

# The Possibility of Geothermal Permeability Detection by Using Seismic Refraction Method

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## The possibility of geothermal permeability detection by using seismic refraction method

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**Abstract.** Jatirunggo geothermal field is a hot spring manifestation with temperatures ranges 35°C-38°C. Previous research by the resistivity method concluded that the Jatirunggo field as an outflow zone of a geothermal system. This study aim is demonstrating the possibility of the permeable geothermal zone detection by using seismic refraction method's a complement of the geothermal conceptual model — the main research method by conducting refraction seismic. The method mainly applying active seismic wave to the media and identify the velocity properties of the pathway as a recording logger used 2D geode module which is consisting of 8 channels geophone by 5 meters geophone interval. The penetrating depth can reach 15 m - 20 m. Processing of velocity model has been used Hagiwara algorithm of 2 layers. The result shows velocity seismic recorded has a range of 138 m/s of topsoil layer up to 1742 m/s on the second layer. Based on the velocity model we can interpret the existence of a fault structure corresponding to the emergence of the hot springs, but the method was impenetrable up to the structured target.

### 1. Introduction

Jatirunggo geothermal field is a geothermal hot spring which is located in the Pringapus sub-district, Semarang Regency, Central Java. The manifestation found in this area is in the form of hot springs that emerge from a cliff side. Today there are many hot springs and spa tourism which are used to attract visitors. The presence of visitors who were originally for the purpose of subsequent treatment was attracted by the beauty of the surrounding mountainous landscape that is actually the mountains as a source of geothermal systems[1]. Part of the tourist attraction of an area is if the existence of the tourist location is located in a community, for example, the presence of a location in the community and environment[2]. Jatirunggo geothermal manifestations in the middle of the social community are quite suitable to be used as a tourist attraction, although its position with limited access can be better developed.

This study aims to determine the permeable zone of the hydrothermal system by applying the seismic refraction method. Because the properties of fluid flow will be controlled by rock permeability as indicated by fault permeability properties[3]. The important value of this study is to determine the nature of geothermal fluid flow due to fluid flow based on the fault determination. Determination of fault permeability in this area is actually only the initial part of the conceptual arrangement. The Conceptual models are the basis for making numerical models. The completeness of exploration data in the field will be able to update the accuracy of the conceptual depiction of the model[4]. The Permeable zone is a part of an important component of the geothermal fluid flow system so that it is quite significant to improve the existing geothermal conceptual model[5].

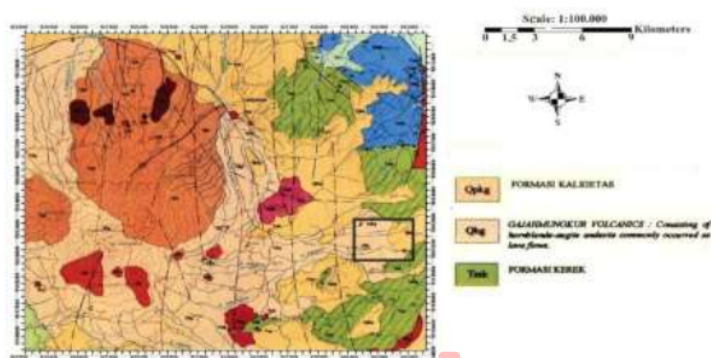


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## 2. Local Geology Area Covered The Survey

The research area is consisting of some layers, which are consisting of various types of rocks, namely volcanic breccia rock, lava flow, tuff, tuff sandstone, and claystone. The local area is grouped into three formations as shown on figure 1, namely the Gajah Mungkur volcanic formation (Qhg), the majority of which are andesite rocks. The second one is the Kerek (Tmk) formation which is a combination of claystone, marl stone, tuff sandstone, and conglomerate. In this formation, there are limestones which are generally layered. This unit is middle Miocene. Around the study, there were also Gajahmungkur Volcanic Rock Formations which consisted of hornblende-augite, generally lava flows [6]. It was also found that the Kaligetas formation (Qpkg) was composed of volcanic breccias, lava flows, tuffs, and clay stones. At the bottom, there are volcanic rocks which are reddish brown and often form large lumps.



**Figure 1.** The intrusion of igneous rock in the eastern part of the study area

On the eastern part of the study area (figure 2), it found an igneous rock was intruded to the surface. When the heat infiltrated the rock, and the process of dehydration and decarbonation from the rock matrix occurs, then the intrusion of the rock will occur an intrusion process and a decrease in temperature [7].

