Journal of Technomaterial Physics
Journal homepage: https://talenta.usu.ac.id/JoTP

Identification of Rock Characteristics Using the Microtremor Inversion Method at Air Putih Geothermal Field, Lebong Regency

M Taufiqurrahman Syah, Andre Rahmat Al-Ansory, Debi Hardiansa, Ardika Panjaitan, Ronni Saragih, Nanang Sugianto*, Halauddin, Budi Harlianto, Refrizon, Arif Ismul Hadi, M.Farid, Suhendra, Nabilah Rofifah, Rona Gustina, Nurul Ilmi Rahmawati, Olga Triutami, and Lulu Indah Setiawati

Geophysic Study Program, University of Bengkulu, Indonesia

*Corresponding Author: nanang.s@unib.ac.id

ARTICLE INFO

Article history:
Received 5 February 2024
Revised 12 February 2024
Accepted 19 February 2024
Available online 29 February 2024

E-ISSN: 2656-0755
P-ISSN: 2656-0747

How to cite:
M. T. Syah, A. R. Al-Ansory, D. Hardiansa, A. Panjaitan, R. Saragih, et al., "Identification of Rock Characteristics Using the Microtremor Inversion Method at Air Putih Geothermal Field, Lebong Regency," Journal of Technomaterial Physics, vol. 06, no. 01, pp. 47-55, Feb. 2024, doi: 10.32734/jotp.v5i1.16047.

ABSTRACT

Research has been carried out to identify rock characteristics based on Vs values using the microtremor method in the Air Putih geothermal field, Lebong Regency, which aims to determine the geothermal prospect area on rock characteristics using Vs values based on the microtremor method. The data obtained in this study were 20 measurement points obtained from data analysis by obtaining the H/V curve through Geopsy software and HVSR inversion to obtain the Vs value of the inverse. The results of this calculation indicate that at a depth of 0-4 meters the homogeneous Vs value 200 m/s, at a depth of 4 meters the Vs value 200-440 m/s, at a depth of 20 meters the value of Vs 440-880 m/s and a depth of 20 meters homogeneous Vs value of 880 m/s and for the distribution of Vp values, at a depth of 0-5 meters the Vp values vary between 2000-2900 m/s, at depths of 6-20 meters in general the value of the Vp wave velocity is the same in the range of 3100-3800 m/s and at depth 21-100 meters the Vp value ranges from 3900-5100 m/s. This shows that the greater the depth, the denser the rock.

Keywords: Geothermal, HVSR, Microtremor, Rock Characteristics

ABSTRAK

Telah dilakukan penelitian identifikasi karakteristik batuan berdasarkan nilai Vs dan Vp menggunakan metode mikrotremor di lapangan geothermal Air Putih Kabupaten Lebong yang bertujuan untuk mengetahui daerah prospek geothermal pada karakteristik batuan dengan melalui nilai Vs dan Vp berdasarkan metode mikrotremor. Data yang didapatkan dalam penelitian ini sebanyak 20 titik pengukuran diperoleh dari analisis data dengan mendapatkan kurva H/V melalui software Geopsy dan inversi HVSR untuk memperoleh nilai Vs dari dinvers. Hasil perhitungan ini menunjukkkan bahwa pada kedalaman 0-4 meter nilai Vs homogen adalah 200 m/s, kedalaman 4 meter nilai Vs 200-440 m/s, kedalaman 4- 20 meter Vs homogen 440 m/s, kedalaman 20 meter nilai Vs 440-880 m/s dan kedalaman 20 meter hingga 100 meter secara umum nilai Vs homogen 880 m/s dan untuk persebaran nilai Vp, pada kedalaman 0-5 meter nilai Vp nya bervariasi berada di antara 2000-2900 m/s, pada kedalaman 6-20 meter secara umum nilai kecepatan gelombang Vp sama berkisar pada 3100-3800 m/s dan pada kedalaman 21-100 meter nilai Vp nya berkisar antara 3900-5100 m/s. Hal ini menunujukkan bahwa semakin besar kedalaman maka batuannya juga semakin padat.

Kata kunci: Geothermal, HVSR, Karateristik Batuan, Mikrotremor

1. Introduction

Geothermal energy is a renewable energy source in the form of thermal energy generated and stored in the earth's core [1]. The increasing need for energy and the scarcity of fossil energy sources have spurred other countries. To reduce dependence on on fossil energy by utilizing geothermal energy to produce electrical energy. Geothermal energy is a renewable energy that is environmentally friendly (clean energy) compared to fossil energy sources, but the utilization of geothermal energy in Indonesia is generally not optimal.

