Relationship Model between Electrical and Elastic Properties of the Surface Rocks

Lantu, D. A. Suriamihardja, A.M .Imran, Tri Harianto

Abstract- A mathematical model has been developed to obtain the relationship between two parameters of electrical resistivity and mechanical elasticity of subsurface rocks of the hydrothermal area of Panggo-Killing in Sinjai Regency.The model was developed using data exploration concerning of both methods from the area under consideration. Constructed model is able to relate a time travel of seismic waves propagation that stands for mechanical elasticity to electrical resistivity in the area. The characterictic properties of the relation show a close connection to the parameter of porosity of the subsurface rocks. Comparing the results derived from the modeling with that of obtained from measurement gives suitable approximation with error level of less than 20%. The study concludes that the model is able to predict mechanical elasticity by using geo-electric method, or electric resistivity by using seismic refraction method.

Keywords: geo-electric, seismic refraction and modeling

I. INTRODUCTION

The increasing consumption of energy and demand of natural resources in the subsurface of the Earth lead to the increasing role of exploration. At the same time, scientific engineering for design and construction of infrastructures need more comprehensive information concerning the structure of bedrock. It is due to the facts that many buildings and roads have been damaged caused by the lack of information of soil properties where structures and building are constructed. The exploration as well asexploitation of natural resources and structural mapping of subsurface rock is reallyrequired whileenvironmental sustainability must remain guaranteed from the impacts.The Geophysical explorations are reasonably less priced and nondestructive method, and are the very potential for the exploration and mapping of the bedrock structure comprehensively. Thedevelopment of science and technology was so advanced currently cause everyone always tried to get work done effectively, efficient and low cost but the remain jst optimal .Rocks beneath the surface store various natural resources that very abundant,need the comprehensive exploration technique to investigate that.Resources(Akintorinwa, 2009). Nevertheless, geophysical explorations are of no absence of fundamental flaws. Consequently, careful activities duringexploration conducted need to obey precautionary principle. Geophysical explorations are the common methods conducting in: (1) indirect measurement; (2) using limited number of parameters; (3) using more than one methodstotransformation model that can link electrical resistivity to mechanical elasticityparameters in exploring subsurface rocks as was previously developed by Meju, Gallardo, and Mohamed (2003), Ayolaby and Adeosun(2009), Ursin and Carsione (2007), Alan G.Jones and David W.Eaton (2009). Meju et al (2003) ultilization the electromagnetic and seismic refraction methods for determine the correlation of electrical resistivity and seismic to adapted to near surface of the earth. In this study their developed the relation of electrical resistivity and p wave velocity in linier relation. Ayolaby et al (2009) have been carried out of Igbogbo to determine the structure setting of the subsurface material and ground water potential without study the relationship between electrical and elasticity properties.

Ursin and Carcione (2007) studied the cross properties relation between electrical conductivity and seismic velocity to determine the stiffness module and density expressing the porosity in terms of those properties.Alan G.Jones and David W.Eaton (2009) studied the relationships of velocity – conductivity for mantle mineral assemblages. In this case he developed the relationship between the transversal velocity v_s and conductivity.In this construct, mechanical elasticity will be represented by travel time of seismic waves propagation, and electrical resistivity represented from geo-electric measurement. Physical parameter which has connection to both parameters of electrical resistivity and mechanical elasticity will be selected to be porosity of the subsurface rocks as was developed by Hossain and Cohen (2012). The analysis will take benefit from the development of technology and information processing to help the process of interpretation. It is assumed that the porosity used in electrical and mechanical properties remains the same for both purposes. Based on this assumption, the transformation model will be developed. The study aims: (1) to explore electrical and elasticity properties of the overburden rocksin the hydrothermal area; (2) to relate mathematically parameter of electrical resistivity to parameter of elasticity.

II. MATERIALS AND METHODS

Data were collected atthe hydrothermal area of Panggo-Kaloling, Sinjai Regency, Province of SouthSulawesi, and performed by the method of electrical resistivity by using geo-electric method together withmechanical elasticity by using the method of seismic refraction. The focus of study cover the stretching of rangesfrom is 90 m to 100 m lengths. Other important parameter to find istheporosity of the subsurface rocks under studied.

