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Characteristic aquifer in volcanic terrains: case study at Caldera Lake Maninjau, West Sumatera - Indonesia

Muhammad Sehabudin^{1,*}, Aan Dianto², Luki Subehi², Singgih Irianto TH¹

¹ Geological Engineering, Pakuan University, Jl. Pakuan Utara, Tegallega, Bogor Tengah, Bogor 16143

² Research Center for Limnology, Indonesian Institute of Sciences, Jl. Raya Bogor-Jakarta, Cibinong, Bogor 16911

E-mail: msehabudin092@gmail.com

Abstract. Lake Maninjau is a caldera lake with volcano-tectonic type. Lake Maninjau composed of andesit and tuff formation. The existence of water was sourced by rain and ground water. The aquifer units consist of local productive aquifers and rare ground water aquifer. The purpose of this research is to know the characteristic of aquifer in volcanic terrains support water stability in lake. Geoelectric measurements with Wenner configuration were obtained to know subsurface resistivity which a device used were IRES T300f, used RES2DINV software. The results showed that characteristic of aquifer divided into two areas, rare aquifer and productive aquifer. Productive aquifer with average 21.2 – 213 ohm meter, located at Tanjung Sani (elevation 462 m) had similar with Batang River (elevation 701 m). Rare aquifer with average value 48.4 – 436 ohm meter located at Hamka School (elevation 632 m) and Lawang Park with (elevation 1,294 m). The results of geoelectric reconstruction revealed that volcanic terrains around Lake Maninjau were dominated by rare groundwater aquifer, where capable to keep groundwater in small volume. Further, Fault with northwest – southeast as the general direction were considered to drain water through volcanic terrains.

1. Introduction

Lake Maninjau located in Agam Regency, West Sumatra. Lake Maninjau has an area of 9,737.5 ha, long 16 km, width 8 km and maximum depth of to 168m. Based on the location of Lake Maninjau include in the central facies volcano [1]. The eruption occurred at a lateral shift towards the Sumatera Fault line that triggers the formation of Lake Maninjau according to geomorphological, Lake Caldera Maninjau has an elongated shape that occurred over one eruption [2]. With the origin of the volcanic caldera lake, the lake Maninjau has aquifer type with a few productive aquifer (silver color) and rare groundwater areas (brown

* To whom any correspondence should be addressed.



color) according to Padang Geohydrology Map [3](Fig 1). Rare ground water aquifers are filled by high dense volcanic rocks, and volcanic rocks can form highly permeable aquifers.

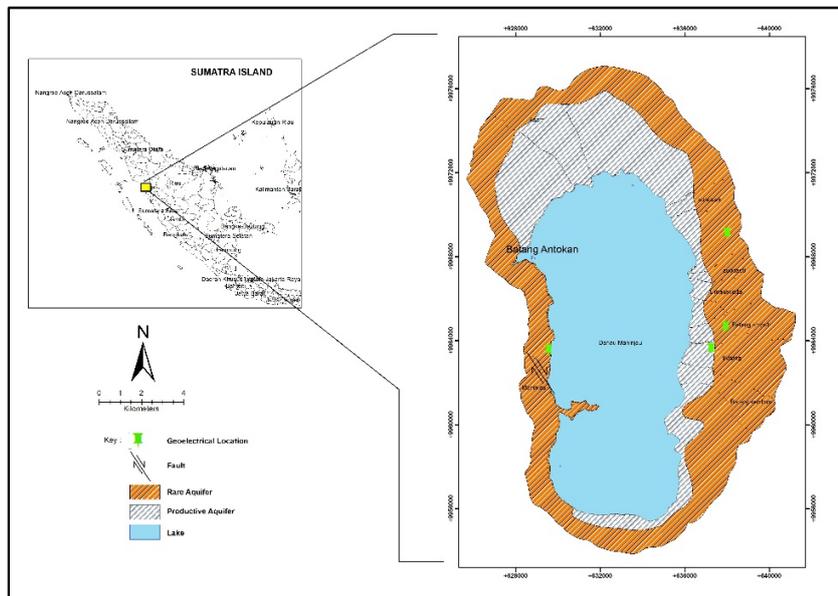


Figure 1. Geohydrological map area and geoelectrical location of study area [3].