Based on Law Number 21 of 2014, geothermal utilization is classified into two types, namely direct and indirect utilization. One of the geothermal energy potentials found in Bengkulu Province is the geothermal energy source located in the Air Putih area, North Lebong sub-district, Lebong district, which has a potential of around 173 MWe, located in the position of 3°LS and 102°BT.

Based on field observations, the geothermal area is located at a topographic height of 446 m above MSL and there are also sources of high temperature hot water (100°C -115°C) located in several places, the source is a surface manifestation of a geothermal system that has not yet been explored by researchers [2]. According to Toth and Bobok (2017), Geothermal Energy is heat energy that comes from the crust, mantle, and core of the earth with high temperatures, when the earth's components are in hotter conditions than conditions on the surface, heat energy will continue to move from hotter subsurface conditions to the surface through impermeable rock [3]. The existence of a geothermal energy system is usually characterized by surface manifestations. Some surface manifestations show symptoms such as fumaroles and solfatara, hot springs, hot mud, soil vapor, geysers, craters, and alteration rocks. The important components of a geothermal system according to Suharno [4] are:

1. Heat source.
2. Reservoir or porous rock where hot vapor is trapped.
3. Caprock or overburden in the form of claycap (impermeable rock).
4. Geological structures (faults, fractures, and misalignments).
5. Water catchment area or subsurface water flow (recharge area).

Various exploration methods can be used to identify potential geothermal energy sources in the subsurface, geophysical methods are methods that are generally often used for the exploration of geothermal energy sources [5]. The geophysical method used in this research is the microtremor method and processed by the HVSR (Horizontal Vertical Spectre Ratio) method. This method is a method of comparing the spectrum of the horizontal component to the vertical component of the microtremor wave [6]. Microtremor consists of a basic variety of Rayleigh waves, it is thought that the peak period of the microtremor H/V ratio provides the basis of the S wave period. The H/V ratio in microtremor is the ratio of the two components that theoretically produces a value. The dominant period of a location can basically be estimated from the peak period of the microtremor H/V ratio [7].

The dominant frequency value can provide information about the type and characteristics of rocks found in the study area. Amplification is the magnification of seismic waves that occurs due to significant differences between layers, in other words, seismic waves will experience magnification, if they propagate in another medium that is softer than the medium that was passed before. The greater the value of the difference produced, the greater the magnification experienced by the wave will be [8]. Previous research conducted by Arintalofa et al. conducted research on geothermal manifestation areas by processing microtremor data that had been measured using the Horizontal Vertical Spectral Ratio (HVSR) method, the conclusion was that the Diwak and Derekan geothermal manifestation areas were in a geothermal system located in the zone of outflow, the appearance of manifestations in the form of hot springs in the Diwak and Derekan research areas is due to the presence of faults in the form of normal faults which are considered as weak zones and cause the release of geothermal fluids to the surface [9].

Microtremor measurement is a passive seismic measurement to record vibrations generated by earth activity or human activity, this method is used to determine the condition of the subsurface structure based on its dominant frequency and amplification factor. The HVSR method was first introduced by Nogoshi and Iragashi who stated the relationship between the ratio of horizontal and vertical components to the ellipticity curve of Rayleigh waves which was later refined by Nakamura [10].

The HVSR analysis method is the vibration of shear waves stored in sedimentary materials or materials located on top of bedrock. The HVSR Equation formula is:

$$HVSR = \frac{\sqrt{\left(A_{(U-S)}(f)\right)^2 + \left(A_{(B-T)}(f)\right)^2}}{\left(A_{(V)}(f)\right)} \tag{1}$$

The subsurface Vs value obtained from the HVSR curve can be used to determine the Vs value based on soil classification [11]. Based on the above background, this study aims to determine the geothermal prospect area on rock characteristics through the Vs value in the Air Putih geothermal area of Lebong Regency based on the microtremor method.

2. Method

2.1. Research Locations

This study was conducted using regional survey in the geothermal area of Water Village Putih, Pinang Berlapis District, Regency Lebong, with 20 number of pickup points data. Geographically the study area located at position 3°02'40" S - 102°11’40”.