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The Schlumberger and Wenner configurations are used to set up the pattern of probes to figure out the vertical profiles of electrical resisitivity of the subsurface rocks. The Schlumberger configuration is set up at four corners to determine the condition of resistivity, while the Wenner configuration is set up on four sides to determine the nature of resistivity in 2-dimensional profiles of vertical layers. It is believed that from the facts reported byHossain and Cohen (2012) that the porosity (∅) will be an important parameter that linked the elctrical resistivity to the elasticity.

The important way to find out the standard model for subsurface rocks is to measure the resistivity at the same area in time andequal conditions for both exploration methods of electrical resistivity and mechanical elasticity. For both methods, the porosity of subsurface rocks is of importance to have equal values whether for the measurement of electrical resistivity as well as for mechanical elasticity.

To develop relationship model between the electrical properties and elastic properties of the rocks, we , started to the directly measurement in the field by using the geo-electrical method and s seismic refraction method.The geo-electrical used to know the resistivity of rocks . Measuring with a seismic refraction methods used to calculate the time of waves propagation of refraction seismic. Research conducted in hydrothermal area at Pang go Sinjai regency. In the hydrothermal area , there are two the local geological fault that across the hydrothermal zone , namely fault of Kalamisu and fault of Pang go. The Equipment used for data acquisition in this exploration, there asingle channel twin probe resistivity meters (g-sound) , a multichannel resistivity meters gl-1400 anda multichannel seismograph kind of geo-sam 12 ch-t.The measuring geo-electrical vertical soundings using Schlumberger configuration the spacing length of disquisition electrodes is between 40 m- 70 m. On measuringfor profiling two diension resistivity profile vertically with 45 m– 100 m of length. Measuring with the seismic refraction method method, the exploration done with 29 mlong. The distance source to first geopon is 5 m and space between each geophone as faras 2 m. The analysis and interpretation of measurement data were calculated theresistivity and the velocity of propagation of elastic wave in rocks , identify kind ofrocks and calculate the thick of each layer. Data analysis of geo-electrical measurement obtained by using IP2WIN and RES2INV softwares. Data analysis with seismic tomography method used software seisimeger / 2dth. Interpretation results of theanalysis data was undertaken by refrensi rocks and geological map at study areas. Developing the model of relationship between electrical with the elasticity properties, using the result of sounding electrical interpretation and the result of seismic refraction tomography for the same rocks