Frozen rock comes from magma that melts and has a density that is less dense compared to the surrounding rocks so that it is capable of penetrating rocks above it. Full or partial magma comes from molten rocks, which when frozen into igneous rock consist of several mineral components. Physically it consists of solid, liquid and gas components. In a liquid component called melt, magma consists of several dominant elements that make up the earth's crust. For solid components, some are composed of crystals which are formed of silicate minerals. The gas component of magma is called volatile, a mineral that evaporates [8].



**Figure 2** The intrusion of igneous rock in the eastern part of the study area

### 3. Methods

This study uses the seismic refraction method to analyze subsurface conditions, both to clarify subsurface layers resulting from geological surveys and fault structures. The seismic refraction method is commonly used by seismic reflection consultants to make static corrections and is generally used for building construction techniques[9][10].

In this study, the expected target is to obtain subsurface rock structure configurations around Jatirunggo geothermal manifestations. The geothermal field is located above the *Geyongan* river; it is quite difficult to apply the method above the emergence of hot water manifestations (as shown in figure 3). The closest area that allows a 300-meter refraction survey to be carried on the south of the hot springs. Field data measurement uses 8 geophones with 5 m intervals and Geode logger (*geometrics*). In this study the research target covers an area of 120 meters, then it is divided into 3 segments (figure 4). The seismic source was used 2 kg hammer struck on a steel plate. Data recording is done by slamming the hammer into the metal plate for 4 to 5 times for each side and reciprocal method[11].

Data processing is carried out using 2 layers Hagiwara method[12]. Measurement data are consist of onset time and the distance between the seismic source (hammer) to each of geophones. Data processing is done by determining the onset time received by each geophone. Furthermore, the determination of seismic velocity the data onset time plotted the geophone distance as a graph. Seismic wave velocity at layer 1 is determined based on the mean value of travel time of direct surface wave.



**Figure 3.** The geothermal field is located above the *Geyongan* river; it is quite difficult to apply the method above the emergence of the hot water manifestation.



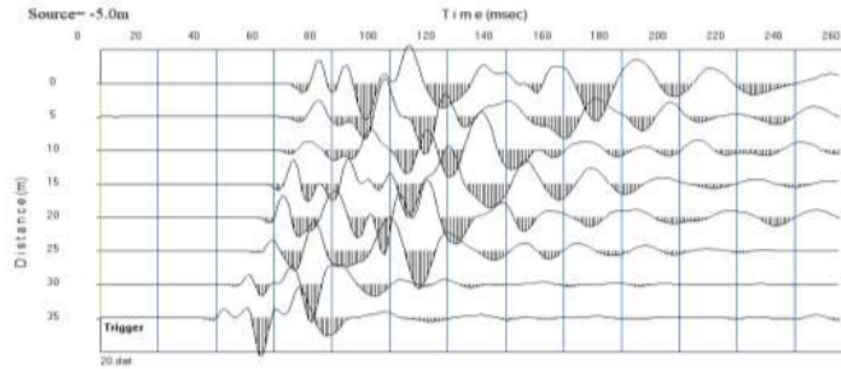
**Figure 4.** The field survey is conducted along the rural roads and divided by 3 segments.

### 4. Results and Discussion

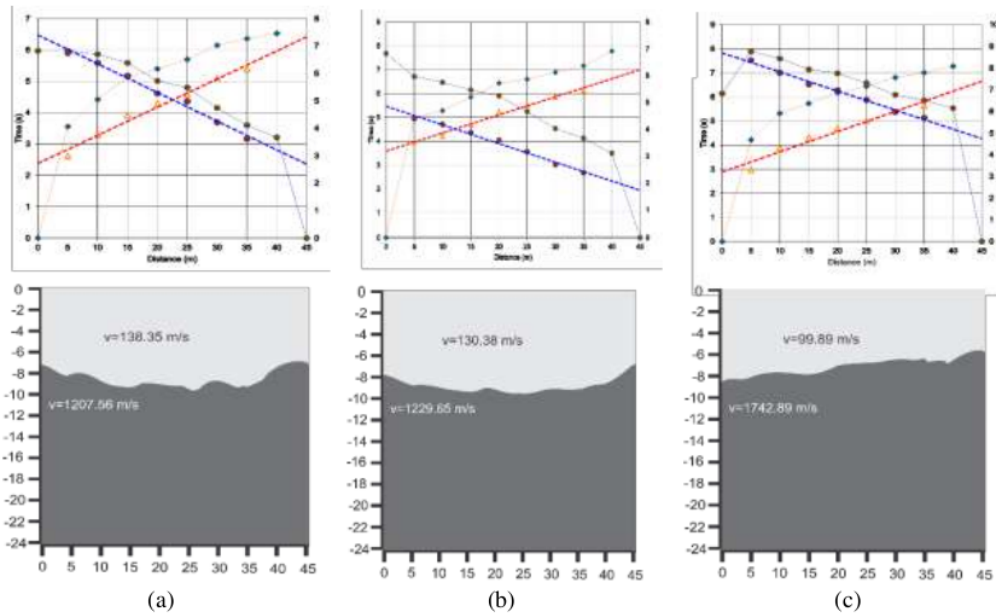
The first arrivals data from the P wave is determined directly from the P arrival (arrival time) record. Figure 5. Shows examples of raw data records that will be determined P arrival of the timesheets. The results of data processing are generally clarified with drilling data, rock outcrop data (lithology) and the results of geophysical measurements by other methods can be quite helpful. In this study the availability of data from resistivity records and the field geological outcrops. Determination of seismic velocity at the first layer (thin surface layer) which is dominated by the topsoil is decided base on the mean value of the direct surface travel time to the geophone interval. In the three segments, data