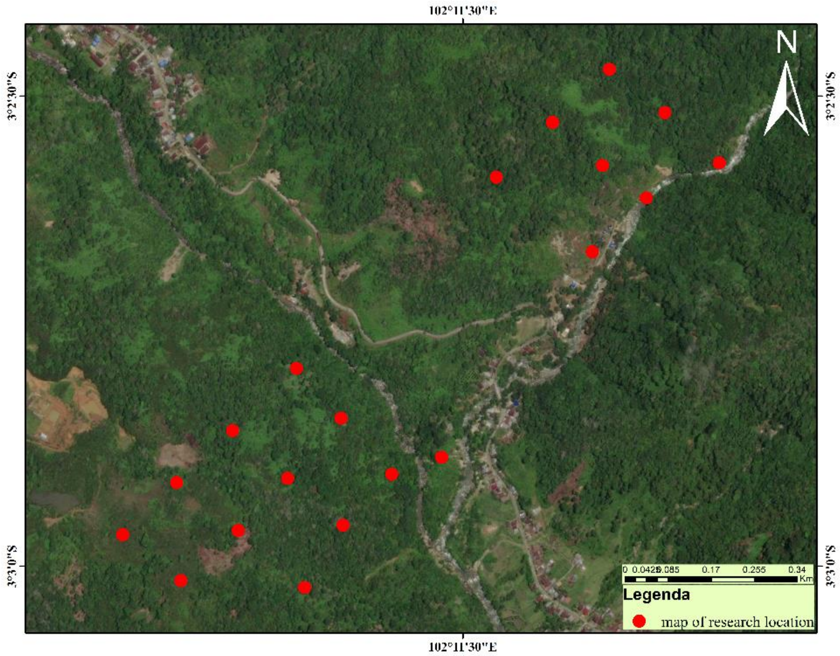

Figure 1. Map of research location.

2.2. Geology

This research was conducted using a regional survey in the geothermal area of Air Putih Village, Pinang Berlapis District, Lebong Regency, with 20 data collection points. Geographically, the research area located at position 3°02'40 "S -102°11'40". The stratigraphic arrangement of rocks in Lebong Regency is from old to young rocks, namely the Hulusimpang formation, Seblat formation, Lemau formation, Bintunan formation and Simpangaur Formation [12].

1. Hulusimpang Formation
   The Hulusimpang Formation consists of lava, volcanic breccia and altered tuff, composed of andesite to basalt. It is estimated that this unit was deposited in the late Oligocene - Early Miocene in the transitional environment of land - shallow sea.
2. Seblat Formation
   This formation is of late Oligocene - Middle Miocene age where the lower part of the unit consists of partly carbonate sandstone and the middle part consists of limestone and claystone. The upper part consists of clay shale, tuff, marl and conglomerate.
3. Lemau Formation
   The Lemau Formation consists of breccia with tuffaceous sandstone inserts containing mollusks in the lower part. The upper part consists of sandstone and tuffaceous sandstone with claystone and limestone inserts. This rock unit was deposited in a shallow marine environment in the Middle to Late Miocene.
4. Bintunan Formation
   The Bintunan Formation consists of conglomerate, breccia, tuffaceous claystone containing a thin layer of lignite. Stratigraphically, this unit was deposited in a brackish water transitional environment in the Plio-Plistocene.
5. Simpangaur Formation
   The Simpangaur Formation consists of breccia and conglomerate with sandstone and coal inserts in the lower part. The upper part consists of siltstone and claystone containing aquatic mollusks freshwater. This rock unit is of Late Miocene-Early Miocene age [13].

The microtremor data analysis process is obtained from the field in the form of vibration waves by the PASI Mod Gemini 2 Sn-1405 Seismometer in the form of SAF files, processed using Geopsy Software with the HVSR method to produce H / V curves to obtain the dominant frequency parameters (f_0) and amplification (f_0). HVSR inversion using Dinver Software aims to model the structure under the earth's surface using the principle of Monte Carlo (MC) by reducing misfit. Parameter calculations are performed iteratively until the H/V curve matches the measured H/V curve and obtains the shear wave velocity (Vs). After the data processing is completed, the final result is a 2.5 dimensional surface model.

3. Results and Discussion

The velocity value of shear waves (Vs) to identify the characteristics of subsurface rocks in the Air Putih geothermal field area of Lebong Regency has been classified based on. Figure 1 is a 1 dimensional profile of the shear wave velocity (Vs) value against depth in meters from microtremor data starting from the H/V curve.