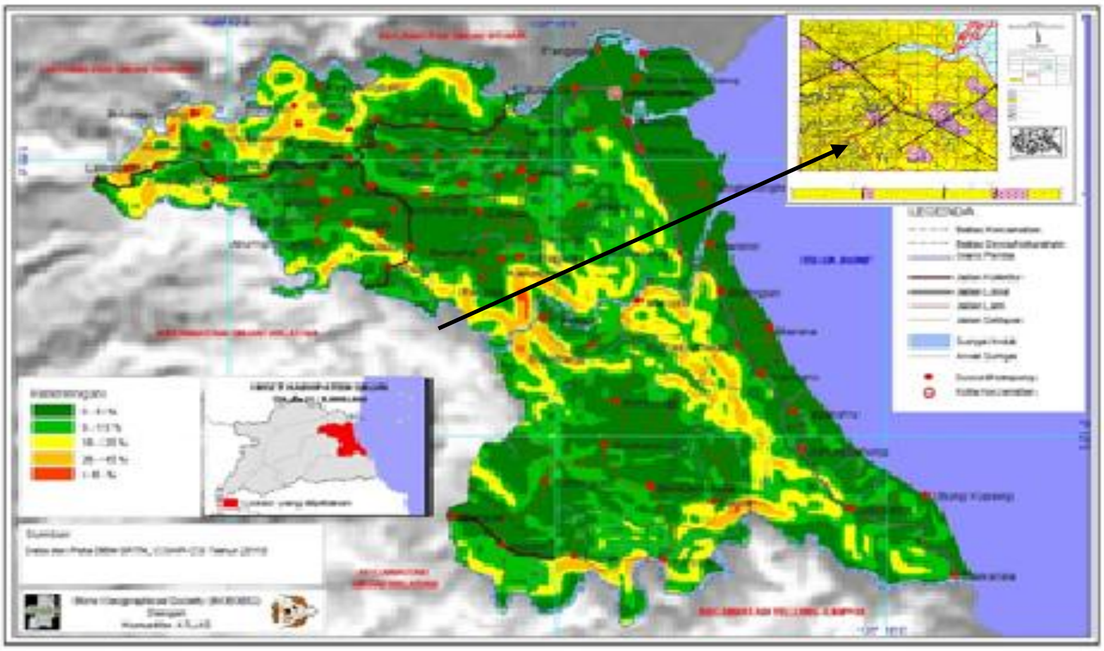

Figure 1.The Administrative Map District Sinjai east

III. RESULTS AND DISCUSSION

a. Geological condition

Distribution kind of rocks kind in kabupaten sinjaidivided into a unit of the 5 namely,: Unit of thevolcano camba formation, Walanae formation , a unitof intrusion basalt , unit of rocks the volcano Lompobatang , unit of rocks the volcano Camba formation a was half miocene final consisting ofbreccia the volcano , lava , conglomerate , and tufasmooth to rocks lapilli. Walanaeformation was earlymiocene and the endpliocene, consisting of sandstones, and conglomerate,silt stone, lam stone ,and limestone. Unit of basalt intrusion wasthe endmiocene pliocene the end, consisting of abreakthrough basalt of beams, and silt.A unit of rocks the volcano Lompobatang was Pleistocene age, consisting of breccia , lava ,

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the sediment lava , andtuffs (Sukamto and Supriatna, 1982). The alluvial sediment, marsh, and coastal was Holocene age , consisting of gravel , sand , clay , mud , and coral limestones (Sukamto and Supriatna , 1982) . A geological structure found in hydrothermalKampala, Sinjai consisting of a structure of geological fault and stout structure while characterized by the rows of hydrothermal in research areas such as hot springs Panggo with the while normal Panggo northeastern - southwest of (ne-sw) where block while the northwest relative move down this fault it cut sedimentary rock and beams are basalt (Eko et2007).

b. Geophysical exploration

IV. GEO-ELECTRICAL RESISTIVITY MEASUREMENT

Measurement using Schlumberger's configuration: covering 4 sounding points successfully has identified 4 (four) layers which is reduced into3 (three) layers of subsurface rocks. In each figure 2.a to 2.d, the vertical axis is resistivity, horizontal axis is electrode space; where ρ =resistivity, h = thickness, d =depth, Alt = altitude; Coulor form bottom to upper layers indicates as apparent resistivity.

At the fourth electrical soundings, identified four and five layerswith depth of investigation about 7m. Fourth locationofsoundings, identified the layers with high resistivity about 232Ω m, 121Ωm, 482 Ωm and 103 Ωm. Thethickness about 1.7 m, 0.85 , 0.6 and 1.72 m. Based on reference resistivity data and geological mapat the studyareas , this layer interpreted as associated basat, alluvial sediment ,gravel, a severe sandstone, loam and mud hardened and identified as overburden.The third and the fourth layers is the low resistivity rocks and identified as hydrothermal zone.

