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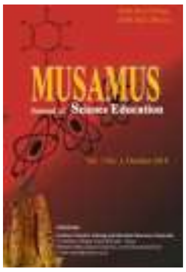

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# 2D RESISTIVITY TIME LAPSE ANALYSIS FOR POTENTIAL ZONING SLIDE WET MUD IN PANEL 7 DEEP ORE ZONE (DOZ)

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**Abstract** High rainfall may disrupt mining operations due to possibility of wet mud slides, occurences. One of the area wet mud slide in the mining area of "DOZ" Panel 7 West PT Freeport Indonesia, Mimika District, Papua Province. Study was needed to image the subsurface where have high probability of wet mud slide might happen. Resistivity method was used using Wenner Alpha configuration with a total length of 270 m. The measurements were performea six times at different dates. Measured data use as the primary data to determine the high possibility areas of mud wet slides. And the primary data were compared with secondary data such as rainfall and geological data. Analysis the resistivity cross-sections show that the low resistivity zones are located in Panel 7 DP # 14E, 16E, 18E, 19E, 20E and 21E. Water enter the DOZ Mine (Deep Ore Zone) by infiltration and precipitation directly through the cave material, permeable zones along the contact zone of diorite/skarn/marble, and the spillover cut crackline or caveline of formation Lower Kais. The correlation between the quantitative data of the apparent resistivity with rainfall data has the highest value of 3.52 %.

**Keywords**: Resistivity, wet muck, panel.

## INTRODUCTION

Indonesia is a country with high rainfall. High rainfall can hamper mining operations if not handled properly. Problems can be caused by this is the phenomenon of wet mud slide *(wet muck)* that often occurs in the *extraction* area / *panel* underground mines. The phenomenon of this wet mud slide, in addition to inhibiting production, can also cause death / accidents to workers in the underground mining area. The study was conducted in the area of underground mining *Deep Ore Zone* (DOZ) with elevations between 3116-3146 meters above sea level.

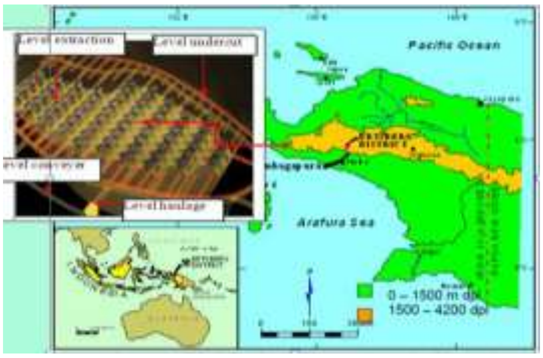


Figure 1. Map of the Doz research area (Samosir, et al, 2004).

(Figure 1). By geographic area of research is in UTM coordinates *(Universal Traverse Mercator)* between mE 736 800 - 737 840 mN mE and 9.54864 million - 9.5493 million mN with the research area of around 1000 mx 660 m (Samosir et al., 2004). Overall DOZ underground mine area consists of 3 levels, namely:

A. Level *Undercut* (3136 - 3146 madpl)

B. Level *Extraction* (3116 - 3126 madpl)

C. *Truck haulage* level (3076 madpl)

The research area is focused on *the extraction level* (3116 - 3126 meters above sea level) because at this level is an area that most experiencing fluctuations due to water conditions and most of the miners working in this area (Dodi, 2015).

## METHODS

Geolistrik Method *Resistivity*

Geolistrik is one of the geophysical methods that studies the nature of the flow of electricity in the earth. This method includes the measurement of potential and current occurring due to injection of currents into the earth. Geolistrik method is one method that is quite widely used in exploration, especially groundwater exploration, because the resistivity of rock is strongly influenced by water content in rock pores.

### Wenner Electrical Configuration

1. Generally the resistivity geolistrik method consists of two s Resistivity *sounding* method: used to investigate changes in the subsurface resistivity in the vertical direction (depth). The use of this method can be known thickness of each layer of rocks that exist beneath the surface. The measurement procedure is done by moving or varying the distance of the current electrode and the voltage varies at a fixed point so that the further the electrode distance, the greater the depth is achieved.
2. *Mapping* the resistivity method: used to investigate changes in the subsurface resistivity laterally (horizontally). This method can also be used to map the resistivity distribution in a particular region associated with the geological condition of the area. Electrode configuration is commonly used *Wenner* configuration or *dipole - dipole.*

The Wenner configuration measurement procedure is performed by moving the measuring point horizontally to the distance between the current electrode and the fixed voltage (Figure 2).