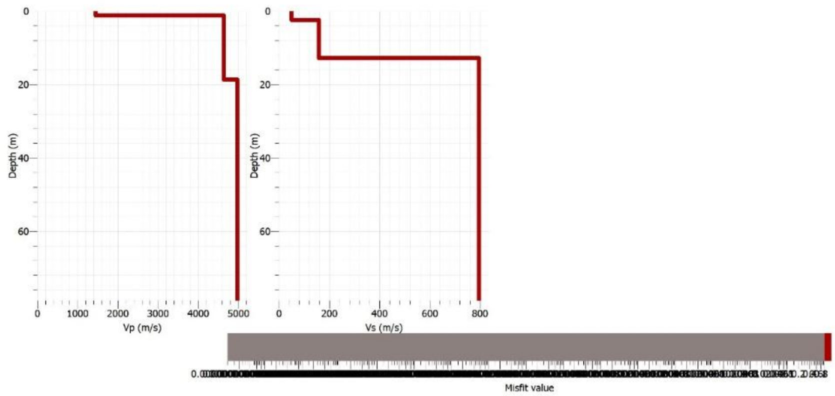

Figure 2. Profile 1 D microtremor data in the form of primary wave velocity (VP) and shear wave (Vs).

Based on the Figure at a depth of 0-4 meters the homogeneous shear wave velocity value is 200 m/s, a depth of 4 meters has a shear wave velocity value of 200-440 m/s, a depth of 4-20 meters has a homogeneous shear wave velocity value of 440 m/s, a depth of 20 meters the shear wave velocity value is 440-880 m/s and a depth of 20 meters the homogeneous shear wave velocity value is 880 m/s. Based on the relationship of the shear wave velocity (Vs) with depth (meters), the deeper the depth, the greater the shear wave velocity (Vs).

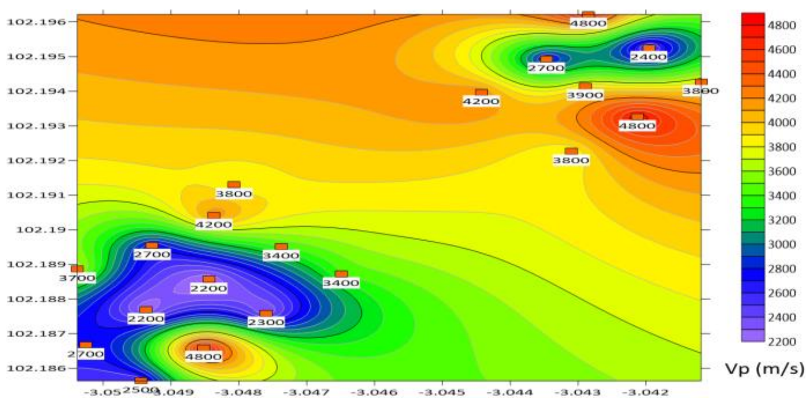

Figure 3. Distribution of Vp values at a depth of 5 meters.

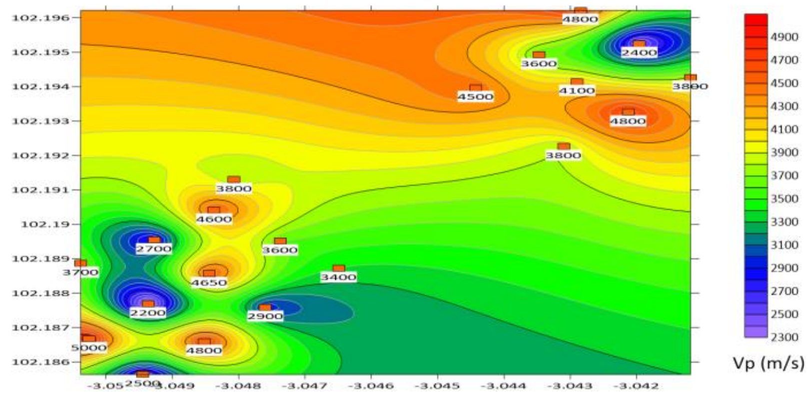

Figure 4. Distribution of Vp values at a depth of 10 meters.

