



Article Info

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Performance Evaluation for an Optimized Wenner (ALPHA, BETA, AND GAMMA) Arrays Using Synthetic Geological Models

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The study aimed at comparing the resolution and effectiveness of three-electrode arrays (Wenner- α , Wenner- β , and Wenner- γ) in the 2D Electrical resistivity method using Numerical analysis of geological models. Three synthetic geological models that simulate block-one dyke and water layer were generated using RES2DMOD software. The inversion used for the geological models was based on smoothness-constrained least-square inversion which was carried out with RES2DINV. The inversion results were imputed into surfer11 software to examine the image resolution, thereafter absolute percentage error (APE) was calculated to measure the effectiveness of the arrays. The result for the block-one model shows that the Wenner- β array has an APE of 14.45%, the Wenner- α array has an APE of 32.67%, and the Wenner- γ array with an APE of 29.15%. Similarly, for the dyke model, the Wenner- α array, Wenner- β array, and Wenner- γ array have an APE of 69.61%, 57.43%, and 45.49% respectively. However, the results for the water layer model show that the Wenner- α array has an APE of 17.11%, the Wenner- β array has an APE of 12.16%, and that the Wenner- γ array has an APE of 16.21%. Wenner- α is expected to produce an image with the best resolution having the highest APE, henceforth APE suggests the resolution capacity of an array.

Keywords: 2D Electrical resistivity; Electrode Arrays; Block-one; Dyke and water layer.

1. Introduction

There are many types of arrays to be used for data acquisition in the field survey. Some of the common arrays are Dipole-Dipole, Pole-Dipole, Wenner- α Wenner- β Wenner- γ and Wenner-Schlumberger. The resolution and accuracy of inverted data sets have been investigated by various researchers (Sasaki, 1992; Dahlin and Zhou, 2004). An appropriate electrode array must be adopted for the data acquisition to ensure maximum anomaly information, high signal-to-noise ratio, and reasonable data coverage (Usman, et al., 2019). The reliability of electrical resistivity survey depends on the electrode arrays used, and this has attracted many geophysicists to research the accuracy assessment of the models produced by different electrode array configurations (Hassan, et al., 2018).

Different electrode arrays configurations have been used in geophysical explorations to detect the ground anomalies, environmental and engineering purposes (Aizebeokhai and Olayinka, 2010; Amidu and Olayinka, 2006).

These arrays include Wenner- α , Wenner- β , Wenner- γ and Wenner-Schlumberger. The arrays provide useful practical options for surface sounding, profiling, and scanning surveys in different situations (Aber and Meshin, 2010). For resistivity imaging, there might be differences in the imaging capabilities of the electrode arrays when applied to a geological model, that is, differences in spatial resolution, tendency to produce artifacts in the images, in deviation from the true model resistivity, and interpretable maximum depth. (Aizebeokhai and Olayinka, 2010; Dahlin and Zhou, 2004). In this study, we investigated the behaviours of three-electrode arrays for imaging three synthetic models (Block one, Dyke, and Water Model), which are intended to reflect some geological structures in practice. An appropriate electrode array must be adopted for the data acquisition to ensure maximum anomaly information, high signal-to-noise ratio, and reasonable data coverage (Usman, et al., 2019). The reliability of electrical resistivity survey depends on the electrode arrays used, and this has attracted

many geophysicists to research the accuracy assessment of the models produced by different electrode array configurations (Hassan, et al., 2018).

All targets of environmental and engineering interest are detected at shallow depths. Geophysical responses from near-surface sources are mostly treated as noise in general geophysical exploration surveys are often the targets of interest in environmental and engineering investigations (Aizebeokhai & Singh, 2013). The subsurface geological structures can be complex at the subsurface, subtle, and multiscale such that spatial variations can change rapidly in two dimensions. Therefore, not much space between the grids is needed for accurate characterization, high spatial resolution from depth to basement, and good target identification. Electrical resistivity surveys must take into account the capabilities of the data acquisition system, resolution capacities of the electrode configurations, and depth to basement investigation is required. Other factors to be considered are the length of the site to be covered, the expenses of the survey, and the time required to complete the investigation (Alhameedawi & Thabit, (2017).

In this study measured and synthetic data set shows that almost all the arrays are capable of defining vertical and horizontal structures with varied sensitivity in vertical and horizontal changes, however, all the arrays depicted the image with Wenner-β array having the best resolution and produced the best image for block one model. Similarly, it is noted that the Wenner-α array produced a good resolution of the image but there exists a shadow depth of the resistivity beneath the target. The wenner-γ array also produced a better image with good resolution.