The existence of water in Maninjau Lake comes from rainfall that directly flow into the lake and groundwater flow. Lake Maninjau has a large volume of water (10.226 million m³), while the water coming out of the lake, through Antokan River, water intake channel (intake) PLTA, evaporation[4]. The differences of rocks resistivity depend on material, density, porosity and pore size [5]. The purpose of this study to determine the characteristics of aquifer in volcanic terrains based on subsurface resistivity value, and the geologic structure.

Geological Setting

Geology of Lake Maninjau based on geological map of Padang [6], West Sumatra, composed of tuff and andesite rocks formation. Caldera maninjau was formed in Pleistocene (1.8 mya). Tuff and andesite generally consist of glass fibers white-clay fragments (5-80%)[7]. Maninjau Ignimbrite deposition characterized by high K rhyolite to calcalkaline andesite [8]. This tuff deposit could be the resulted of eruptions that associated with the Great Sumatera Fault [9]. The study area lies in a large segment of the Sumatra active fault oblique system known as The Great Sumatera Fault [10]. The geomorphic expression of the sianok segment is fault direction is very interested as it crosses the mountain side of Merapi and the northeast coast of Lake Singkarak. The main direction of the Sianok River is determined by tuff maninjau [11].

2. Method

2.1 Study Site

Geoelectric measurements were conducted in 4 locations around Lake Maninjau: Batang River, Tanjung Sani, Hamka School and Lawang Park, and Geological structure measurement at Tanjung Sani location partially in April 2018. Data collections were performed by measurments the resistivity geophysical

geoelectric method of 2D and measurement (tension and shear fracture) and the direction of brecciation there. Data processing and analyzing were carried out by the following stages:

- 1) Resistivity measurement used IRES T300f Resistivity meter with Wenner configuration that introduced by Wenner [12]. In the field data acquisition Wenner configuration the distance between the current and potential electrode are the same. Data was processed by Res2dinv software version 3.56.73. From 2D inversion result using non-linear least square method in Res2dinv software, we got subsurface resistivity distribution imaged with different color and different resistivity value. The inversion results show the actual resistivity value different from the apparent resistivity of the calculation. The error percentage between the apparent resistivity values obtained through modeling with the actual subsurface resistivity known as RMS error. RMS errors are considered optimal if subsurface resistivity variations and underground rock coating systems are in accordance with the approximate geological conditions of the inquiry area and should not be the smallest value [13].
- 2) The site is located about 1.5 km from geoelectric location and got water springs with affected extension fractures. This fracture is helpful in determining the type of fault, given the structure of the fault is a fracture in the earth caused by a shift so that for structural analysis it is attempted to know the direction and magnitude of the shift. The data collected include are gash fracture, shear fracture and brecciations [14]. Concludes that gash fracture and shear fracture patterns form angular hose boundaries, while brecciation is the evidence used to estimate the straightness or severity of the fault movement. The entire data was analyzed by Dips software version 5.103, include rosette and stereo net diagrams.

3. Result and Discussion

3.1 Interpretation of electrical data

Employing a 2D inversion scheme to the Res2dinv data in Lake Maninjau, we constructed 2D resistivity section for several profiles. The result zones showed the resistivity profiles consist of two major zones. The resistivity section obtained from 2D inversion of Lawang Park and Hamka School indicated the distribution of the high resistivity anomaly (48,4 – 436 O/hm) in the depth 27m spread in the outer of Lake Maninjau watershed. This anomaly is may considered as andesit and tuff zones, vice versa the low resistivity anomaly (21,2 – 213 ohm) in the depth 26,7m spread, the distribution is inner Lake Maninjau watershed , This anomaly is may considered alluvial zone at Batang River and Tanjung Sani. In addition, m table 1 from [13] is used for interpretation of lithology at field masurments.