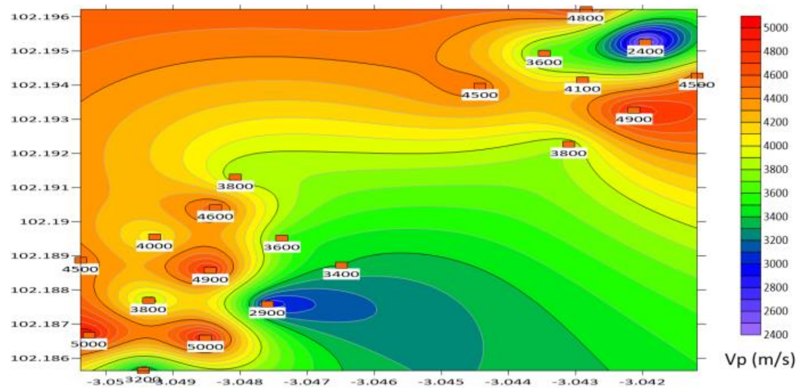

Figure 5. Distribution of Vp values at a depth of 30 meters.

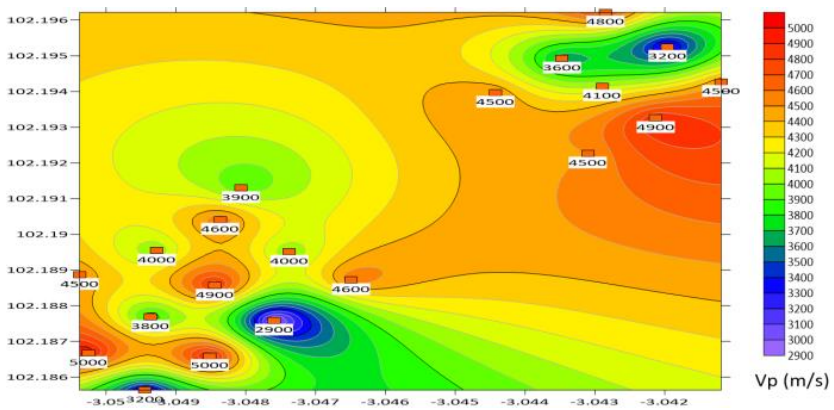

Figure 6. Distribution of Vp values at a depth of 50 meters.

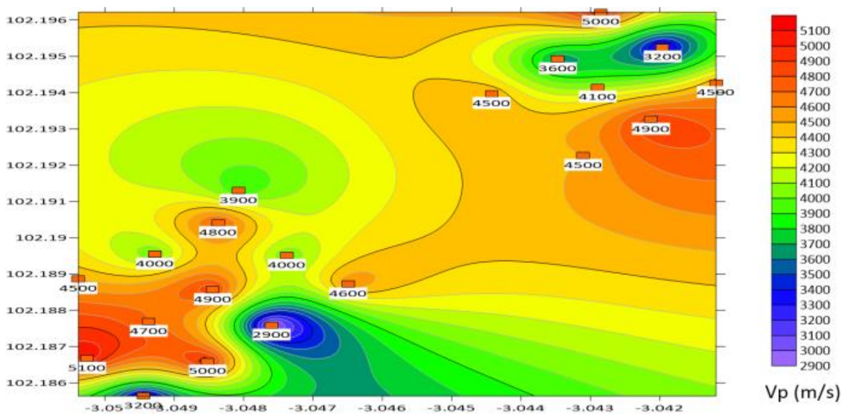

Figure 7. Distribution of Vp values at a depth of 100 meters.

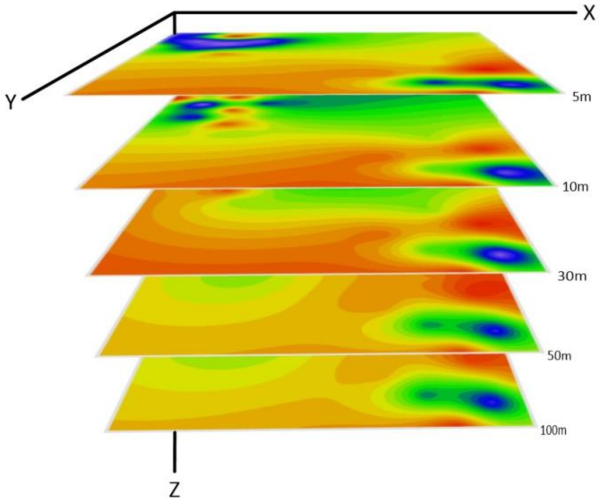

Figure 8. Model 2.5 D values of Primary wave speed (Vp).

