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# RELATIONSHIP BETWEEN ELECTRICAL AND MECHANICAL PROPERTIES OF TUFF ROCK ON SUBSURFACE AT THE SPORTING CENTER HASANUDDIN MAKASSAR INDONESIA

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## ABSTRACT

A geophysical survey employing seismic refraction and vertical electrical sounding have carried out at the sport center area of Hasanuddin University, South Sulawesi, Indonesia to determine the structural setting and the depth of bedrock at the subsurface using a 12 channel seismograph and Resistivity-meter single-channel Twin Probe Resistivity (G-Sound). The VES has a maximum current electrode separation of 400 m; the result of the survey has enabled the delineation of the bedrock of the area. Data interpretation were using to determine the relationship between electrical and elasticity properties of subsurface in this area. The vertical electrical resistivity has a maximum current electrode of 300 m. The result of the survey has enabled the delineation of the bedrock of the area. The hard rock distinct geo-electrical layer were observed namely volcanic tuff with the resistivity varying from 121Ωm to 735 Ωm with depth ranging from 5.36 m to 7.5 m. the seismic refraction thomography show three layer, the layer with velocity about 1000 m/s interpreted as the volcanic tuff situated at the second layer third layer. For both trends, the resistivity (ρ) and the time propagation per unit length ofp wave $(t_p)$ obtain that theare relation between electrical properties and the time propagation per unit length. This relation obtained by utilization of porosity parameter. and calculated by least square method.

**Keywords:** porosity, transformation, resistivity and the travel time ofp-wave propagation.

## INTRODUCTION

Over the last several decades, geophysical methods have been very famous and successfully used to get information below the earth surface. The study of geophysics described in this survey is based mainly on geo-electrical resistivity surveys is to determine subsurface resistivity distribution by taking measurement of the apparent resistivity. Geo-electrical resistivity surveys have become an important tool in environmental and engineering applications. The electrical resistivity is complementary in the many ways although this method measures resistivity of subsurface. In seismic refraction method, energy is introduced into the ground by striking steel plate with a hammer. The seismic energy generated is detected by a line of 12 equally spaced geophone which are placed in the ground and produce a small voltage in response to earth vibration. Electrical resistivity and seismic refraction are used singly or in combinations for engineering site investigation. The application of such geophysical investigation was determine the depth of bedrock structure mapping and evaluation of subsoil component. In civil engineering foundation studies, geophysics play significant roles in the investigation of the geotechnical integrity of the subsurface material and structures which are likely to beer on the floating of the foundation. Several work have establish the relevance of application of geophysical methods in the investigation of geomaterials underlying engineering foundation side (Ofomol a, *et al* 2009), and the geophysical methods have been established to play complementary roles in the geotechnical studies, besides that they are less expensive and non-invasive. The electrical resistivity method usually furnish the engineers information about the depth of to the bedrock, the composition of the geological layers and trend of geological fissures that can jeopardize oethreaten the life span of the structure. In this study, the electrical resistivity survey of the geophysical technique is use to investigate the bedrock structure and soil condition of the studied area based on electrical resistivity. Seismic refraction method is widely used in site investigation to determine the elastic properties of the subsurface materials. The seismic refraction method can be used to obtain a very clear picture of variations in rock horizons (steward *et al.,* 1997). The method depends upon seismic wave travel through different material at the different velocity. The exploration, exploitation of natural resources and mapping of bed rock structure in sub surface of was really needed, but environmental sustainability due to the exploration and exploitation must remain guaranteed. The Geophysical explorations are the methods that are reasonably priced and nondestructive method, the very potential for the exploration and mapping of the bedrock