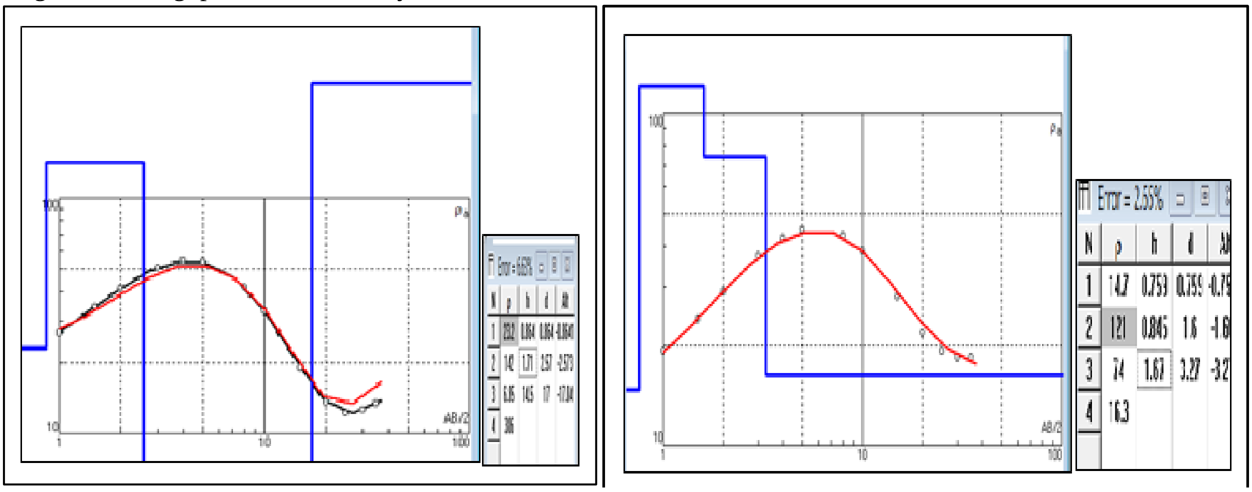


Fig.2. (a) Resistivity curve at the first soundingFig.2 (b). Resistivity curve at the second soundin

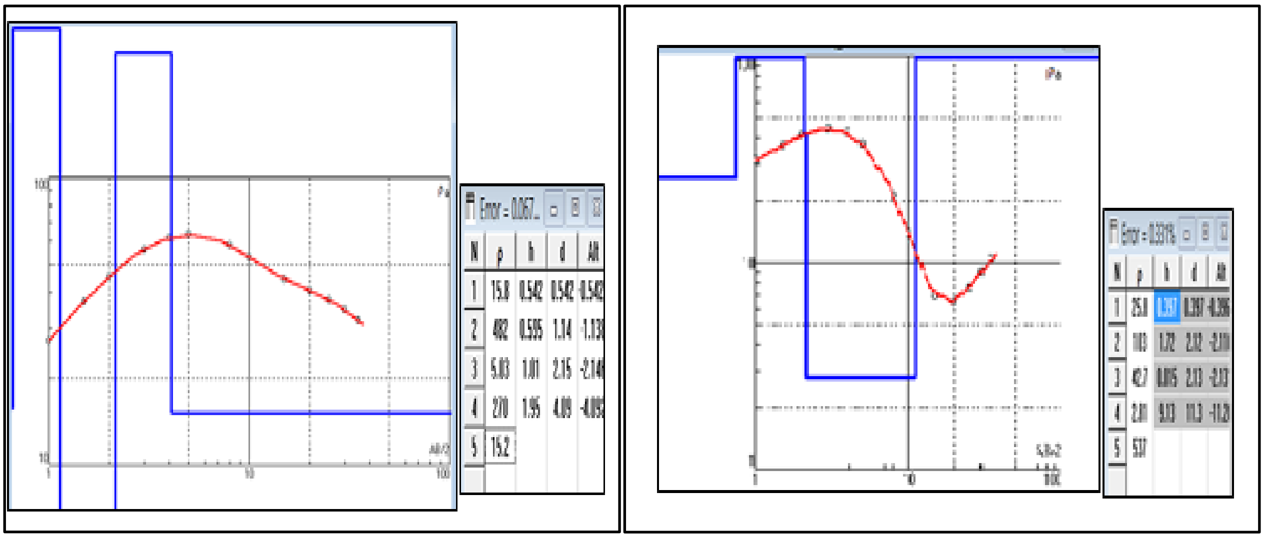


Fig2. (c) Resistivity curve at the third sounding Fig.2(d). Resistivity curve at the fourth sounding

V. SEISMIC INTERPRETATION

The relationship between electrical resistivity with mechanical elasticity which is represented by travel time of wave propagation of subsurface rockshas been completed by using both exploration methods of geo-electric and seismic measurements. Seismic data acquisition is done and performed in the same location and condition that of the geo-electric measurement.The results give us with six trajectories of exploration which are carried out on each side of the hydrothermal area.