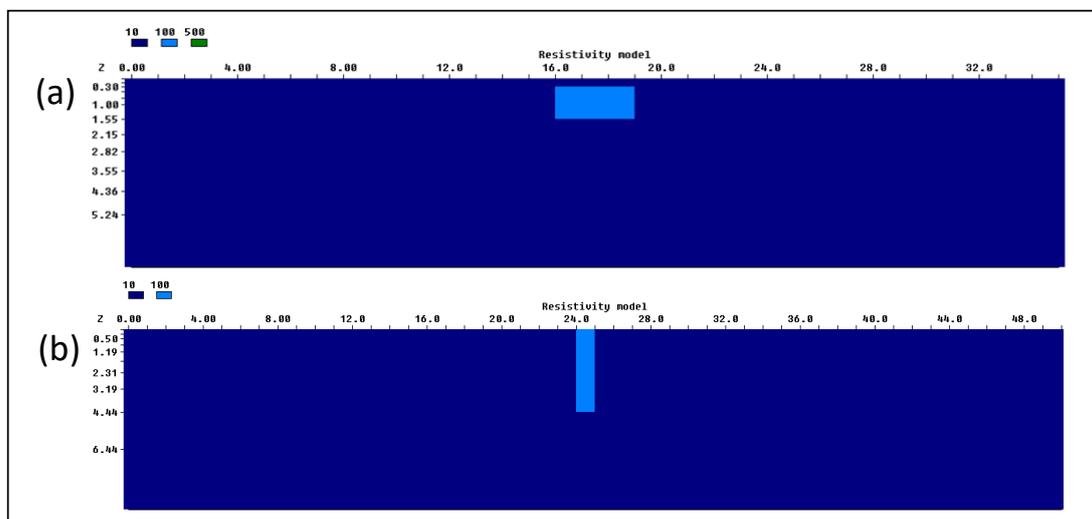
2. Methodology

The materials used to carry out this research are; Computer System, RES2DMOD software, RES2DINV software, and Surfer11 software. A virtual survey was designed using res2Dmod software by selecting block-one, dyke, and water models using Wenner-α, Wenner-β, and Wenner-γ arrays. The arrays and models were selected because they are some of the most commonly used arrays and geological models at the subsurface respectively. In all cases, the resistivity of 100Ωm and 10Ωm (i.e. 1:10) was maintained for each model. The depth value for each array was read to know the maximum depth it can reach.

For block-one model specification, 36 electrodes were used at a spacing of 1m with a total spread length of 35m while for the dyke model specification, 51 electrodes were used at a spacing of 1m with a total spread length of 50 m. Similarly, 51 electrodes were used at a spacing of 1m with a total spread length of 50m for water model specification. Figure 1. Shows the model for block one, Dyke and water models.

After designing the models, a virtual survey was carried out to generate the apparent resistivity data, and the result was saved in res2dinv format. The data was imported in the res2dinv software and the smoothness-constrained least-square inversion was used to run the inversion to get the true resistivity data which was saved in surfer format. The data was imputed in surfer11 and plotted to get the resistivity sections. Errors were finally calculated using Equation 1.

$$| \text{ERROR} / (\text{AREA OF THE BLOCK}) \times 100 \text{ \%} \dots\dots\dots(1)$$



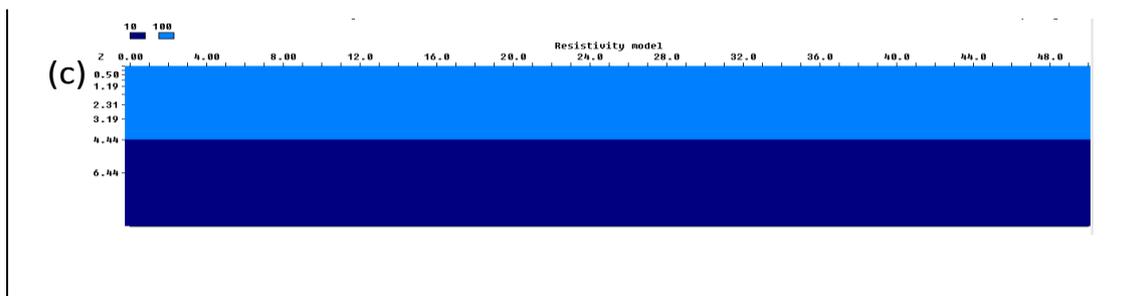


Figure 1. (a) Block-one model (b)Dyke (c) Water Model

3. Results and Discussion

3.1 Results

Block-One Model - wenner- α

Figure 2. Below shows the block model before the inversion and the contour map after the inversion, for block one Wenner alpha array.