Table 1. Value of Result Geoelectric [13]

Number	Material	Resistivity Ohm meter
1	Air	◇
2	Pyrite	0,01 – 100
3	Quartz	500 – 800.000
4	Calcite	$1 \times 10^{12} - 1 \times 10^{13}$
5	Rock Salt	$30 - 1 \times 10^{13}$
6	Granite	200 – 100.000
7	Andesite	$1,7 \times 10^{12} - 45 \times 10^4$
8	Basalt	200 – 100.000
9	Limestone	500 – 10.000
10	Sandstone	200 – 8.000
11	Shales	20 – 2.000

12	Sand	1 – 1.000
13	Clay	1 – 100
14	Ground Water	0.5 – 300
15	Sea Water	0.2
16	Magnetite	0.01 – 1.000
17	Dry Gravel	600 – 10.000
18	Alluvium	10 – 800
19	Gravel	100 – 600

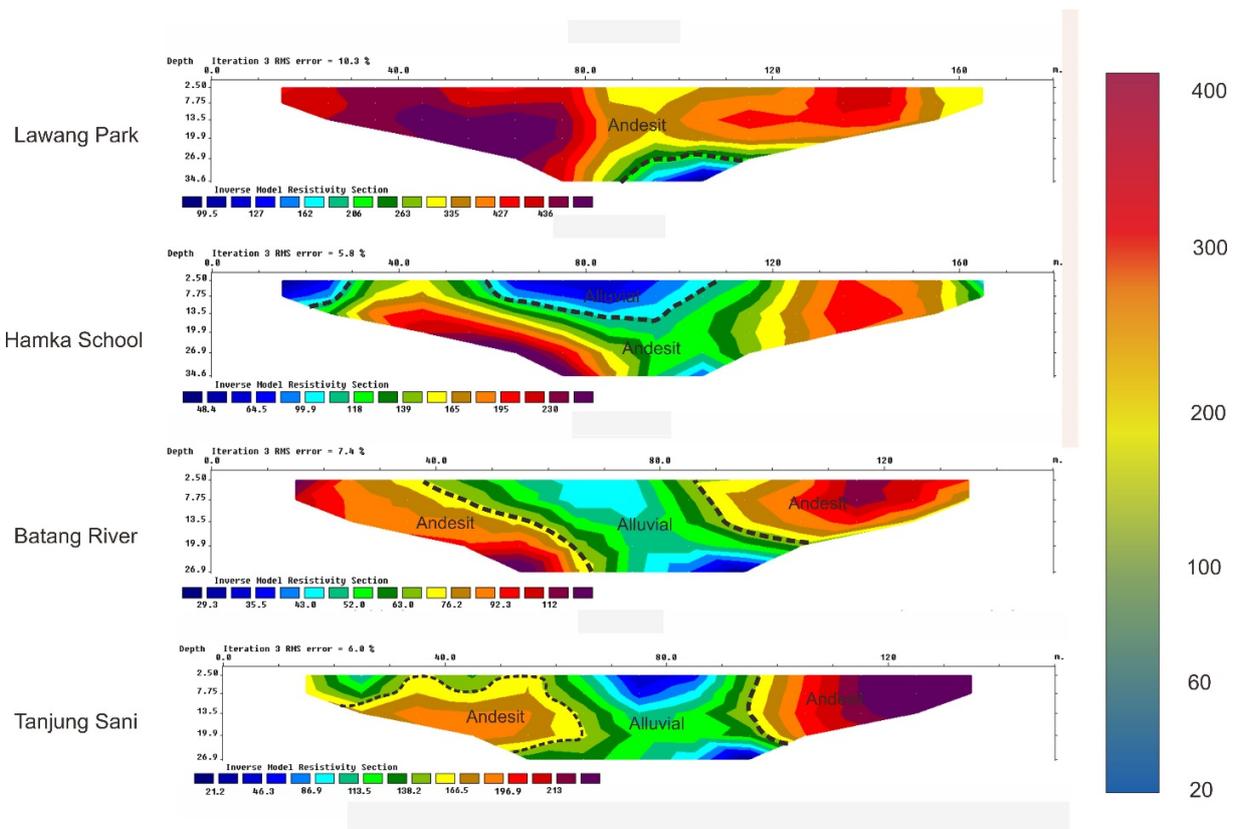


Figure 2. Construted Electrical Data

The andesit and tuff zone are impossible for groundwater potential because it's compact and solid rocks[13] and this zone is a part of rare aquifer. However, alluvial zone are possible for groundwater potential because composed of loose material rock and this zone a part productive aquifer. The results of geoelectric reconstruction revealed that volcanic terrains around Lake Maninjau were dominated by rare groundwater aquifer, where capable to keep groundwater in small volume.

3.2 Geology structure analysis

Measurement of Gash facture 50 points, Shear Fracture 50 points and Breksiasi 20 points conducted at the location of Tanjung Sani water springs. Brecciation data using rosette diagram to knew the dominant direction based on azimuth frequency. The gash fracture and shear fracture data were processed using stereo net contour diagrams to know the average position of each support fracture. The dominant direction

of brecciation is N 140° E and N 310° E (northwest-southeast). Analysis of gash fracture and shear fracture by using stereo net N 235° / 57° E and N 114° / 63° E. The kinematic analysis of the measured field data shows the position of the fault plane N 144° E / 48° with the position of net-slip 23°, N 161° E and pitch of 18°. The name of this fault is Reverse Right Slip Fault [14] with the position of the fault field it can be ascertained is southeast – northwest. According to the structure data, Tanjung Sani become the area with aquifer productive[15], because catchment area maninjau is local.