acquisition are consist of low seismic velocity, the range of 99 m/s to 138 m/s. The layer is composed of a depositional layer with a thickness of about 5 m - 8 m — this layer contained silt, sand, and gravel (weathered surface deposit). Figures 6 are the results of seismic velocity calculations in each segment.



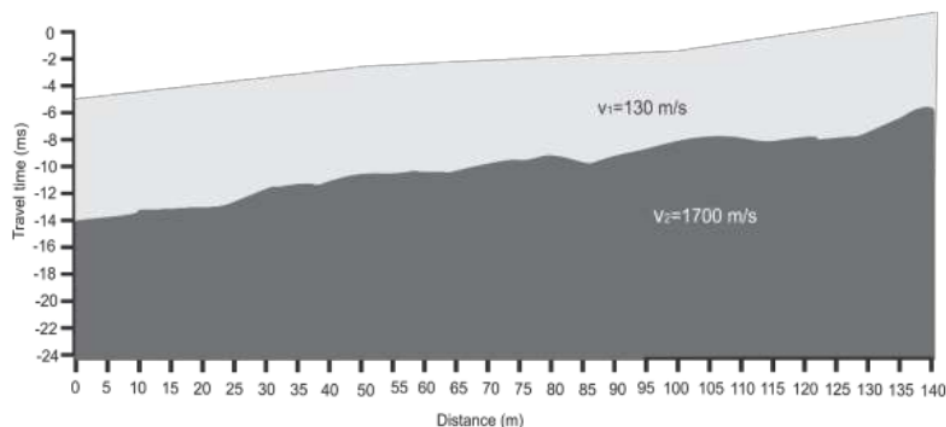
**Figure 5** Samples of the collected raw data



**Figure 6.**Subsurface velocity structure of all segments

The second layer comprises higher seismic velocity; the P-wave velocity ranges between 1207 m/s to 1742 m/s. It coincides to the tufan clay and sandstone. According to the three measurement segments, then interpreted into a profile layout. The calculation results of each segment provide a penetration depth of the second layer is obtained at a depth of 8 m to 10 m (as shown in figure 7). The penetration depth by using seismic refraction depends on the number of geophones or the length of the measurement path[13].

The application of the refraction method for determining the permeability of a formation for hydrological purposes can be applied primarily to determine its porosity and permeability as done in the Galapagos field[14]. Hydrological study obtaining porosity zones in Galapagos was concluded that for wet areas the seismic velocity values were in the range of 2300 m/s to 2700 m/s, and in dry areas in the range of 1300 m/s - 1500 m/s[9]. This research was conducted in the dry season, August 2018, so that it refers to the seismic velocity associate to the field porosity that corresponds to the fluid flow in the dry areas, but the evidence based on seismic velocity is not enough to conclude the hydrothermal flow.



**Figure 7.** Interpreted of the subsurface field structure

## 5. Conclusion

The application of seismic refraction method can be used to observe the hydrological of a field corresponding to the velocity value and the nature of the porosity. This research achieves the seismic velocity results coincided well to the lithological properties and showed the same rock types as the resistivity results. There are 2-layer of Hagiwara method obtained the seismic velocity on topsoil layer of 99 m/s up to 138 m/s and for the second layer with a seismic velocity of 1207 m/s up to 1742 m/s. We conclude that the use of the seismic refraction method to determine the fluid permeability of a field can be used, but for the geothermal field, the penetration is too shallow.

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