E-ISSN : 2541-5794
P-ISSN : 2503-216X

Journal of Geoscience,
Engineering, Environment, and Technology
Vol 10 No 1 2025

RESEARCH ARTICLE

Geothermal Potential of the Dimanjar District, Sumberarum,Tempuran Area Using Resistivity and Geochemical Data Approaches

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Received: Feb 13, 2024; Accepted: Mar 17, 2025.
DOI: 10.25299/jgeet.2025.10.1.16333

Abstract

Hot springs in geological science are associated with geothermal manifestations. The appearance of these hot springs indicates certain geological conditions in the area. In the Dimanjar area, Sumberarum sub-district, Tempuran sub-district, Magelang regency, there are hot springs which residents use for tourism. This research is about the geochemistry of hot springs and looks at the depth of hot springs using the Schlumberger configuration geoelectric method. There are two Schlumberger measurement lines, namely west east and north south, this is because the measurement target or the presence of the spring is perpendicular to the Ngasinan River. The data shows that there are two salt water aquifers at depths of 20-30 meters and 130 meters with resistivity values below 0.5 ohm meter, which is theoretically the resistivity of salt water. Geochemical data also shows that the Cl content is high and this is a mature hot spring. This geochemical data was analyzed from the chloride values of 10 hot springs that emerged both naturally and through drilling. Plotting data in a trilinear triangle indicates the water source comes from a reservoir. The data shows that all water samples are of the chloride type in the range of 40% to 10% mature water. Subsurface and subsurface data show that there are two saltwater aquifers that are quite far apart in depth, this could be due to developing tectonics.

Keywords: Geolistric, Hot Spring, Salt Water.

1. Introduction

Geothermal manifestations can be used for electricity generation and tourism, one of which is hot springs, but not all hot spring samples are the standard for studies of the feasibility of extracting the use of geothermal energy. Geochemical surveys were carried out to determine the chemical type of subsurface water using hot spring samples. The equilibrium process occurs when water below the surface experiences heating and dissolution of compounds in rocks below the surface (Pirajno, 2009), so that hot spring samples have the same characteristics as chemical conditions below the surface.

In general, hot water samples are classified into two types of hot water; chloride sulfate types are usually associated with volcanic rocks, and bicarbonates are associated with carbonate rocks (Nicholson, 1993).

The research area is in the Dimajar area, Sumberarum, Tempuran Magelang. In this area, several hot springs are found and some have developed into warm springs. Geologically, most of the research locations are in the Mount Sumbing Muda Sedimentary Rock Unit which is the result of the last eruption of Mount Sumbing in the form of tuff sand, sandy tuff and andesite breccia.

Other rock units that have quite extensive exposure at the research location are the Lava Rock and Porphyry Andesite Units and the Mount Sumbing Tua Deposits. Lava rocks and porphyry andesites were formed during the Pleistocene and are composed of tuff breccia, lava deposits and porphyry andesite. The Sumbing Tua Mountain Deposit Unit is composed of andesite breccia, agglomerate and tuff which are deposits resulting from the eruption of Mount Sumbing, previously Rahardjo et al (1995).

2. Regional Geology

Magelang and Temanggung Regencies, according to PUPR (2016) use groundwater as the main source of raw water. This is because these two districts are rich in springs, especially found on the eastern slopes of Sumbing Volcano. This condition is caused by the location of the research area which is included in the Quaternary volcanic zone (Van Bamelen 1949) which is composed of andesite, coarse-fine pyroclastic rock, and decomposed rock in the form of lava flows or domes.

The geology of the research area is found on two sheets of regional geological maps, namely: the Magelang sheet (Rahardjo, et al 1995) and Semarang (Thanden 1975). The aquifer-forming formations on the eastern slopes of Sumbing Volcano consist of Volcanic breccia (Qb) as the oldest formation, Deposits of Sumbing Muda Volcano (Qsm), Alluviun (Qa) as the youngest formation, and Dacite (da). However, the geological conditions of the research area are dominated by Deposits of Sumbing Muda Volcano. Apart from that, referring to the regional geological map, faults were found that trended in a northwest-southeast direction and north-south direction. This fault causes a layer of rock which acts as an aquifer to stop and influence the flow of ground water. Therefore, Mount Sumbing has many springs on the eastern slopes (Kresic N and Stevanovic Z 2010; Todd D K and Mays L W 2005). Rahardjo, et al (1996) have conducted regional stratigraphic research (Figure 1) in the research area listed on the Regional Geological Map of the Magelang Sheet (Figure 2).