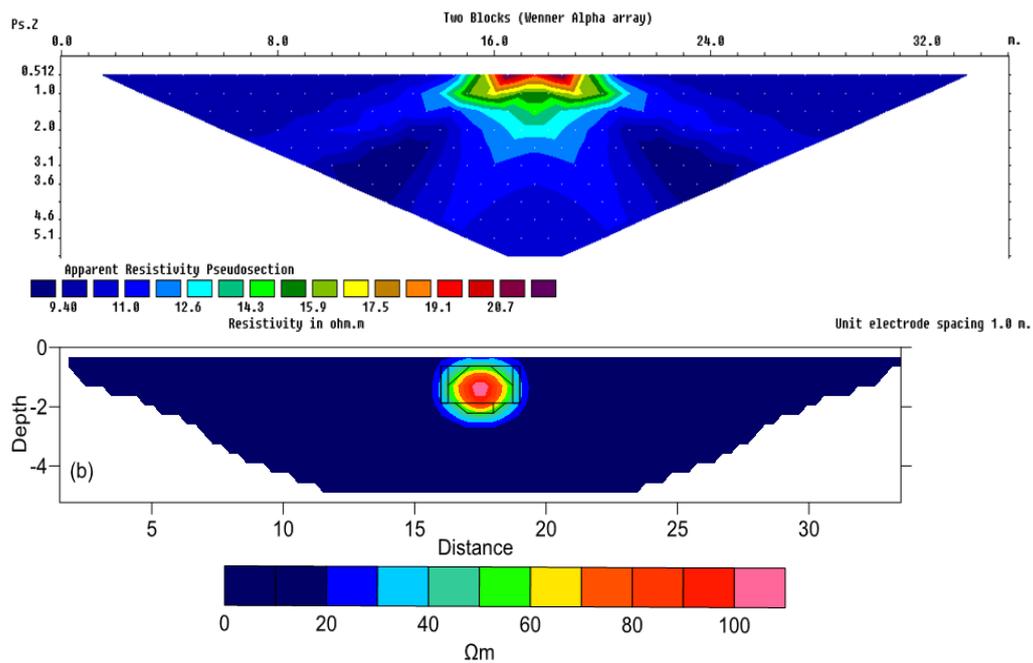
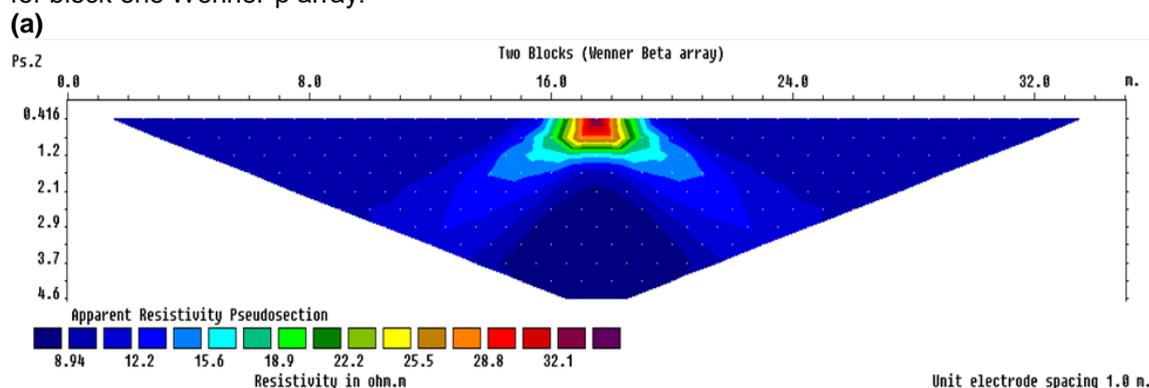


Figure 2. Block model for Wenner alpha array; (a) apparent resistivity with an electrode spacing of 1.0m (b) True resistivity with a depth of more than 4km.

Block-One Model- β Array

Figure 3. Below shows the block model before the inversion and the contour map after the inversion, for block one Wenner- β array.



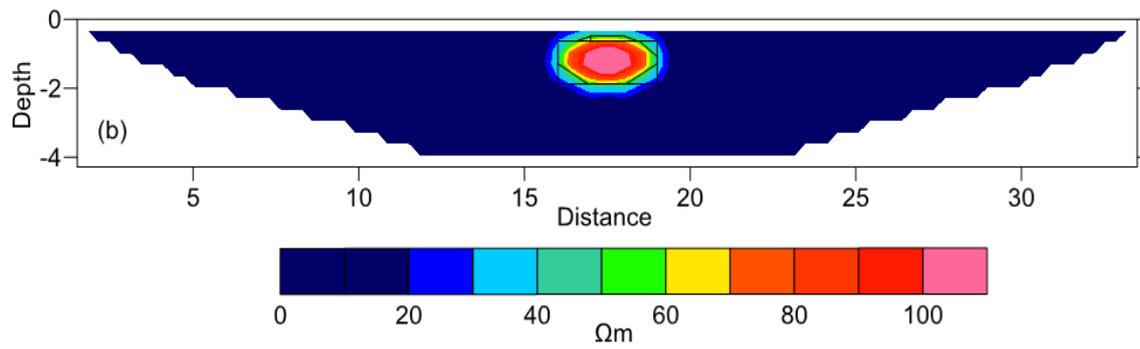


Figure 3. The block model results given by Wenner- β array. (a) apparent resistivity with an electrode spacing of 1.0m (b) True resistivity with a depth of more than 4km