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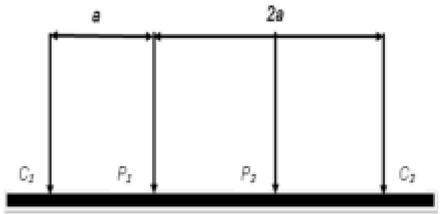


Figure 2. The arrangement of the electrodes in the Wenner configuration when the ratio of a potential electrode distance to a current electrode 2a (www.geocis.net).

While the measurement procedure using the Wenner configuration is done by moving the measuring point horizontally to the distance between the current electrode and the fixed voltage. Wenner configuration is one configuration that is often used in geoelectric exploration with the arrangement distance between the electrodes of the same length as shown in Figure 3.

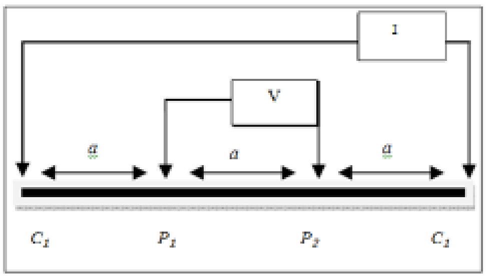


Figure 3. The arrangement of the electrodes in the Wenner configuration When the ratio of potential and current electrode distance (a) (Http://www.geocis.net).

The electrode configuration according to Figure 5 with a distance of $C_1 C_1 = R_1$, $C_2 C_2 = R_2$, $C_1 P_2 = R_3$, $C_2 P_1 = R_4$, so that resistivity pseudo be measured theoretically as Equation (4) by a factor of the geometry of each electrode arrangement depends on the distance spaced electrodes (Telford, et al, 1976). Wenner electrode arrangement distance is $R_1 = R_4 = a$, $R_2 = R_3 = 2a$, in order to obtain a potential difference between the point $P_1$ and $P_2$ of:

$$\Delta v = \frac{\rho.I}{2\pi}\left[\left(\frac{1}{R1}-\frac{1}{R2}\right)-\left(\frac{1}{R3}-\frac{1}{R4}\right)\right] \quad (1)$$

then:

$$\Delta v = \frac{\rho.I}{2\pi}\left[\left(\frac{1}{a}-\frac{1}{2a}\right)-\left(\frac{1}{2a}-\frac{1}{a}\right)\right]$$

if $a << r$ (Its small eccentricity) then Equation (1) can be written as follows:

$$\Delta v = \frac{\rho.I}{2\pi} \quad (2)$$

Wenner's configuration has advantages and disadvantages. According to Burger in Ristianto (2007), the advantages of Wenner's configuration is that with large wide potential electrode spaces it does not require sensitive equipment. While the drawback is that all electrodes must be removed for each reading of resistivity data. This is to obtain higher sensitivity for local areas and near-surface lateral variations. While the Wenner geometry factors are:

$$k_W = 2\pi\left\{\left(\frac{1}{a}-\frac{1}{2a}\right)-\left(\frac{1}{2a}-\frac{1}{a}\right)\right\}^{-1} \quad (3)$$

while the apparent resistivity ($\rho_a$) is read in a Wenner configuration is expressed as:

$$\rho a = 2\pi.a\frac{\Delta v}{I} \quad (4)$$

with $\rho_a$ is the apparent resistivity, $a$ is the spacing between electrodes, $\Delta V$ is a potential difference, and $I$ is an electric current. From equation geometry

factors, the tribe $2\pi a$ a geometry factor Wenner Alpha. This property causes the Wenner configuration to detect the local


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homogeneity of the measuring site. The target depth is obtained from resistivity measurements using Wenner configuration is $\frac{1}{2}a$.

**Nature of Resistance of Porous Rock Type**

The measured type resistance to the measured rock is a combined electrical resistance between the matrix electrical resistance and the fluid electrical resistance in the porous rock. The relationship between electrical resistance and rock porosity in sedimentary rocks (sandstones, limestone's, and clay stone) was first proposed by Archie (Telford, et al., 1976). Based on his observations, the resistivity of rocks saturated with salty water is proportional to the resistivity of brine that fills the pores into which prisoners are reflected by the kind of matrix formation factor *(F).* Archie proposes two empirical equations, namely:

1. The Equation of Archie 1, the empirical equation concerning the relationship between the rock type resistance where the rock pores are saturated by water which is mathematically written as follows:

$$\rho b = \frac{a \cdot \rho\omega}{\phi_m} \quad 5$$

   with $\rho_b$ is the resistivity of rock measured (Ohm.m), $\rho_w$ is the resistivity of water that fills the pores of rocks, *a* is a constant that characterizes the type and character of the rock (structure, texture, etc.), *m* is a constant that characterize cementation, and $\phi$ stating rock porosity (%).