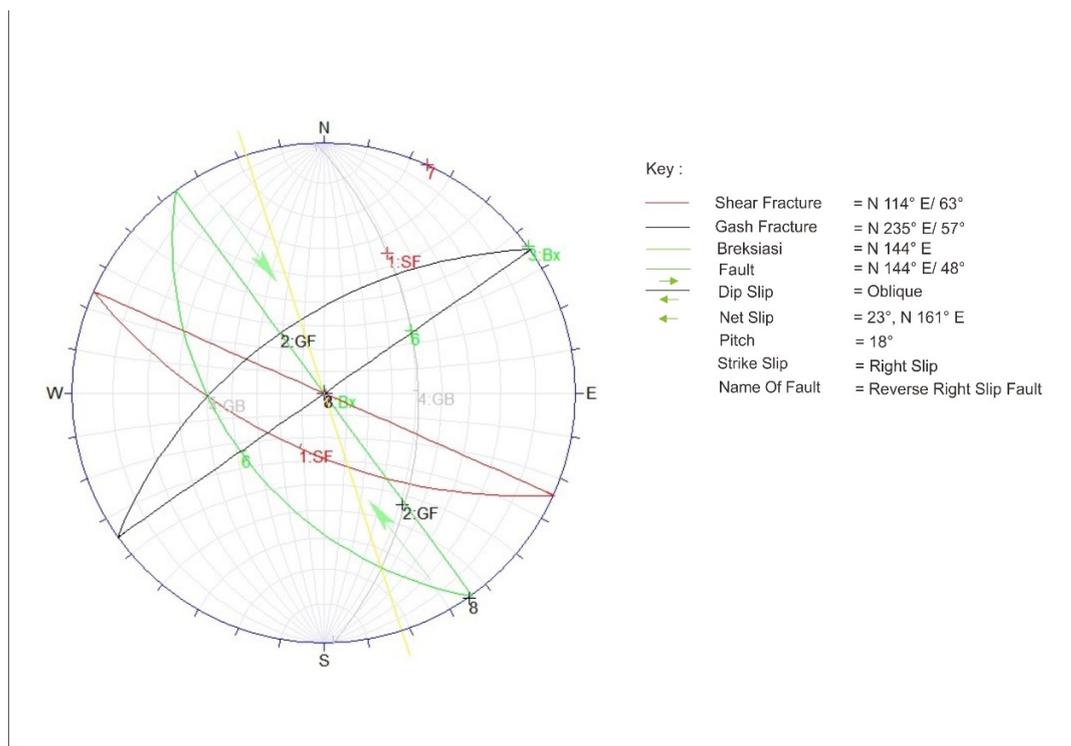


Figure 3. Result analysis geology structure Tanjung Sani location

4. Conclusion

The electrical method are successful to revealed anomalously low resistivity in Batang River and Tanjung Sani. By this method, it related to groundwater at Lake Maninjau even more detailed result. However, the structure method support result that may indicate the existing potential groundwater (productive aquifer), compared with Lake Maninjau literature, productive aquifer has a very important role in Lake Maninjau watershed. As for the rare aquifer need to do further research and detail because it is not composed by andesite all but there are layers of tuff.

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References

- [1] Bronto, S, 2006 *Facies Gunung Api dan Aplikasinya*, Jurnal Geologi Indonesia, Vol 1 No 2, Pusat Survey Geologi Bandung.
- [2] Santoso, U.M Lumban Batu 2007 *Morfogenesis Daerah Danau Kaldera Maninjau, Sumatera Barat* Jurnal Geologi dan Sumberdaya Mineral, Vol XVII No 2 : 91-104
- [3] Arief S. & Ruchijat, S. 1989, *Peta Hidrogeologi Regional Lembar Padang Sumatera Barat*, Bandung, Badan Geologi KESDM RI
- [4] Fakhruddin M, dkk, 2002. *Karakteristik Hidrologi Danau Maninjau Sumbar*. Dalam Proseding Seminar Nasional Limnologi LIPI, Bogor
- [5] Todd D K, and Larry W. Mays, 1980, *Groundwater Hydrology* :Third Edition, United States John Wiley & Sons, Inc.