Block-One Model - γ Array

Figure 4. Below shows the block model before the inversion and the contour map after the inversion, for block one Wenner- γ array;

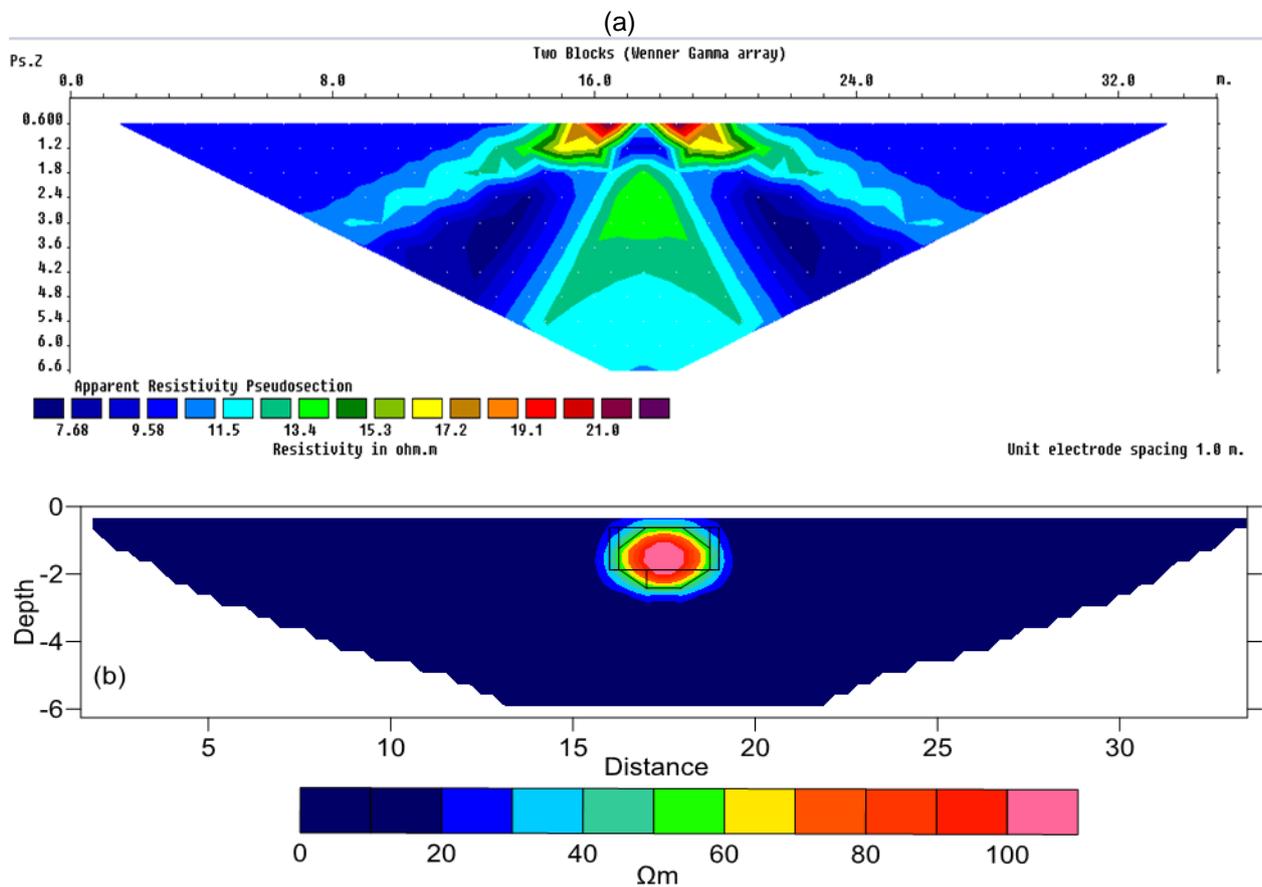


Figure 4. Block model results given by Wenner- γ array. a) apparent resistivity with an electrode spacing of 1.0m (b) True resistivity with a depth of more than 6km

Dyke Model- Wenner- α

Figures 5. Below shows the dyke model before the inversion and the contour map after the inversion, for the Wenner alpha array;

(a)