2. The Equation of Archie II, describes the conditions in which the porosity of the unsaturated rocks is filled by water which is mathematically expressed as follows:

$$\rho t = \frac{a \cdot \rho\omega}{\phi^m \cdot S_w^n} \quad (6)$$

with $\rho t$ is the resistivity of rock that is not saturated with water (Ohm.m), $\rho b$ is the resistivity of rock when saturated with water (Ohm.m), *n* is a factor of water saturation, *a* is a constant that characterizes the type and character of the rock (structure, texture, etc. ), *m* is a constant that characterize cementation, $\phi$ stating rock porosity (%), and *Sw* is the water saturation (%).

**Table 1. Reference values *chargeability* some material**

| Material | *Chargeability (ms)* |
|---|---|
| *20% sulfides* | 2.000 – 3.000 |
| *8 - 20 % sulfides* | 1.000 – 2.000 |
| *Volcanic tuffs* | 300 – 800 |
| *Sandstone, siltstone* | 100 – 500 |
| *Dense volcanic rock* | 100 – 500 |
| *shale* | 50 – 100 |
| *Granite, grandodiorite* | 10 – 50 |
| *Limestone, dolomite* | 10 – 20 |

***Wet Muck***

*Wet muck* (*wet sludge*) is a mixture of fine grained material with water that has the potential to flow arrived - arrived from *the draw point. Wet muck draw point* is a point draw condition based on visual observations, where there are damp or wet conditions (with an indication of the flow or seepage of water) and the grain size of the wet muck (rough or smooth) depending on which is more dominant. How to determine the *wet muck draw point* by visual observation is to observe the


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condition of *the draw point* qualitatively, ie in dry conditions, humid, or wet:

1. Score 1 for dry conditions.
2. Score 2 for damp conditions.
3. Score 3 for wet conditions (indicated by flow or water droplets).

**Table 2. Classification *of wet muck* (Surya dan Anwar, 2014).**

| | Material Size 5 cm (M) | | |
|---|---|---|---|
| Wetness Water Content | M > 70 (dominated by coasse grain) | 30 % < M < 70 % | M < 30 % (dominated by fine grain) |
| <8.5 % (Dry) | A1 | B1 | C1 |
| 8.5 – 11 % (Moist) | A2 | B2 | C2 |
| ≥ 11 % (Wet) | A3 | B3 | C3 |

Table .2. shows the percentage of water content and grain size of the material. As an example for the water content in the material < 8.5% and has a grain size > 5 sm more than 70% are categorized as *wet muck* dried (figure 4,5,6).


Figure 4. Classification of wet muck A3.


Figure 5. Classification of wet muck B1.

Figure 6. Classification of wet muck B3 (Surya dan Anwar, 2014).

## RESULT AND DISCUSSION

For wet muck map data, the data used is the mapping in the first week of May 2015, so that the resistivity data and map data can be synchronized. In this case, this wet muck map is a wetness value map of a draw point that is done by visual observation, as focused on Figure 7.