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structure comprehensively. However, the excellence of geophysical exploration, these methods also have fundamental flaws. That problems are .it is not the direct measurement, with only using one method the number of parameters obtained limited. To obtain accurate results and much parameters measured, needed used more than one method. To use more than one exploration method on an object with a common purpose, it is not efficient and ineffectual in use of time, funds and equipment. The resolve this problem, have been developed a transformation model that can link between electrical properties and mechanical properties of rocks. That transformation model is a model of the relationship between the travel time wave propagation with the electrical resistivity. Realization of these issue, by developing mathematical models that can be establishing a relation of representative stocks between the mechanical properties and the nature of electricity rocks at the sub surface of the earth through the utilization of porosity parameters developing mathematical models that can be establishing a relation of representative stocks between the mechanical properties and the nature of electricity rocks at the sub surface of the earth through the utilization of porosity parameters. By using the porosity parameters, be able to constructed a correlation between the nature of electricity and of the mechanical properties of rocks at the sub surface By using the porosity parameters, we able to constructed a correlation between the nature of electricity and of the mechanical properties of rocks at the sub surface (B. Ursin, and J.M. Carsione, 2007) and (zakir Hossain; alan J. Cohen, 2012).

**Location of the study area**

The area study is the sport center area at campus Hasanuddin University south Sulawesi Indonesia. An integrated geophysical method which includes electrical resistivity and seismic refraction method were carried out to study the depth of bedrock and determine the relationship between electrical resistivity and elasticity properties bedrock at the sport center building Hasanuddin University and surrounding areas.

## MATERIALS AND METHODS

**Resistivity method**

The electrical resistivity method in thi study is the Schlumberger array configuration. Electrical makes use of a variety of principles, each base on some electrical properties or characteristics of the material. In this method, measurement was made with increasing separation between electrodes about midpoint. The instrument used for data acquisition was Resistivity meter single-channel *Twin Probe Resistivity (G-Sound).* This equipment has ability of computing and displaying the apparent resistivity of the subsurface with the input data of the current electrode and potential electrode separation. The location is as follows:

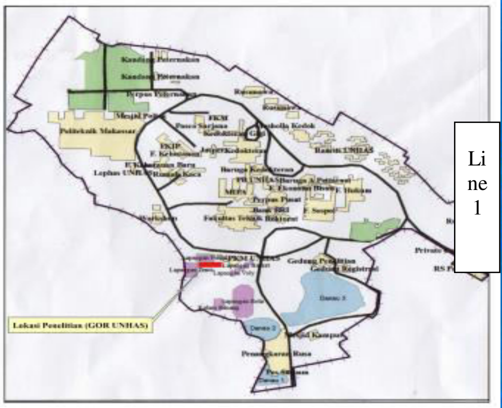

**Figure-1.** Location of survey area.

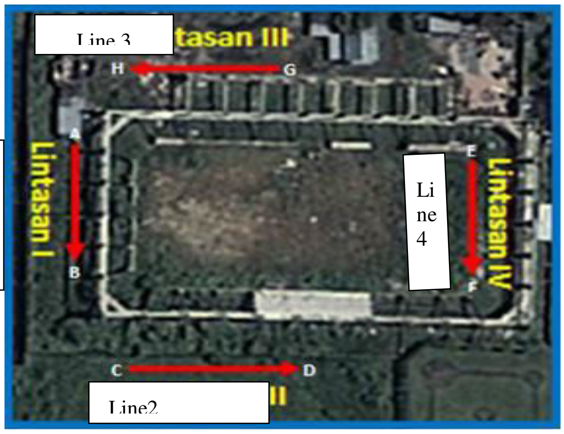


**Figure-2.** Lines of data acquisition of seismic.

**Seismic refraction method**

For the recording seismic refraction data acquisition with a chosen field configuration of 12 geophone were planted a long a multi-core which was then connected to the 12 channel seismic recorder pot of equipment. The distance within the each geophone is 2m. The sledge hummer was used as the source of wave energy. The trigger metal and base metal plate were placed and every connection intac. The seismic refraction uses were recoded for the forward, reverse and split shots. The data analysis of velocity were calculated by using tomography seismic to obtain the velocity variation dan the depth profile Model of Resistivity -velocity relation The important parameter to find the relationship between time of wave propagation per unit length with the resistivity of rocks is the porosity. To obtain the accurate relation between resistivity and velocity, the survey by resistivity and seismic refraction method were observed at the same location and the same condition. In this case, if is assumed that the travel time $t_p$ as function of porosity