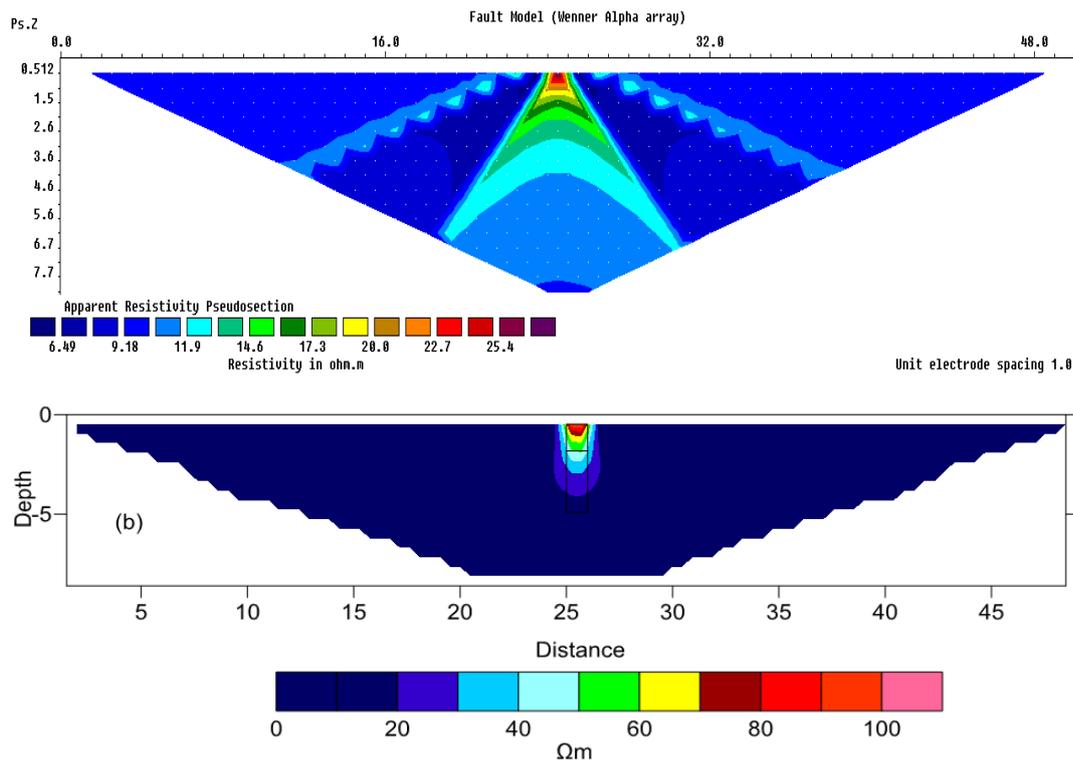


Figure 5. The dyke model results given by Wenner alpha array. a) apparent resistivity with an electrode spacing of 1.0m (b) True resistivity with a depth of more than 5km

Dyke Model- β Array

Figures 6. Below shows the dyke model before the inversion and the contour map after the inversion, for the Wenner- β array;

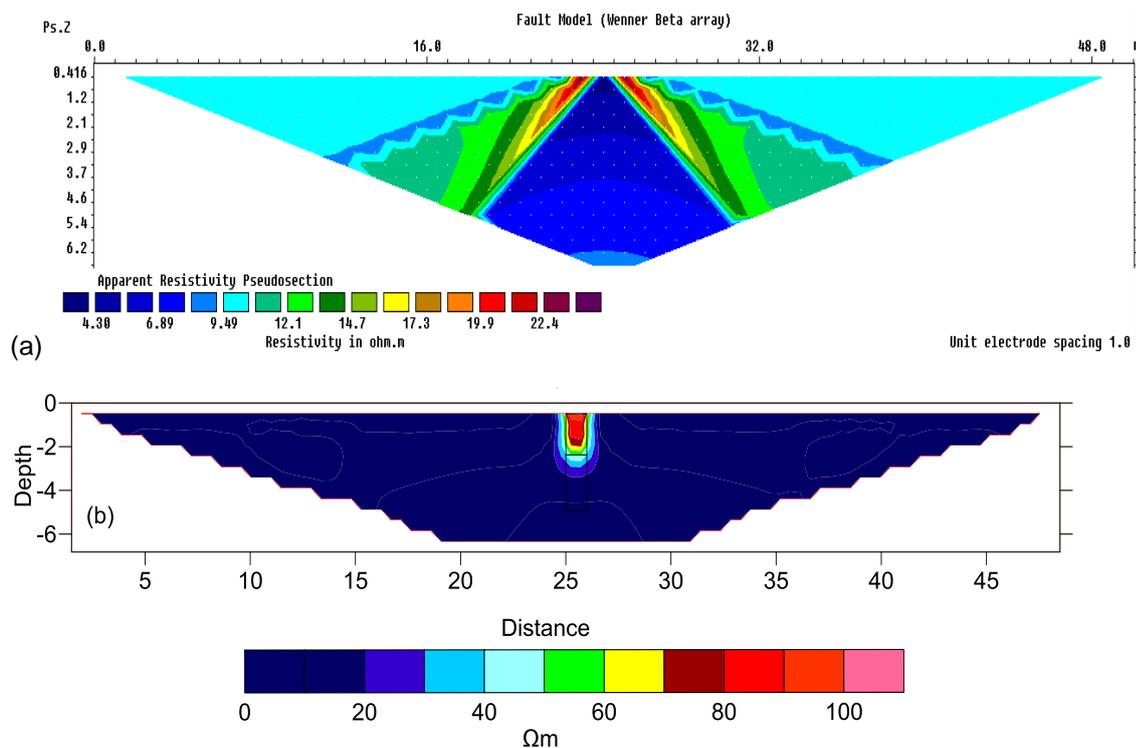


Figure 6. the dyke model results given by Wenner- β array. a) apparent resistivity with an electrode spacing of 1.0m (b) True resistivity with a depth of more than 6km.