The structural analysis of the shear wave velocity value Vs is guided by the table of soil site groups according to SNI 1726 (BSN, 2019). regarding the relationship of the Vs value with the site group and the assumption of the layer structure in the rock, especially the hardness level of the rock and its characteristics.

Table 1. Group of soil or rock sites according to SNI 1726.

Site Class	Vs (m/s)
SA (hard rock)	>1500
SB (rock)	750-1500
SC (hard, very dense soil, as well as soft rock)	350-750
SD (medium soil)	175-350
SE (soft soil)	<175

Table 2. The value of seismic wave velocity in volcanic rocks according to Gardner and House (1987).

Rock Type	Vp (m/s)	Vs (m/s)
Tuff	1430	870
Silicic Tuff	2160	830
Rhyolite	3270	1980
Latite	3770	2210
Volcanic Breccia	4220	2490
Trachyte	5410	3050
Andesite	5230	3060
Basalt	3350	1640
	4760	2190
	5060	2720
	5410	3210
	6400	3200
Basaltic Scoria	4330	2510

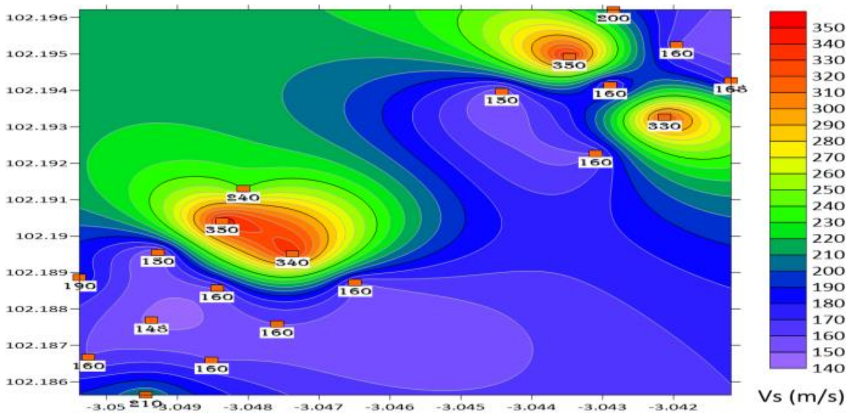

Figure 9. Distribution of Vs values at a depth of 5 meters.

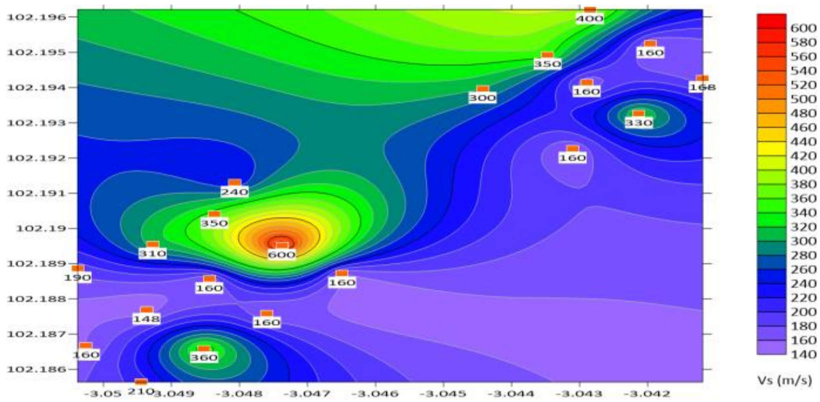

Figure 10. Distribution of Vs values at a depth of 10 meters.

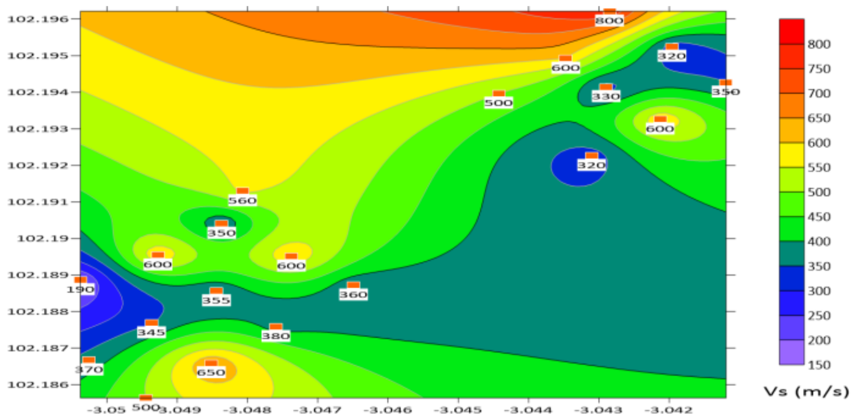

Figure 11. Distribution of Vs values at a depth of 30 meters.