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$\emptyset_r$ and resistivity R 1s also as function of porosity $\emptyset_e$ as follow$t_p = f(\phi_r)$ $and$ $R = g(\phi_e)$ Future more, if the geoelectric and seismic methods are used on the same line at the same location and equal conditions then the relation of electrical porosity and seismic porosity

is:$\phi_r = \phi_e = \emptyset$ (2)

The travel time of propagation per unit length can be write as:

$$t_p = f\{g^{-1}(\phi)\} \quad (3)$$

With the resistivity method, the relation between porosity and electrical resistivity is

$$\emptyset_e = \left(\frac{R_f}{R_o}\right)^{1/m}\left(\frac{R_M-R_o}{R_M-R_f}\right) \quad (4)$$

With $R_o$= the measured resistivity; $R_f$= fluid resistivity filled rocks and $R_m =$ resistivity of rock matrixAnd with the seismic exploration method, the relation between porosity with the time of wave propagation per unit length given by:

$$\emptyset_r = \frac{(t_p-t_M)}{(t_f-t_M)} \quad 5(a)$$

or$t_p = \emptyset_r t_f + (1-\emptyset_r)t_M$ 5(b)

where $t_p$ is the measured time propagation per unit length, $t_f$ is time propagation in fluid per unit length and $t_M$ is the time propagation per unit length of rocks matrix To obtain the standard model for one kind of rocks, the measurement by resistivity method done at the same location in time and equal conditions. This is important for its porosity obtained at both types of the method of measurement is having the same value. With substitution the equation (4) into the equation 5(b) to be obtained:

$$t_p = AR^{-\frac{1}{m}} + B\,R^{\frac{m-1}{m}} + C \quad (6)$$

where $A = \frac{R_f^{\frac{1}{m}}R_M}{R_M-R_f}\left(t_f - t_M\right)$ , 7(a)

$$B = \frac{R_f^{1/m}}{R_M-R_f}\left(t_M - t_f\right) \quad 7(b)$$

$$C = t_M \quad 7(c)$$

Mathematical model of the relationship between $t_p$ and R can be obtained by calculate constants A, B and C using the least square method.

## RESULT AND DISCUSSIONS

### Electrical resistivity

The interpreted sounding curve show the resistivity, thickness and depth of the each subsurface. There are four vertical electrical sounding (VES) curves whose layer varies from 4 to 6 were analyzed. The first line having high resistivity of 475 Ωm at the second layer thickness about 0.67 m. Based on the geology map, this layer layer varies from 4to 6 were analyzed. The first line having high resistivity of 475 Ωm at the second layer thickness about 0.67 m. Based on the geology map, this layer consisted of volcanic tuff is a layer of alluvial deposits, like gravel and, sandstone. Similar rocks also obtained in the three other with the different thickness. The resistivity curve as followsThe first sounding depicted in Figure-3(a) discovers layer (1) having 59.72Ωmofresistivity with 1.074 m of thickness; layer (2) having 196Ωm of resistivity with 1.534 m of thickness; layer (3) having 8.21Ωm with 4.35 m of thickness; and last layer having 66.54 Ωm.