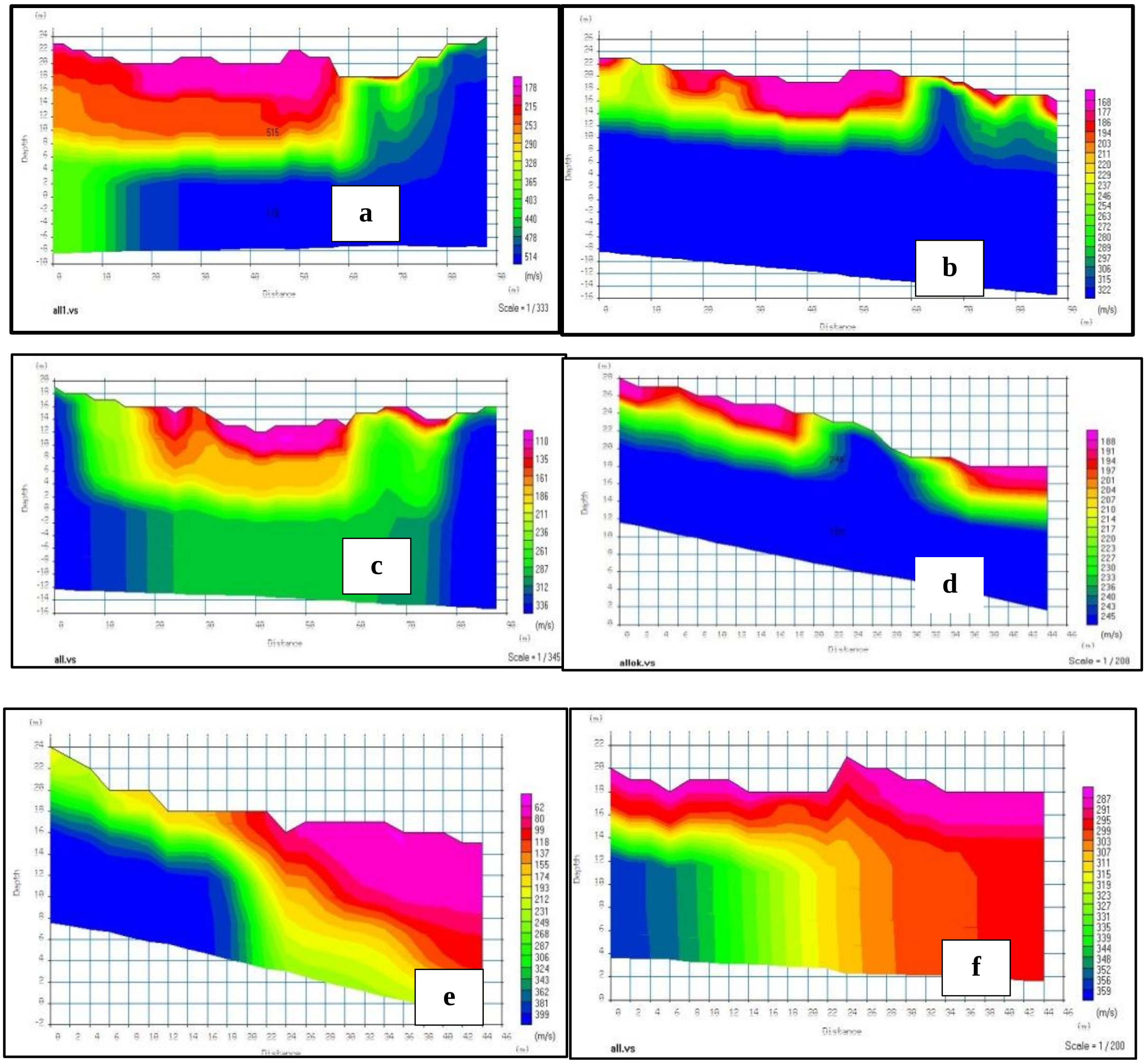


Fig.3.a Velocity Profile (a) the first trajectory (b). the second trajectory (c) the third trajectory (d) the four thttrajectory(e). the fifth trajectory (f) the sixth trajectory

The results have identified three layers ofpropagating velocity of P-waves. Those are layer (1) having velocity of 200 m/s, layer (2) havingvelocity of 350 m/s, and layer (3) having velocity of 500 m/s