Based on the interpretation which provides a general description of the research area, it includes volcanic rocks which are composed of 23 rock formations, this includes alluvium, Volcanic Cone Deposits, Basalt, Sumbing Volcanic Lava, Sindoro Volcanic Rocks, Sumbing Volcanic Rocks, Merbabu Volcanic Rocks, Merapi Volcanic Rocks Muda, Gajahmungkur Volcanic Rocks, Jembangan Volcanic Rocks, Sindoro Lama

Volcanic Rocks, Kekep Volcanic Rocks, Crystal Tuff, Gianti Volcanic Rocks, Condong Volcanic Rocks, Porphyry and Lava, Sumbing Lama Volcanic Rocks, Kemalon and Sangko Volcanic Rocks, Telomoyo Volcanic Rocks, Batuan Kaligesik Volcano, Andong and Kendil Volcanic Rock, Gilipetung Volcanic Rock, Blalak Volcanic Rock and Jongkong Volcanic Rock.

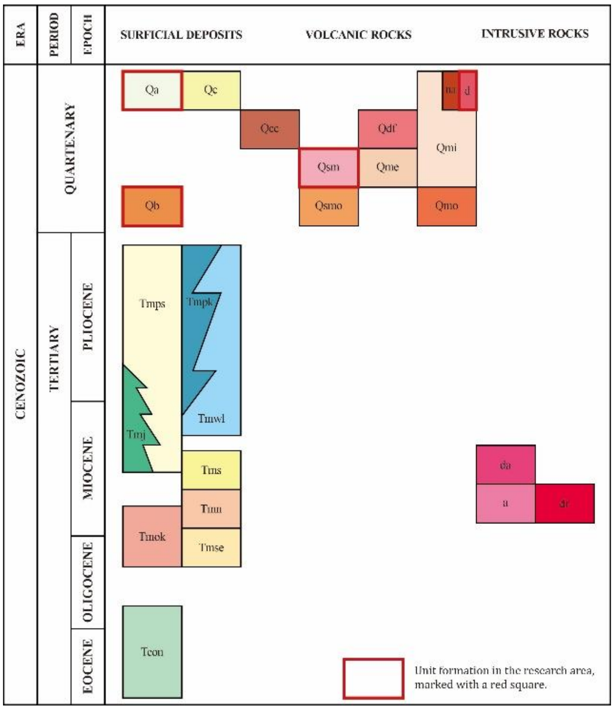

Fig 1. Correlation Map Units of Tempuran

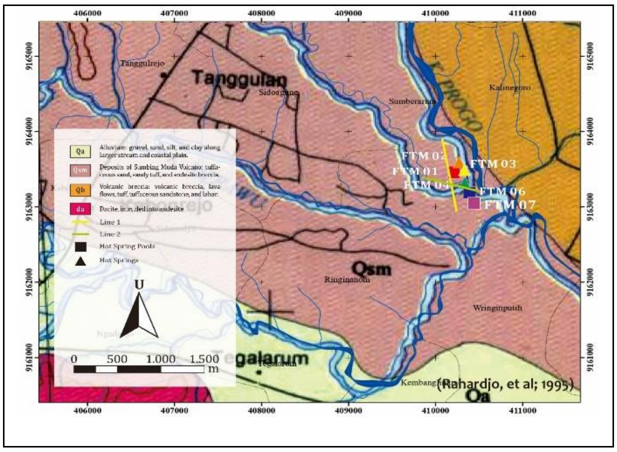

Fig 2. Regional Geology of Tempuran and its surroundings.

3. Geoelectric

This research uses the Schlumberger configuration to identify aquifers and groundwater. Apart from Schlumberger, the geoelectric method has many types of configurations in the data acquisition process in the field, such as Dipole-dipole, Wenner, Pole-pole, and others (Akintorinwa, 2012). Research (Fatimah et al, 2021) to determine the availability of water in aquifer rocks by analyzing surface geology and subsurface layers (geophysical methods) in carbonate areas. The Sclumberger method has shown good results in previous research because it can reach the optimum depth, so it can describe the characteristics of the aquifer precisely (Bharti et al., 2019). supported by good geological knowledge. This is because geological knowledge is useful for interpreting rock types based on the resistivity values obtained. Each type of configuration used affects the apparent resistivity value of the dipole during data acquisition in the field. The reason is because each configuration has a different geometric factor (K) value. In general, to obtain the resistivity value through Equation 1. The Schlumberger method of data shows significant similarity while statistical analysis of geoelectric parameters obtained from various formations in various lithological units shows that there is a strong relationship between various field methods (Oladunjoye & Jekayinfa, 2015).