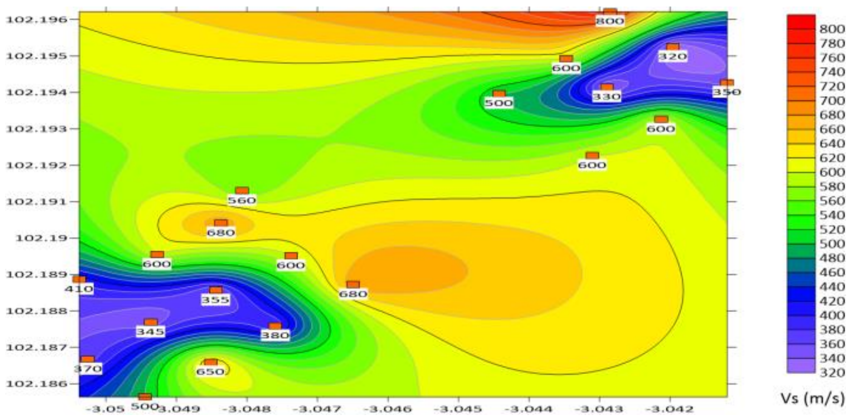

Figure 12. Distribution of Vs values at a depth of 50 meters.

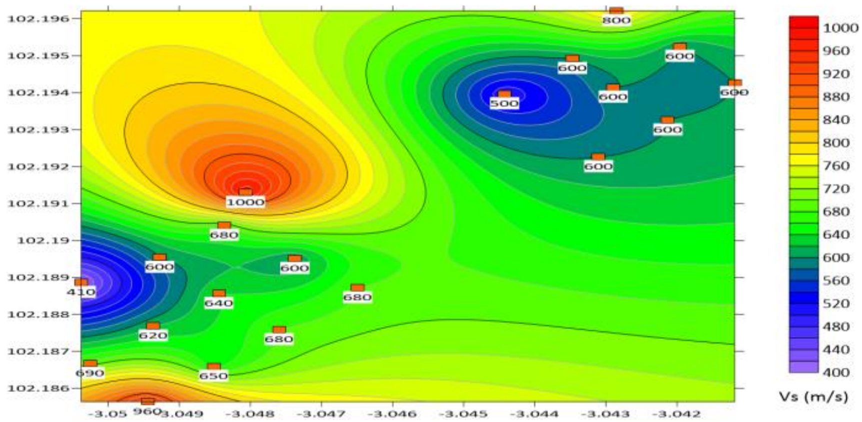

Figure 13. Distribution of Vs values at a depth of 100 meters.

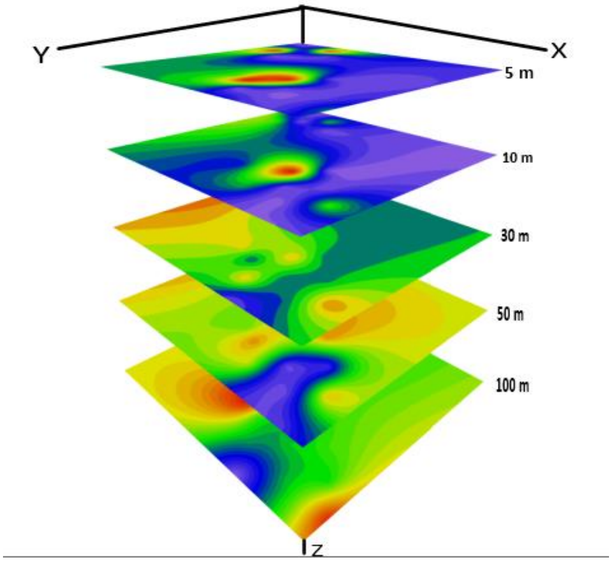

Figure 14. Model 2.5 D value of Shear wave velocity (Vs).