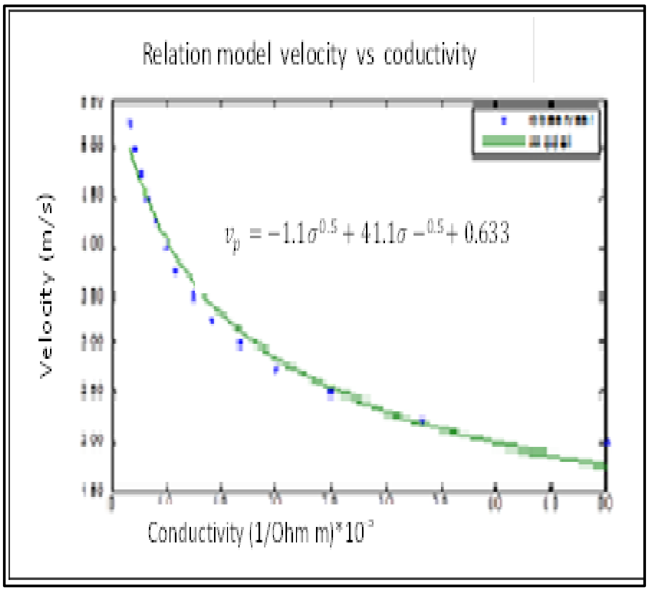
At all of trajectory there are the shallow depth of hydrothermal zone (green) color. Also at the all trajectories.In to six the such measurement identified the fault zone. These Faulting are estimated as a source of the emergence of geothermal system .

Relationship between the electrical and the elasticity properties of of rocks.

Correlation resistivity model from Archieand Bussian with the time average equation (wyllie)obtained the relationship between conductivity and the time of propagation a wave as:

$$v_p = A(\sigma_p)^{1/m} + B(\sigma_p)^{(1-m)/m} + C$$

Where A, B, and C are constant, v_p= resistivity ,σ_p= konduktivityand m is cementation factor. Numerically relation between electrical resistivity and time propagation of wave obtained by utilization of least square method. The solution of this model obtain by using the MATLAB program.



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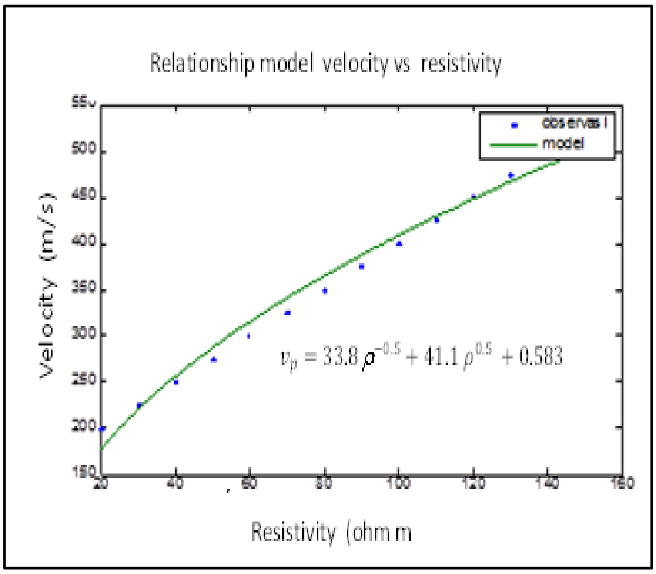

Fig. 4 Relationship Model between electrical properties and velocityof wavepropagation in the rocks(a) velocity vs conductivity (b) velocity vs Resistivity

VI. CONCLUSION

Conclusions and Recommendations

Using the analysis and interpretation of geo-electrical method and seismic refraction tomography data asinput data program, have been developed mathematical model the relationship between resistivity and speed / thetime of propagation waves be concluded that.

1. Relationship model between of the nature of electricity and elastic properties of rocks at overburden at hydrothermal area isa nonlinear function with the correlation excellent with the degree of correlation ore then 85 % ..
2. From the results note that relationship between resistivity with travel time ofwave propagation, shows that the less travel time of wave's propagation followed by increasing resistivity of rocks or otherwise.

RECOMMENDATION

To further research should factors pressure and temperature , have also been considered , because there is apossibility that of the nature of electrical conductivity and rate of propagation of the wave also influenced by pressure and temperature rocks.

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