Identification of aquifer characteristics and soil potential using the geoelectric method must be collected using the Schlumberger method with a stretch of 600 meters. The stretch in the Schlumberger method is a measure of depth that can be measured. A. There are many measurements to determine the mechanisms below the surface which can see the resistivity value of the surrounding lithology. In the aspect of geothermal systems, where thermal manifestations such as hot springs and fumaroles are found, low resistivity can explicitly be caused by the presence of hot water with dissolved minerals in the porous media. The Schlumberger configuration uses 4 electrodes (A, B, M, and N) and during acquisition the spacing between the electrodes is gradually enlarged. The electrode arrangement in the Schlumberger configuration is presented in Figure 3. Result of the distribution of current electrodes AB/2 is equal to or greater than five times the distribution of potential electrodes MN/2 with the depth of investigation as a function of electrode distance (Bassey et al., 2019). In the Schlumberger array configuration, it is difficult for a depth of 100m, so it is better to use the half Schlumberger method, because the ratio of distribution to depth is 2:1 (Diya'ulhaq et al , 2024). Half Schlumberger configuration reveals a better vertical geometry accuracy compared to measurement result from the Dipole-dipole method (Hermawan & Putra 2016).

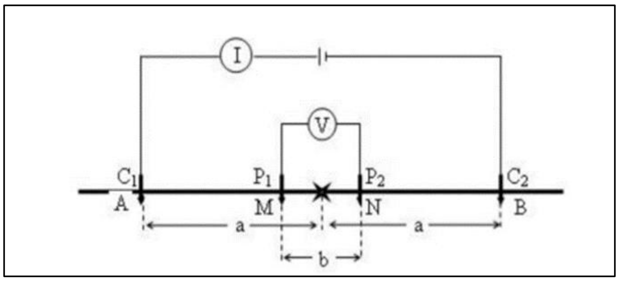

Fig 3. Schlumberger Configuration Electrode Arrangement

In general, rocks are poor electrical conductors and exhibit high resistivity, but as electrolytes fill the pore spaces, the average resistivity decreases. Hydrothermally, the altered rock that forms clay material is a better conductor compared to the protolith. Low resistivity zones are encountered beneath volcanically active areas, high temperature hydrothermal reservoirs may exist. (Hersir, 2009). Apparent resistivity is the most important parameter analyzed when describing a geothermal system because the components of the system have very good contrast in resistivity values. The resistivity value is influenced by the physical and chemical properties related to the existing geothermal system such as fluid salinity, changes, porosity or permeability, and temperature.

Based on regional geological data, the research location is included in the volcanic breccia formation consisting of breccia, molten lava, tuff, tuffaceous sandstone and lava. Sumbing Muda Volcanic deposits consist of tuff sand, sand tuff and andesite breccia and there are quaternary deposits consisting of gravel, sand, silt and clay (Wartono, et al, 1995). Based on the results of surface lithology data collection in the field, it was found that andesite breccia rock, blackish brown in color, massive structure, bolder grain size (256 mm) - sand (1mm), tapered grain shape, open packing, poor sorting, composition of andesite fragments and tuff matrix.

The existence of a hot spring with a salty taste that comes to the surface follows the cracks that cut the andesite breccia rock which is a product of the young Sumbing volcano. The interpretation of the existence of the fault is seen from the direction of the river continuity which is trending northwest-southeast. Based on the clear direction of the sunagi above, measurements were carried out in two directions of geophysical expanse, namely north-south and southwest-northeast. Based on the direction of the joints that cut the breccia rock in the field, it is found that the direction is northeast - southwest with the name Tangsi fault (Helmy, 2014).

Administrative data collection was located around the Ngasinan river, where geologically it is deposits from Mount Sumbing and there is breccia on the river walls. This data was collected with a stretch of 600 meters southwest, northeast and north south. This stretch of data collection is based on heat sources and the Ngasin river.