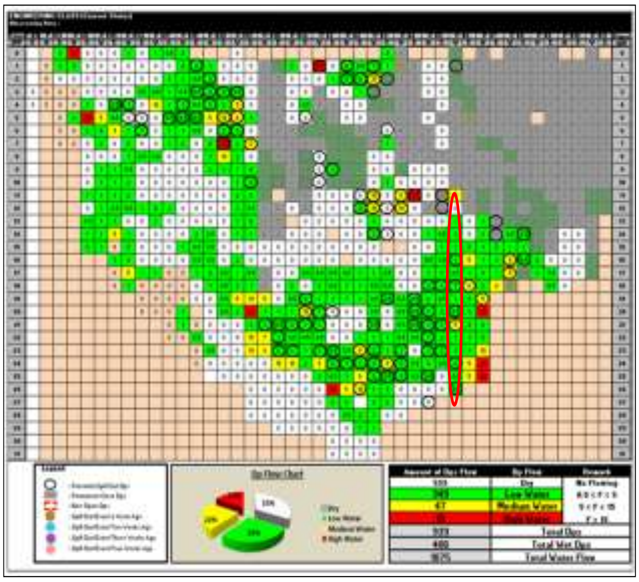


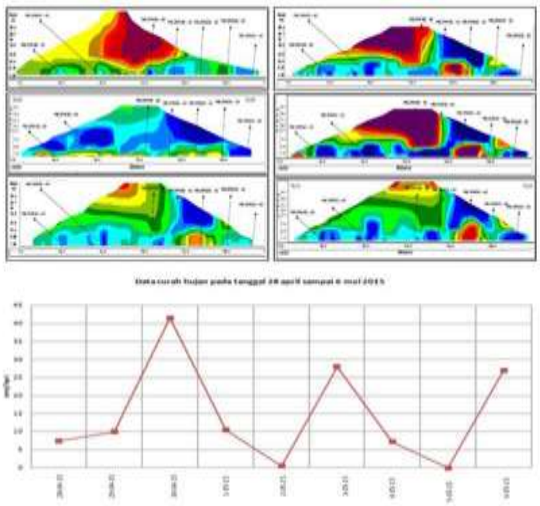
Figure 7. Wet Muck Map in Deep Ore Zone area (Surya dan Anwar, 2014).

From the inversion of geoelectric data, 6 cross-sectional maps of resistivity are obtained. This data is interpreted based on:


Print ISSN: 2622-7851, Online e-ISSN: 2622-786x

1. Low resistivity represents highly conductive material / rocks (eg, water, clay, and rocks with large water content) and vice versa
2. In the case of the use of resistivity methods for mapping / monitoring / determination of wet muck material, the wet mud is indicated by low resistivity values.

Below is presented a cross-sectional map of resistivity of measurement results for 4, 5, 7, 9, 11, and May 12, 2015. In the 2D pseudocection section (Figure 8) processed using RES2DInv Software, a cross-sectional model of resistivity of the iterated results was obtained, while the summary value Resistivity on the 2D pseudo -ection section is presented.



Gambar 8. Cross section comparison resistivity and bulk data rain on the day that was done measuremen of resistivity data (Felisitas 2015).

**A. Geoelectric track in Panel 7 draw point 13 to 25 on May 4, 2015.**

**Table. 3. Mapping resistivity value using Wenner configuration on May 4, 2015.**

| No | Location | Resistivity | Depth | Information |
|---|---|---|---|---|
| 1 | Panel 6 DP#14E | 65.8 Ωm - 1806 Ωm | 1.25 – 19.8 m | Wet muck B1 |
| 2 | Panel 6 DP#16E | 198 Ωm - 1806 Ωm | 1.25 – 39.6 m | Wet muck A3 |
| 3 | Panel 6 DP#18E | 21.8 Ωm - 16431 Ωm | 1.25 – 28.7 m | Wet muck B3 |
| 4 | Panel 6 DP#19E | 65.8 Ωm - 5447 Ωm | 1.25 – 18.5 m | Wet muck A3 |
| 5 | Panel 6 DP#20E | 198 Ωm - 559 Ωm | 1.25 – 16.5 m | Wet muck A3 |
| 6 | Panel 6 DP#21E | 198 Ωm – 599 Ωm | 1.25 – 12.4 m | Wet muck A3 |
| 7 | Panel 6 DP#22E | 65.8 Ωm – 198 Ωm | 1.25 – 6.8 m | Wet muck B3 |

**B. Geoelectric track in Panel 7 draw point 13 to 25 on May 5, 2015.**

| No | Location | Resistivity | Depth | Information |
|---|---|---|---|---|
| 1 | Panel 6 DP#14E | 7.23 Ωm - 198 Ωm | 1.25 – 15.5 m | Wet muck B1 |
| 2 | Panel 6 DP#16E | 7.23 Ωm - 599 Ωm | 1.25 – 36.2 m | Wet muck A3 |
| 3 | Panel 6 DP#18E | 21.8 Ωm - 198 Ωm | 1.25 – 43.1 m | Wet muck B3 |
| 4 | Panel 6 DP#19E | 7.23 Ωm - 65.8 Ωm | 1.25 – 36.9 m | Wet muck A3 |
| 5 | Panel 6 DP#20E | 7.23 Ωm – 1806 Ωm | 1.25 – 26.2 m | Wet muck A3 |
| 6 | Panel 6 DP#21E | 21.8 Ωm – 1806 Ωm | 1.25 – 15.6 m | Wet muck A3 |
| 7 | Panel 6 DP#22E | 7.23 Ωm – 21.8 Ωm | 1.25 – 12.6 m | Wet muck B3 |