4. Conclusion

The value of shear wave velocity (Vs) in Air Putih, Lebong Regency shows that at several points of the data collection location the wave velocity Vs at a depth of 1 meter to 100 meters does not change much, meaning that it is assumed that the type of material in the layer at that point is homogeneous. And most of the research locations show that at a depth of 100 meters the Vs value varies until the largest value is 1000 m/s, this indicates that at a depth of 100 meters it is assumed that the rock type is hard rock (hard rock) because given the nature of seismic wave propagation in the subsurface medium, the greater the Vs value, the denser the rock and vice versa.

References

[1] H. Andayany and M. Y. S. Risakota, "Potensi Energi Panas Bumi Dan Rekomendasi Pemanfaatannya Pada Daerah Haruku Maluku Tengah," *BAREKENG J. Ilmu Mat. dan Terap.*, vol. 13, no. 2, pp. 69–74, 2019, doi: 10.30598/barekengvol13iss2pp069-074ar768.

[2] M. Farid, A. I. Hadi, and Fetusianti, "Analisis Resistivitas Batuan Berdasarkan Data Geolistrik Untuk Memprediksi Sumber Panas Bumi (Studi Kasus: Daerah Air Putih, Kec. Lebong Utara, Kab. Lebong, Prov. Bengkulu)," *J. Sains MIPA*, vol. 14, no. 2, pp. 79–84, 2008.

[3] A. Toth and E. Bobok, *Flow and Heat Transfer in Geothermal Systems: Basic Equations for Describing and Modelling Geothermal Phenomena and Technologies*. Elsevier Inc., 2017.

[4] Suharno, *Pengembangan Prospek Panas Bumi*. Bandar Lampung: Universitas Lampung, 2010.

[5] N. Nasution, "Penentuan Daerah Potensi Geothermal dengan Menggunakan Metode Seismik di Medina," *J. Einstein*, vol. 8, no. 1, pp. 25–31, 2020.

[6] L. Lantu, S. Aswad, F. Fitriani, and M. Marjiyono, "Pemetaan Wilayah Rawan Bencana Gempabumi Berdasarkan Data Mikrotremor Dan Data Bor," *J. Geocelebes*, vol. 2, no. 1, pp. 20–30, 2018, doi:

10.20956/geocelebes.v2i1.3721.
[7] R. Kurniawan, M. N. Eva, Marjiyono, and Sismanto, “Pemetaan Daerah Rawan Resiko Gempa Bumi Menggunakan Metode HVSR di Kotamadya Denpasar dan Sekitarnya, Bali,” *Kurvatek*, vol. 2, no. 1, pp. 21–30, 2017.
[8] S. S. Arifin, B. S. Mulyatno, Marjiyono, and R. Setianegara, “Penentuan Zona Rawan Guncangan Bencana Gempa Bumi Berdasarkan Analisis Nilai Amplifikasi HVSR Mikrotremor dan Analisis Periode Fundamental Daerah Liwa dan Sekitarnya,” *J. Geofis. Eksplor.*, vol. 2, no. 1, pp. 30–40, 2014.
[9] V. Arintalofa, G. Yulianto, and U. Harmoko, “Analisa Mikrotremor Menggunakan Metode HVSR untuk Mengetahui Karakteristik Bawah Permukaan Manifestasi Panas Bumi Diwak dan Derekan Berdasarkan Nilai Vp,” *J. Energi Baru dan Terbarukan*, vol. 1, no. 2, pp. 54–61, 2020, doi: 10.14710/jebt.2020.9276.
[10] N. A. F. Tanjung, H. P. Yuniarto, and D. Widyawarman, “Analisis Amplifikasi Dan Indeks Kerentanan Seismik Di Kawasan Fmipa Ugm Menggunakan Metode HVSR,” *J. Geosaintek*, vol. 5, no. 2, p. 60, 2019, doi: 10.12962/j25023659.v5i2.5726.
[11] R. Fatimah, T. Ardianto, and N. Qomariyah, “Mikrozonasi Gempabumi Di Desa Medana Dan Jenggala Kecamatan Tanjung Kabupaten Lombok Utara Menggunakan Metode Mikroseismik,” *Indones. Phys. Rev.*, vol. 2, no. 1, pp. 18–26, 2019, doi: 10.29303/ipr.v2i1.19.
[12] M. H. Yasrullah, “Geologi dan Tektonik Neogen Daerah Kedurang dan Sekitarnya, Bengkulu Selatan,” Universitas Sriwijaya, 2018.
[13] S. Gafoer, T. Amin, and R. Pardede, “Peta Geologi Lembar Bengkulu, Sumatera. Skala 1 : 250.000,” Bandung, 1992.