Dyke Model- γ Array

Figure 7. Below shows the dyke model before the inversion and the contour map after the inversion, for the Wenner- γ array;

(a)

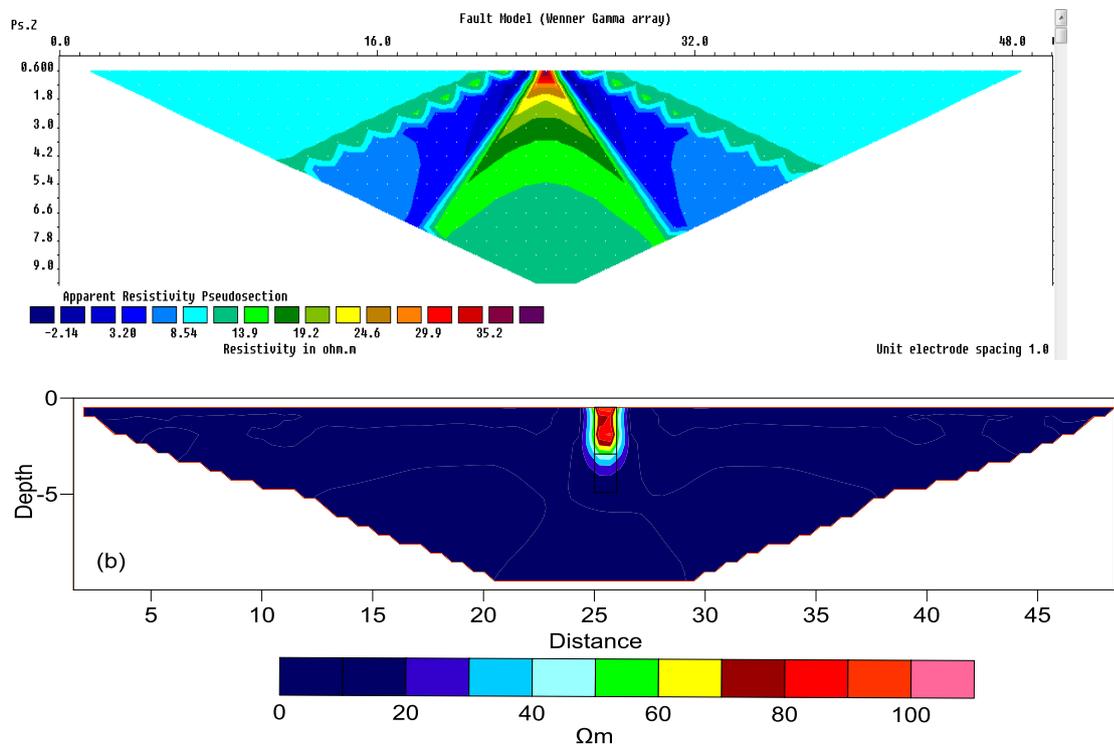
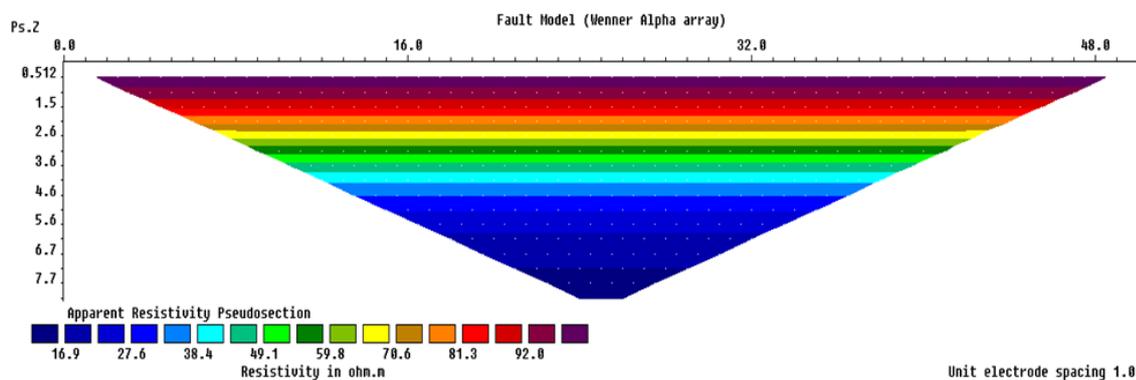


Figure 7. The dyke model results given by Wenner- γ array. a) apparent resistivity with an electrode spacing of 1.0m (b) True resistivity with a depth of more than 5km

Water Table Model- wenner- α

Figure 8. Below shows the water model before the inversion and the contour map after the inversion, for the Wenner alpha array;