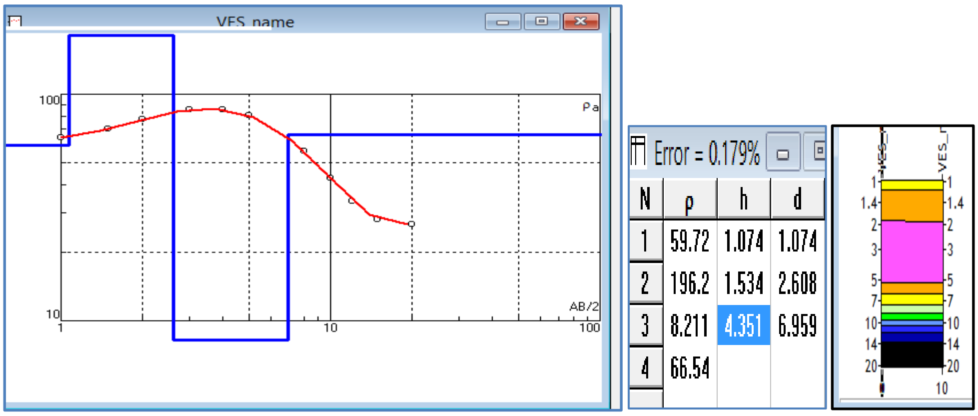


**Figure-3(a).** VSE. Schlumberger configuration 1.

The second sounding depicted in Figure-3(b) discovers layer (1) having 4.8Ωm of resistivity with 0.32 m of thickness; layer (2) having 518.2Ωm of resistivity with 0.76 m of thickness; layer (3) having 0.85Ωm of resistivity with 1.29 m of thickness; layer (4) having 428.9Ωm of resistivity with 4.5 m of thickness and last layer having 13.43 Ωm.

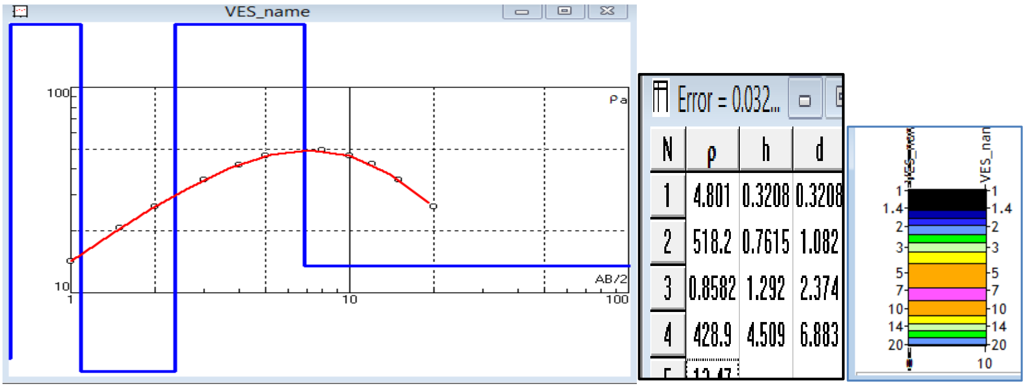


**Figure-3(b).** VSE. Schlumberger configuration 2.

The third sounding depicted in Figure-3(c) discovers layer (1) having 3.772Ωm of resistivity with 0.266 m of thickness; layer (2) having 126Ωm of resistivity with 0.66 m of thickness; layer (3) having 3.68Ωm of resistivity with 5.76 m of thickness; and last layer having 92.93 Ωm.

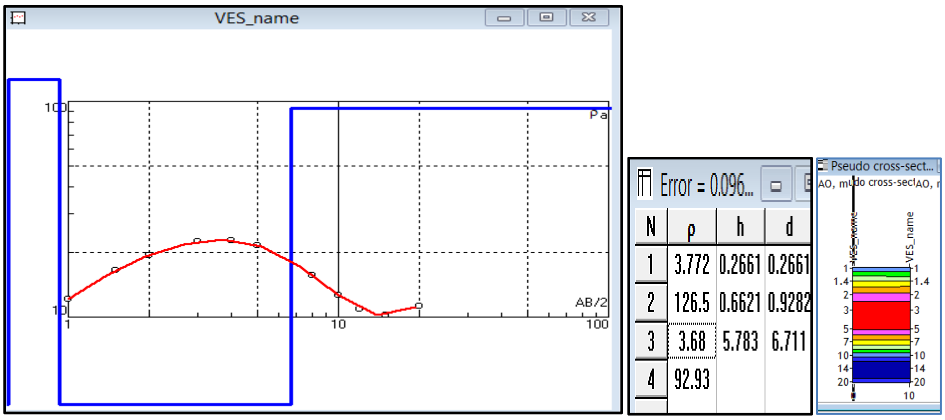


**Figure-3(c).** VSE .Schlumberger configuration 4.

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**Refraction seismic thomography**

The seismic tomography section show three layer. The velocity of the first layer about 1- to 300 m/s, the second layer with 301- 800 m/s and the third layer about 801 to 1000 m/s. the profile of the velocity of three layer as follow:

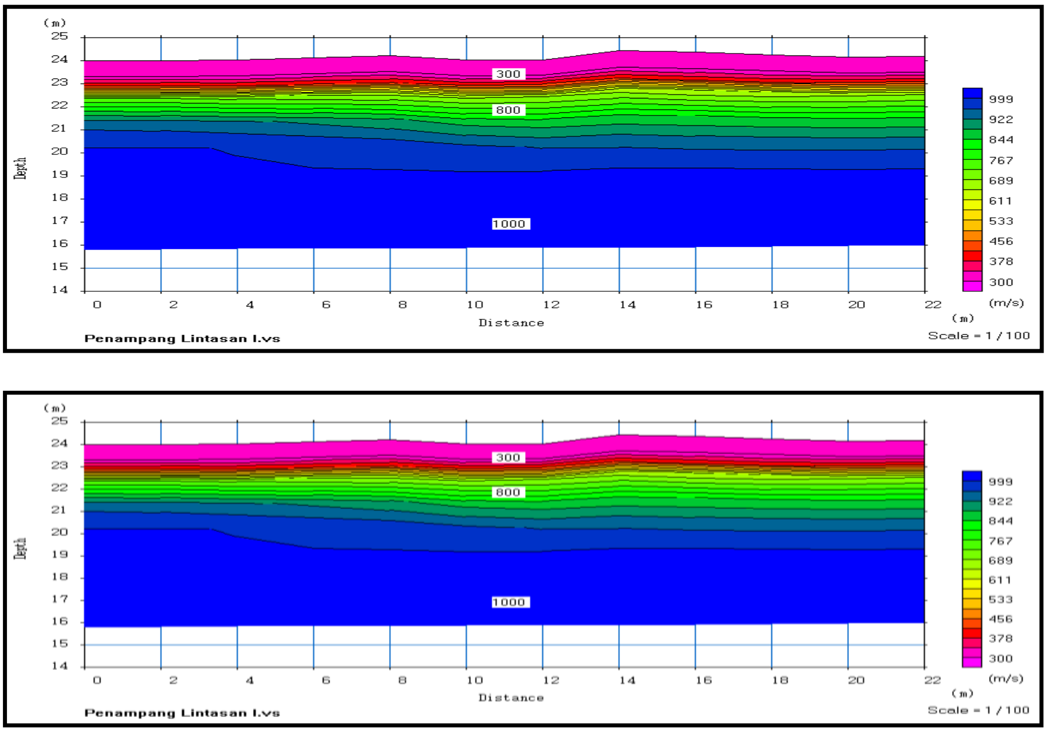


**Figure-4(a).** The trajectory of a cross section of seismic 1.

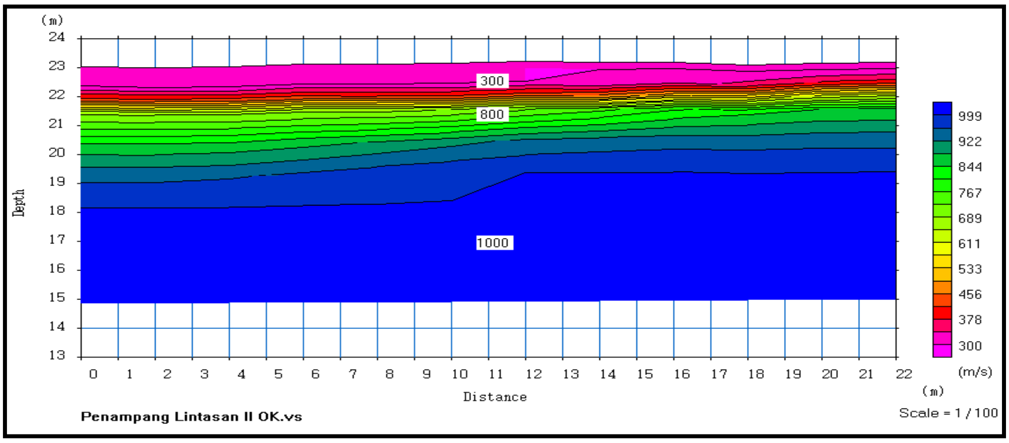


**Figure-4(b).** The trajectory of a cross section of seismic 2.

VOL. 10, NO 20, NOVEMBER, 2015 ISSN 1819-6608
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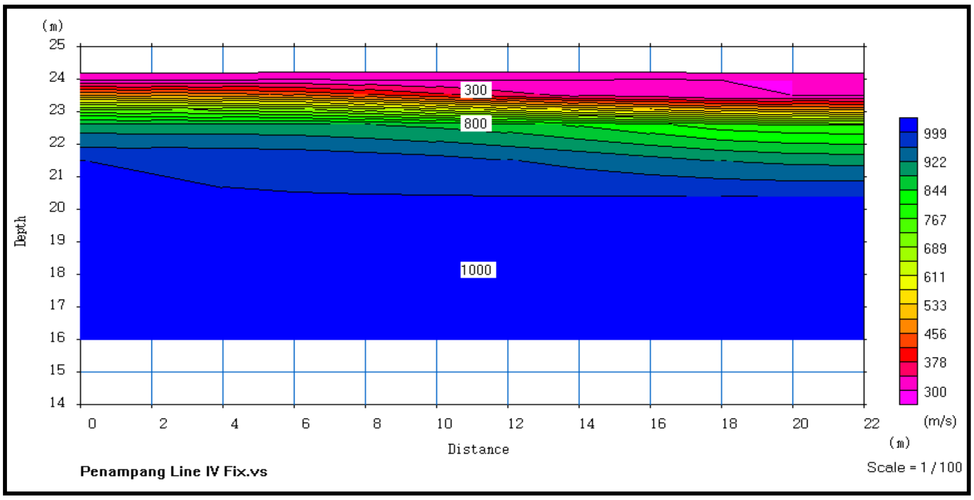


**Figure-4(c).** The trajectory of a cross section of seismic 4.

**Relationship between electrical resistivity and elasticity mechanic**

Relationship between electrical resistivity and elasticity mechanic of the tuff rock able to be analysis by determining the value of the constant A, B and C the equation (6) by utilization the non linear least square method. By the least square method, the equation can write as follows:

$$F = \left\{\sum_i^n \left(v_{pi} - \left(A\rho^2_{i\,i} + B\rho_i + C\right)\right)^2\right\} \quad (8)$$

The optimation value the coefficient A, B and C by the Minimization method use least square method. The condition must meet the following conditions.