- [6] Kastowo, Leo, G.W., Gafoer, S., Amin, T.C. 1996. *Peta Geologi Lembar Padang, Sumatra Barat*. Pusat Penelitian dan Pengembangan Geologi.
- [7] Pribadi A, Mulyadi E, and Pratomo I 2007 *Mekanisme Erupsi Ignimbrit Kaldera Maninjau, Sumatera Barat* Jurnal Geologi Indonesia, Vol. 2 No. 1: 31-41
- [8] Wiwik E, 2017. *Geochemical study of pyroclastic rocks in Maninjau Lake, West Sumatra*. IOP Conf. Series : Earth and Environmental Science 71 : Geology Study Program, Faculty Engineering, Sriwijaya University
- [9] Verstappen, H.Th; 1973. *A geomorphological reconnaissance of Sumatra and adjacent island (Indonesia)*. International Institute for Aerial Survey And Earth Sciences (ITC): Enchede: Wolter Noordhoff Publishing Groningen
- [10] Hamilton, W., 1979. *Tectonic of the Indonesian Region*. US Geol. Surv. Prof.Paper 1078
- [11] Sieh, K. and Natawidjaja, D. H., 2000, *Neotectonics of the Sumatran Fault*, Indonesia Journal of Geophysical Research, 105(B12) 28,295–28,326.
- [12] Reynolds, J.M. 1997. *An Introduction to Applied and Enviromental Geophysics*. NewYork : John Wiley& Sons.
- [13] Telford, W. M; Geldart, L. P; Sherif, R.E and Keys, D. D. 1976. *Applied Geophysics* First Edition. Cambridge University Press. Cambridge.New York
- [14] Rickard, M. J. 1972. *Geological Structure and Maps*. Pergamon Press.
- [15] Hendrayana H 2013 *Hidrogeologi Mata Air Geological Engineering Dept.*, Faculty of Engineering Gadjah Mada University