluid in Volcanic Area, Northern Sumatra

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ABSTRACT

Induced polarization (IP) method has been implemented in investigation of groundwater, geothermal and metallic ores. The surveys intend to study structure of area nearby to hot spring which located at Ie-Seu’um Village, Krueng Raya in Aceh Besar. Geothermal sources often have high fluid mobility within circulating groundwater and give rises to low resistivities that can be detected using IP method. Four survey lines were carried out using Pole-dipole array with 2 m minimum electrode spacing. The data processed using Res2Dinv and the volcanic rocks identified with chargeability value of > 2.5 msec. The zones with chargeability value of 0.01-0.5 msec indicate the water with sulphur.

KEYWORDS: Induced polarization (IP), geothermal, Ie-Seu’um, chargeability, volcanic rocks.

INTRODUCTION

Ie-Seu'um village, where the 80~90°C hot spring spotted located at the Krueng Raya, Aceh Besar (Indonesia). The source of hot spring is on the east side of the Krueng Raya river valley (Syukri, 2009). Geothermal resources vary widely from one location to another, depending on the temperature and depth of the resource, the rock chemistry, and the abundance of groundwater (Sukanta, 2012). Mostly hot springs are volcanic as their source of heat; however the faulting is a major control of the hot spring at the Ie-Seu'um. In area of about 2974.12 km², this area located in faulting zone that extending from Sabang fault to Lam Teuba faults and already experienced nine tectonic periods. The Lam Teuba-Bora fault as well known as Seulimeum fault has a vertical component in this area with down throw to the southwest and has uplifted a diorite intrusion immediately northwest of the spring (Syukri, 2009). Generally, the Great Sumatera fault probably controls the distribution of geothermal systems in Sumatera (Suari, 1991). Fault structures can potentially deliver geothermal fluid production by boosting the bulk permeability and fluid storage of a production zone. Commonly, permeable fault structures present an attractive geothermal exploration target as faults have been proven to boost substantially reservoir permeability and fluid production at some existing geothermal energy operations (Mortimer, 2010).

GENERAL GEOLOGY

The Krueng Aceh valley is bounded to the south-west by the Aceh fault and to the northeast by the Seulimeum fault. The volcanic of Pleistocene to Holocene age cover most of the North coast foothills on the side of the Seulimeum fault. Within the upper Krueng Aceh valley, the tertiary rocks are covered by up to 500 m thick with Plio-Pleistocene semi-consolidated calcareous and tuffaceous sandstones. From upstream of the town of Jantho to downstream of the town of Indrapuri, the Pleistocene coarse-grained partly volcanic sands and gravels form a prominent terrace surface on either side of the Krueng Aceh valley. These older terrace deposits may attain a thickness up to 75 m. The alluvium near the coast of the city of Banda Aceh extends to a depth of more than 200 m below ground level becoming thinner upstream (Bennett et al., 1981).

The Lam Teuba-Bora fault has a vertical component in this area with downthrown to the SW and has uplifted a diorite intrusion immediately NW of the spring. Apart from the Lam Teuba caldera ring faults the other major structure in the area is the Lam Teuba-Bora fault, which is an offshoot of the Great Sumatera fault. The age of the diorite is not clear but it is likely to be upper Tertiary as similar diorites intrude Miocene sediment further to the east (Syukri, 2009).

STUDY AREA

The study was carried out at hot spring spotted namely Ie-Se'um, which located in the area of Krueng Raya district, Banda Aceh (Figure 1). Four survey lines were conducted, L1-L4 across the hill nearby the hot spring, covering coordinate from N 5.547528° E 95.548639° and N 5.546829° E 95.548842° until N 5.548180° E 95.548890° and N 5.546398° E 95.549191° which suspected as the location for the water sources. Total lengths for L1and L2 are 80 m meanwhile the length for L3 and L4 are 200 m.