Geoelectric data processing using Excel to calculate apparent resistivity. This apparent resistivity is obtained from the current (I) divided by the voltage (V) multiplied by the constant of the configuration in question.

Used is the Shlumberger configuration. Plotting the resistivity and depth values will later obtain a curve between the apparent resistivity and the electrode spacing of the Shlcumberger configuration.

This math curve can show that the processed data is far from the existing model conditions. Errors that can be tolerated are below 30%. As we know, the aim of the inversion process is to estimate rock physical parameters that were previously unknown (unknown parameters). The inversion process is divided into certain levels starting from the simplest such as line fitting for refraction seismic data to complex levels such as acoustic tomography and multidimensional resistivity curve matching. So, the aim of this research is to determine the resistivity of subsurface structures at depth by carrying out geophysical measurements and calculations and to obtain the results of estimating resistivity values by arranging electrodes in various configurations (Yuliana 2017).

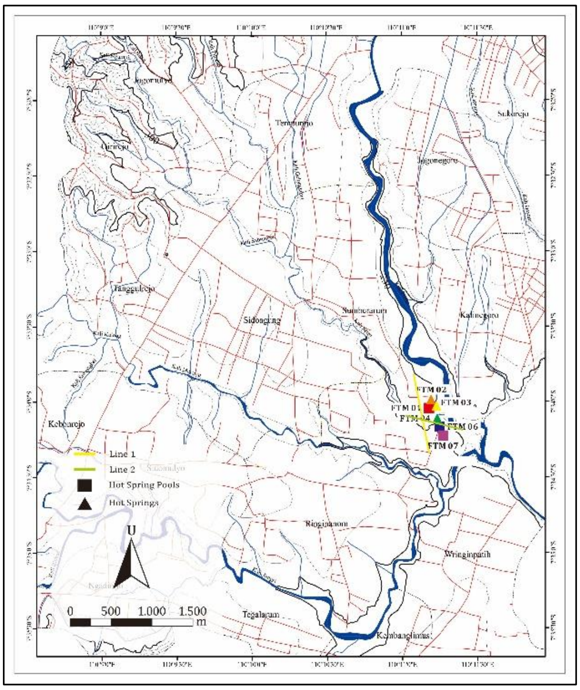

Fig 4. Observation site and geoelectric line in the research area.