$$\frac{\partial F}{\partial A} = 0; \quad \frac{\partial F}{\partial A} = 0 \quad and \quad \frac{\partial F}{\partial C} = 0 \quad 9(a)$$

$$\sum_{i=1}^n \left(v_{pi} - (A\rho_i + B\rho_i^2 + C)\right)\rho_i = 0 \quad 9(b)$$

$$\sum_{i=1}^n \left(v_{pi} - (A\rho_i + B\rho_i^2 + C)\right)\rho_i^2 = 0 \quad 9(c)$$

$$\sum_{i=1}^n \left(v_{pi} - (A\rho_i + B\rho_i^2 + C)\right) = 0 \quad 9(d)$$

$$\sum_{i=1}^n \rho_i v_{pi} = A\sum_{i=1}^n \rho_i^2 + B\sum_{i=1}^n \rho_i^3 + C\sum_{i=}^n \rho_i \quad 9(e)$$

$$\begin{bmatrix} \sum_{i=1}^n \rho_i v_{pi} \\ \sum_{i=1}^n \rho^2_{i\,i} v_{pi} \\ \sum_{i=1}^n v_{pi} \end{bmatrix} = \begin{bmatrix} \sum_{i=1}^n \rho_i^2 & \sum_{i=1}^n \rho_i^3 & \sum_{i=1}^n \rho_i \\ \sum_{i=1}^n \rho_i^3 & \sum_{i=1}^n \rho_i^4 & \sum_{i=1}^n \rho_i^2 \\ \sum_{i=1}^n \rho_i & \sum_{i=1}^n \rho_i^2 & n \end{bmatrix} \begin{bmatrix} A \\ B \\ C \end{bmatrix} \quad (10)$$