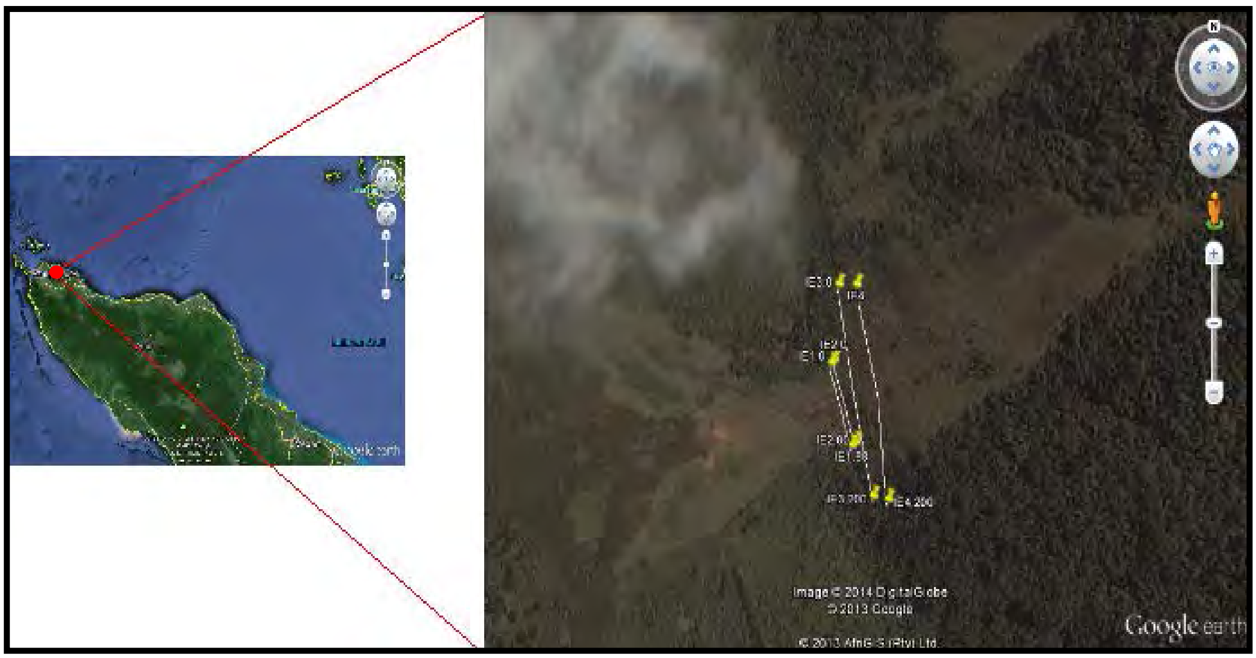

Figure 1: Four study lines at Ie-Se'um, nearby the hot spring spotted. (Google, 2013)

THEORY OF INDUCED POLARIZATION (IP)

The induced polarization (IP) is an electrical method which used the capacitive action of the subsurface to locate zones where clay and conductive minerals are disseminated within their host rocks. The method used in the field to measure induced polarization is similar in many ways to those employed for resistivity measurements. Current is introduced into the Earth with two electrodes, and the potential is measured across the other two electrodes after the current is shut off. Generally the geometry of the electrode configuration is kept uniform while the position is changed laterally along the profile (Dobrin, 1998). The parameter measured by IP is chargeability, a physical property that describes how well materials tend to retain an electrical charge. Common geological materials that are chargeable include disseminated sulfides, clays, and graphite. Table 1 and Table 2 show the chargeability of common minerals and rocks respectively (Telford et al., 1976).

Table 1: Chargeability of minerals at 1% concentration in the samples with charging and integration times of 3 seconds and 0.02-1.0 seconds respectively (Telford, 1976).

Mineral	*Chargeability (ms)*
Pyrite	13.4
Chalcocite	13.2
Copper	12.3
Graphite	11.2
Chalcopyrite	9.2
Erubescite	6.3
Galena	3.7
Magnetite	2.2
Malachite	0.2
Hematite	0.2

Table 2: The value of charging and integration times of 3 seconds and 0.02-1.0 seconds respectively (Telford, 1976).