(a)



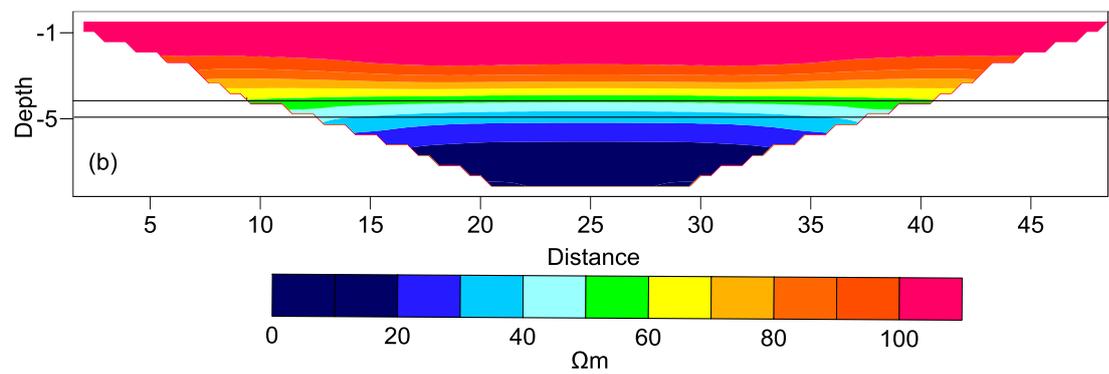


Figure 8. The water table model results given by Wenner alpha array. a) apparent resistivity with an electrode spacing of 1.0m (b) True resistivity with a depth of more than 5km.

Water Table Model- β Array

Figure 9. Below shows the water model before the inversion and the contour map after the inversion, for the Wenner- β array;

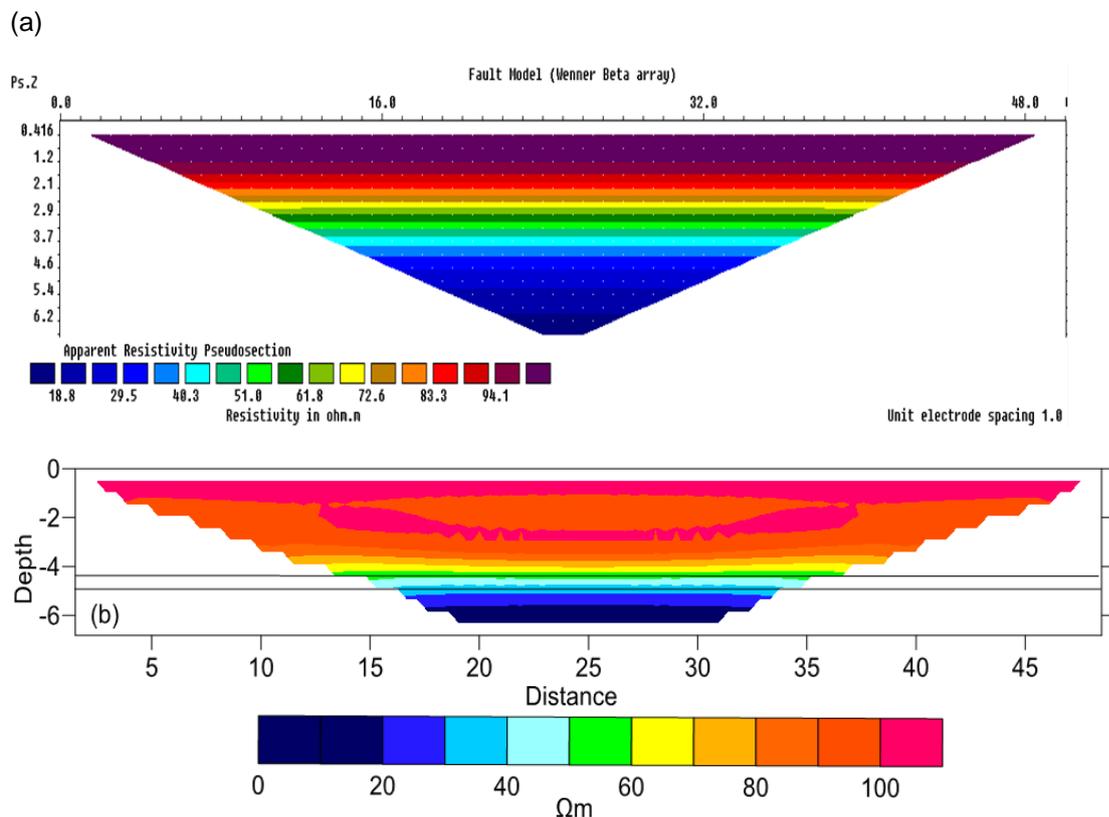


Figure 9. The water table model results given by Wenner- β array. a) apparent resistivity with an electrode spacing of 1.0m (b) True resistivity with a depth of more than 6km.