From the relationship of equation (13), the value of A, B and C were obtained =0.0015

The value of A, B and C were obtained as follows: A = 142.4; B =0.08 C =0.0024 Thus the relationship between resistivity and travel time is:

$$t_p = 142.4\,\rho^{-0.5} + 0.0.08\,\rho^{0.5} - 0.0024 \quad (11)$$

relationship betweenConductivity and travel time is

$$t_p = 1.424\,\sigma^{0.5} + 16.57\,\sigma^{-0.5} - 0.004$$

The curve of mathematical model of relationship between resistivity/conductivity with the time propagation/velocity as Figure-5.

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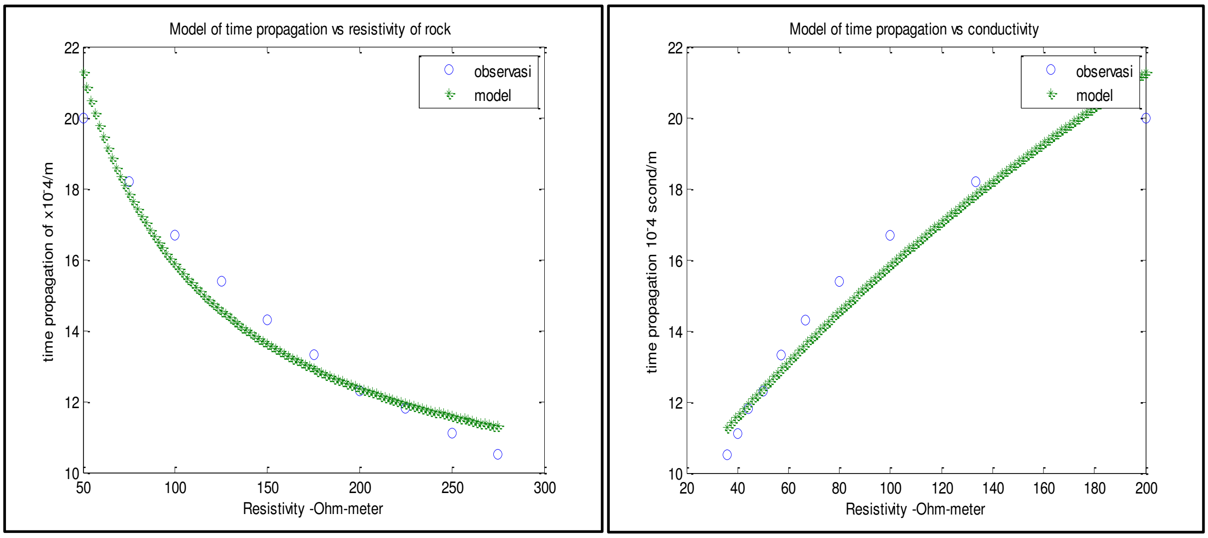


**Figure-5.** Model of relationship between electrical conductivity and wave velocity in volcanic tufa.

## CONCLUSIONS

From the analysis and interpretation of the data acquisition and the development of mathematical models that can be inferred.

a) Taking advantage of the porosity parameters can be constructed a mathematical model of transformation that connects between the geoelectric parametric and seismic parameters
b) The relationship can be written on the form velocity equation as a function of resistivity, equation propagation time as a function of resistivity, equation propagation time as a function of conductivity and equation of propagation time as a function of the conductivity function
c) When one of the physical parameters of the rock is substituted into the five models above, the other physical parameters are modeled, indicating the equivalent value.
d) This solution shows that all mathematical models are built, can be used as a model transformation

## ACKNOWLEDGEMENTS

Data were collected sport center area Hasanuddin University campus Tamalanrea Makassar Indonesia. While data analysis was done at the Geophysical Laboratory, Department of Physics, Faculty of Science, Hasanuddin University. We are really indebted to personals and institution being involved in the survey and laboratory works, to whom we express our deep appreciations.

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