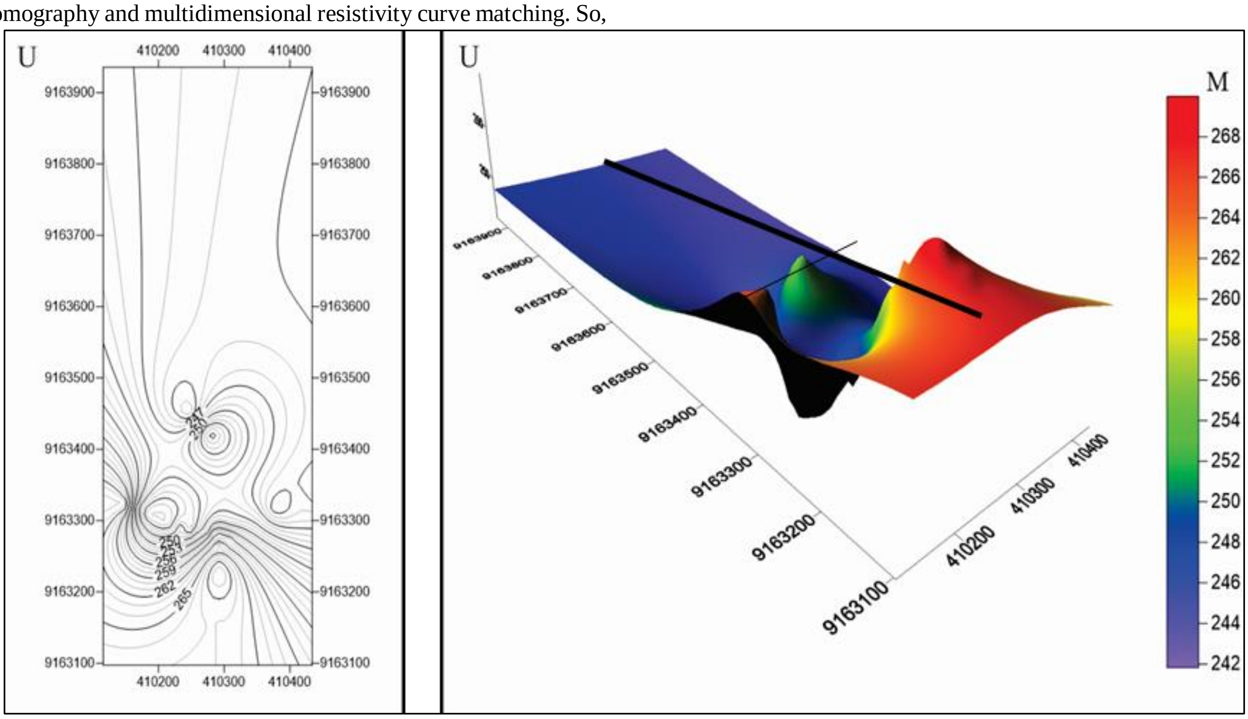

Fig 5. Line of aquisition data

The research results show that resistivity values vary from those indicating rocks that are saturated with water and those that are water sources or aquifers. Based on Telford's classification. The results in this study show that there is a salt water aquifer, which is indicated by a value below 0.5 in the Telford classification. Ordinary water has an indicated resistivity value of 1. In the study of Darisma, et all (2020), the aquifer can be seen from its resistivity value and semi-confined aquifers are at medium depths and low resistivity. From the study (Wahyuni et al, 2021) sandy layers, shale/clay, sandstone, alluvium, sandy in seawater and metal minerals. From the results of the layer analysis, all areas showed a resistivity of 0.5 ohm meters - 10 ohm meters. In research on seawater intrusion (Koesuma, 2025) Resistivity in shallow aquifers containing salt water at 0.1 Ωm - 2.5 Ωm, low resistivity indicates the presence of saltwater rocks.

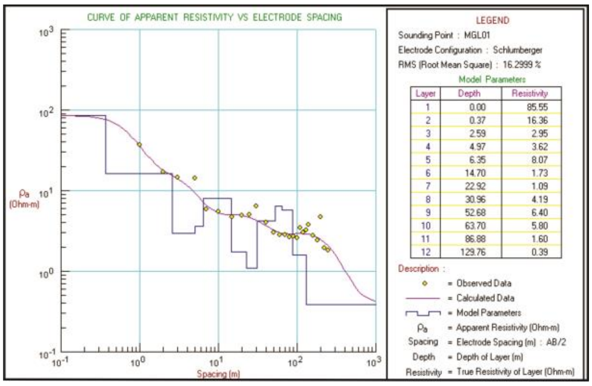

Fig 6. Kurva match of data

The curve resulting from this modeling calculates observation data and calculation data. Correlation from data processing will describe the resistivity value with depth. Analyzing this data with a 600 meter stretch will get a depth of one third of the stretch, which is around 200 m. Line 1 shows that the trend of the Maching curve is decreasing and the resistivity value is still included in the Maching curve. The interpretation results with an RMS error of under 5% to show the different layer variations are good (Daruwati et all, 2023). Line 2 shows that there is a dynamic up and down curve but the resistivity value is still linear with the macthing curve. Vertical cross-section of rock layers can be used to see the condition of rock layers and the thickness of the aquifer and the depth of the aquifer at the measurement point. (Zuhdi et all 2022).