**C. Geoelectric track in Panel 7 draw point 13 to 25 on May 7, 2015.**

| No | Location | Resistivity | Depth | Information |
|---|---|---|---|---|
| 1 | Panel 6 DP#14E | 21.8 Ωm - 198 Ωm | 1.25 – 17.0 m | Wet muck B1 |
| 2 | Panel 6 DP#16E | 65.8 Ωm - 1806 Ωm | 1.25 – 37.5 m | Wet muck A3 |
| 3 | Panel 6 DP#18E | 65.8 Ωm - 599 Ωm | 1.25 – 43.1 m | Wet muck B3 |
| 4 | Panel 6 DP#19E | 65.8 Ωm - 198 Ωm | 1.25 – 40.2 m | Wet muck A3 |
| 5 | Panel 6 DP#20E | 21.8 Ωm – 5447 Ωm | 1.25 – 24 m | Wet muck A3 |
| 6 | Panel 6 DP#21E | 21.8 Ωm – 599 Ωm | 1.25 – 16.9 m | Wet muck A3 |
| 7 | Panel 6 DP#22E | 65.8 Ωm – 198 Ωm | 1.25 – 5.67 m | Wet muck B3 |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| No | Location | Resistivity | Depth | Information |
|---|---|---|---|---|
| 1 | Panel 6 DP#14E | 21.8 Ωm - 198 Ωm | 1.25 – 17.0 m | Wet muck B1 |
| 2 | Panel 6 DP#16E | 65.8 Ωm - 1806 Ωm | 1.25 – 37.5 m | Wet muck A3 |
| 3 | Panel 6 DP#18E | 65.8 Ωm - 599 Ωm | 1.25 – 43.1 m | Wet muck B3 |
| 4 | Panel 6 DP#19E | 65.8 Ωm - 198 Ωm | 1.25 – 40.2 m | Wet muck A3 |
| 5 | Panel 6 DP#20E | 21.8 Ωm – 5447 Ωm | 1.25 – 24 m | Wet muck A3 |
| 6 | Panel 6 DP#21E | 21.8 Ωm – 599 Ωm | 1.25 – 16.9 m | Wet muck A3 |
| 7 | Panel 6 DP#22E | 65.8 Ωm – 198 Ωm | 1.25 – 5.67 m | Wet muck B3 |

**E. Geoelectric track in Panel 7 draw point 13 to 25 on May 11, 2015.**

| No | Location | Resistivity | Depth | Information |
|---|---|---|---|---|
| 1 | Panel 6 DP#14E | 7.23 Ωm - 599 Ωm | 1.25 – 12.97 m | Wet muck B1 |
| 2 | Panel 6 DP#16E | 7.23 Ωm - 16431 Ωm | 1.25 – 36.2 m | Wet muck A3 |
| 3 | Panel 6 DP#18E | 21.8 Ωm - 16431 Ωm | 1.25 – 43.1 m | Wet muck B3 |
| 4 | Panel 6 DP#19E | 7.23 Ωm - 5447 Ωm | 1.25 – 36.9 m | Wet muck A3 |
| 5 | Panel 6 DP#20E | 7.23 Ωm – 16431 Ωm | 1.25 – 26.2 m | Wet muck A3 |
| 6 | Panel 6 DP#21E | 65.8 Ωm – 16431 Ωm | 1.25 – 19.8 m | Wet muck A3 |
| 7 | Panel 6 DP#22E | 7.23 Ωm – 65.8 Ωm | 1.25 – 6.38 m | Wet muck B3 |

## CONCLUSION

From this research, it can be concluded that:
Mine DOZ Panel 6 targets the research area, there are some consistent draw points showing a low resistivity value, which is correlated to the potential for wet muck launch or wet mud that could cause mine equipment accidents or employee accidents, this area is Panel 6 Drow Point 14E , 16E, 18E, 19E, 20E and 21E.

The correlation between the quasi-resistivity quantitative data and rainfall data has the best value of 3.52% when delayed 8 times back which means there is a delay of rainfall data for ± 8 days so that anticipate the time of water flow from the surface (mine / Subsidence) to the draw bell of the research area.

Based on the results of the analysis it can be seen that there are two different streams between the aquifers located in the western part of the mining site, having no hydraulic connection with the aquifer in the east of the Mine site. The hydraulic relationship of Kais Formation and Faumai Formation is due to a crack in the impermeable plane which forms the bottom of the Sirga Formation. And the flow that flows in Formation Faumai comes from the Meren Valley area and flows into Waripi Formation and Kais Formation through the fracture field.

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