Rock	*Chargeability (ms)*
Aquifer	0
Alluvium	1 – 4
Gravel	3 - 9
Volcanic	8 - 20
Gneiss	6 - 30
Schist	5 - 20
Sandstone	3 - 12
Argilite	3 - 10
Quartzite	5 - 12

METHODOLOGY

The technique used in the field to measure induced polarization is similar to those employed for resistivity measurements. The 2-D IP survey was conducted using ABEM SAS4000 Terrameter, smart cables and stainless steel electrodes. The survey used Pole-dipole array with 2 m minimum electrode spacing for L1 and L2, meanwhile 5 m was used for L3 and L4. 2-D resistivity data was modeled using Res2Dinv software.

RESULTS AND DISCUSSION

The IP results of Line 1-4 suggested that the study area is underlain by volcanic rocks with chargeability value of > 2.5 msec (Figure 2-5). These volcanic rocks covered vary in depth as the study line are at different elevations, up to 30 m, 35 m, 85 m, and 90 m for the L1, L2, L3 and L4 respectively. The zones with chargeability value of <0.5 msec indicates the conductive zone perhaps the sources for the hot water. These values are acceptable as the hot water containing sulphur disproved by the strong smell at the hot spring.

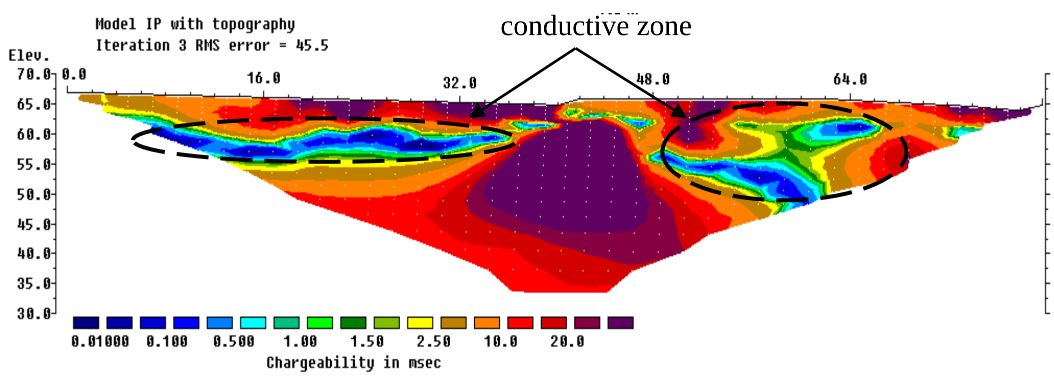

Figure 2 : Pseudosection of L1, shows the distribution of chargeability value.

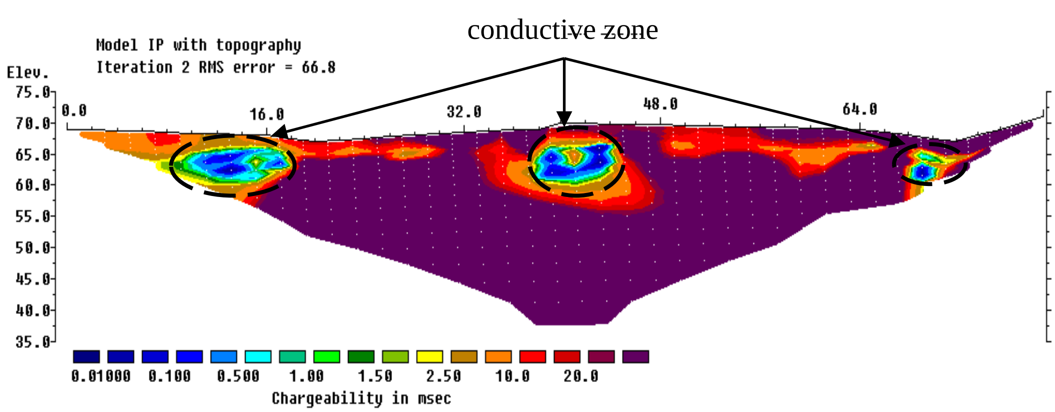

Figure 3 : Pseudosection of L2, shows the distribution of chargeability value.