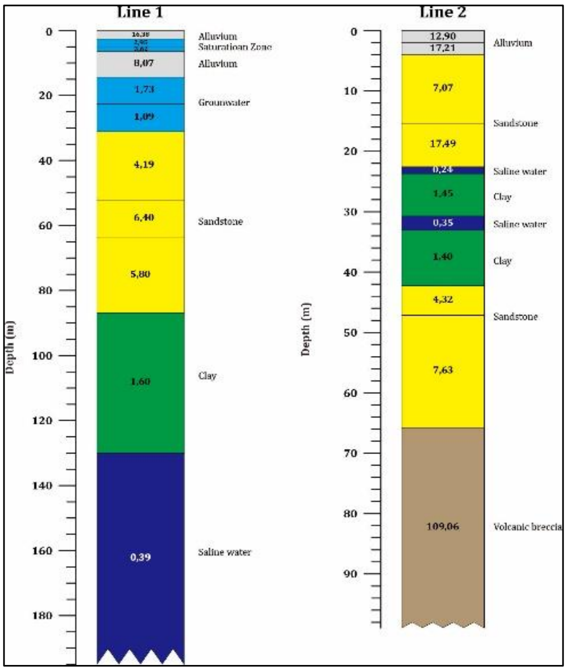

Fig 7. Log of data line1 and line 2

Line 1 shows that subsurface conditions include groundwater aquifers, sandstone, clay and saltwater aquifers. The results from line 2 also show rocks that are almost similar, but here there is breccia (Figure 7). On line 1, the salt water is at a depth of 130 meters, where data is collected through high topography. Line 2 shows that there are two aquifers in salt water, namely at a depth of 20 meters and 30 meters. Data collection for line 2 is on the plains in the direction of the Ngasinan river. The difference in resistivity values is due to differences in characteristics between freshwater aquifers and saltwater aquifers. Saltwater aquifers conduct electric current more easily than freshwater aquifers, so the resistivity value of saltwater aquifers is lower than the resistivity value of freshwater aquifers. The resistivity values of saltwater and freshwater aquifers produced are in accordance with previous research which produced resistivity values for saltwater aquifers. The lower resistivity value of the salt water aquifer is in accordance with other research which states that the characteristics of the salt water aquifer are indicated by a very low resistivity value (Ayu et al 2020).

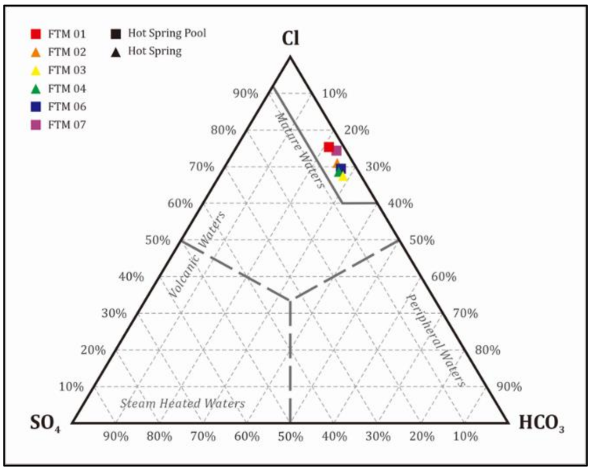

Fig 8. Source of hidrotermal groundwater type.

Determination of geothermal fluids requires chemical data. The chemical data used is the relative content of chloride (Cl), sulfate (SO4) and carbonate (HCO3), the percentages of which have previously been calculated. Trilinear diagram showing the classification of water based on the composition of the main anions, namely Cl-, SO42- and HCO3, as well as the main cations, namely Na+K, Ca and Mg (Vespasiano et al., 2014). The chloride type (mature water) corresponds to the trilinear diagram which indicates the water source comes from a reservoir (Figure 8). Based on the data it can be seen that all water samples are of the chloride type in the range of 10% to 40% mature water. SO4-HCO3-Cl which represents a mixture of shallow groundwater and hot water. In contrast to shallow groundwater, water from hot springs and hot water drilled wells does not show the presence of nitrate content. Based on physico-chemical characteristics and type evaluation groundwater chemical facies, it can be interpreted that the groundwater in the research area comes from 2 aquifer systems, namely a shallow-free aquifer system composed of volcanic breccia rock and a deep-confined aquifer system composed of old Sumbing Volcanic deposits with the depth of the confined aquifer being at depth of approximately 200 m from the ground surface.

4. Conclussion

Based on the research results, three conclusions can be drawn regarding the research objectives and conditions of the Tempuran Area, as follows:

1) Referring to the resistivity value, the dominant subsurface lithology variation is sandstone and mudstone with volcanic breccia as the base of both rocks.
2) In the Tempuran Area, two types of aquifers have developed, namely: a) saltwater aquifer at a depth of ± 23 m which deepens - 130 m - to the south and b) groundwater at a depth of 15 - 30 m in the north.
3) The fluids that make up the Tempuran Area are mainly a) Calcium-Magnesium Bicarbonate Type, a characteristic of shallow groundwater which is

estimated to be the source of water for residents' wells and the Merawu River and b) Sodium-Chloride Type, a characteristic of saltwater aquifer which is estimated to be the source of hot water in bathing pools, hot springs, and the Asin River.

Acknowledgements

Thank you to ITNY for helping with funding through the basic research scheme. Thank you to the team of research lecturers, field assistants and data processing.

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