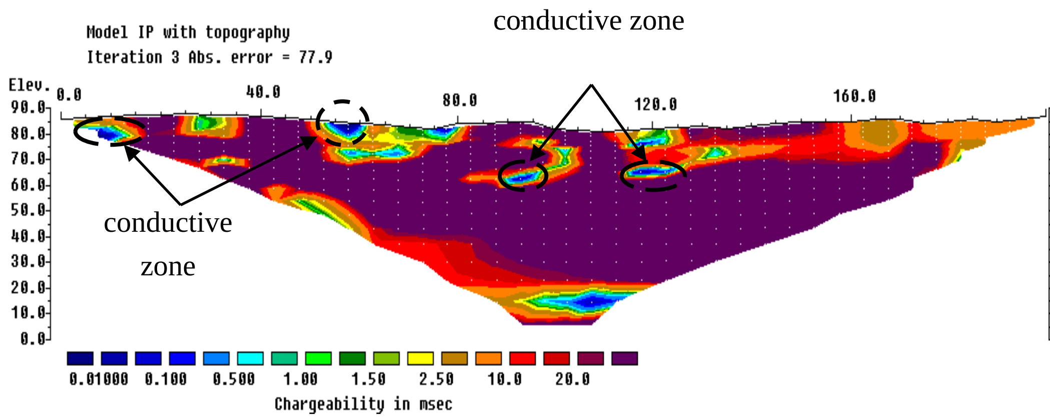

Figure 4 : Pseudosection of L3, shows the distribution of chargeability value.

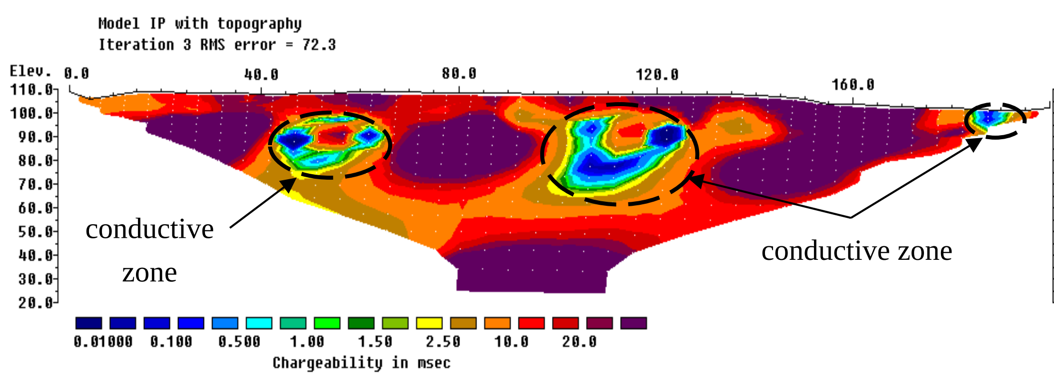

Figure 5 : Pseudosection of L4, shows the distribution of chargeability value.

CONCLUSION

In short, the study area largely comprises of volcanic rocks with chargeability value of >2.5 msec and vary with depth (>30 m). The low chargeability value (0.01-0.5 msec) indicates the presence of water with sulphur, which as the source of hot water.

ACKNOWLEDGEMENTS

Thanking to the Ministry of Education and Culture, Indonesia for financial support in the scheme of Decentralized Research Competitive Grants Program 2013. Special thanks are extended to the technical staffs of the geophysics laboratory and geophysics postgraduate students, School of Physics, Universiti Sains Malaysia and geophysics students, Faculty of Sciences and Faculty of Engineering, Syiah Kuala University for their assistance during the data acquisition.

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