Water Table Model- γ Array

Figure 10. below shows the water model before the inversion and the contour map after the inversion, for the Wenner gamma array;

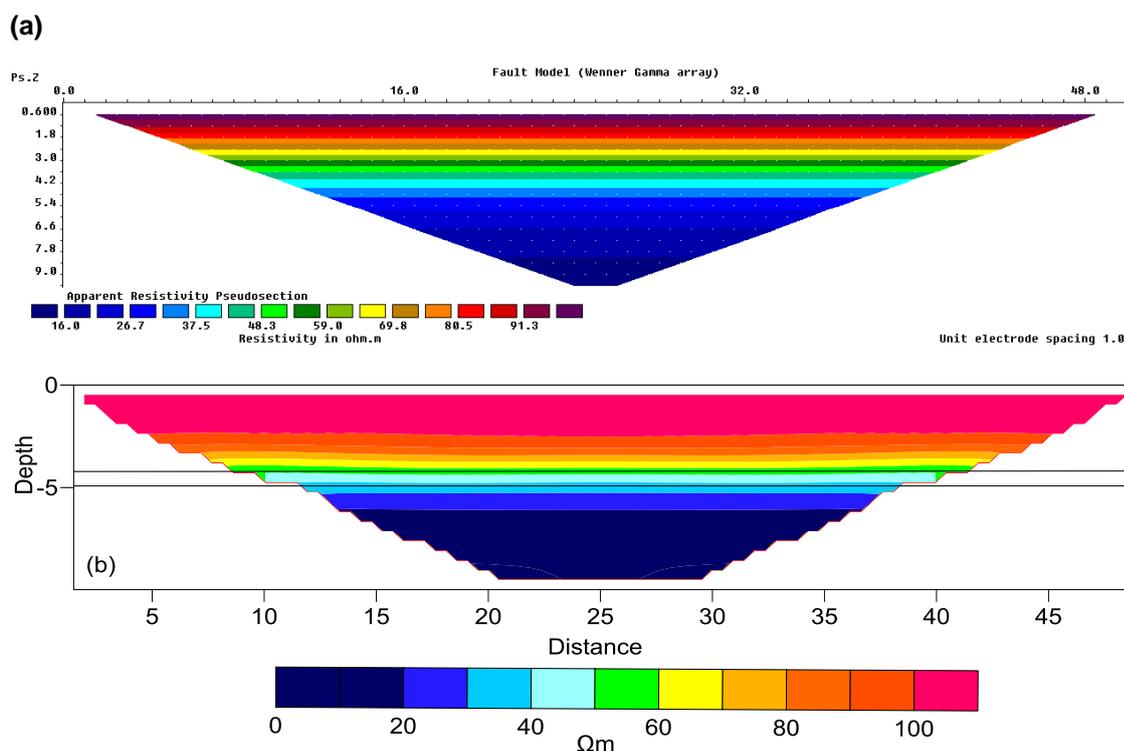


Figure 10. The water table model results given by the Wenner gamma array. (a) apparent resistivity with an electrode spacing of 1.0m (b) True resistivity with a depth of more than 5km.

Table 1: Summary of the Results

STRUCTURES	ERRORS (APE) %		
	Wenner- α	Wenner- β	Wenner- γ
Block one	32.67	14.45	29.15
Dyke	69.61	57.43	45.49
Water table	17.11	12.16	16.21

3.2. Discussion

Figure 2-10 shows the generated apparent resistivity and the inversion result of Block-One, Dyke, and water layer models. The depth of investigations for Wenner- α , Wenner- β , and Wenner- γ arrays are 4.25 m, 6.25 m, and 5.18 m as shown in Figures 2b, 3b, and 4b respectively, for the Block-One model. For the Dyke model, Wenner- γ has a depth of 9.94 m, Wenner- α has a depth of 8.61 m whereas Wenner- β has a depth of 6.81 m. For the water layer model, Wenner- β (Figure 9b) has a depth of about 6.81 m, Wenner- α (Figure 8b) has an 8.59 m depth of investigation and the Wenner- γ (Figure 10b) has a depth of 9.97 m. Therefore Wenner- γ array appeared to have the maximum depth of investigation. However, this depth does not depend on the generated apparent resistivity. (Figure 2a-10a).

Table 1 above shows that using all models Wenner- α has an APE of 32.67, 69.61, 17.11 respectively while an APE of 14.45, 57.43, and 12.16 against Wenner- β . Lastly, Wenner- γ has

an APE of 29.15, 45.49, and 16.21 for Block one, Dyke, and Water table models. This implies that using APE for the effectiveness of electrode arrays, Wenner- α is expected to produce an image with the best resolution. However, the inversion result of the models (Figure 1-3, 4-9) gave Wenner- β as the array with the best resolution. The result of calculated APE for the dyke model shows that the Wenner- α also has the highest APE than Wenner- β with Wenner- γ having the least APE. Wenner- α was expected to be very effective in producing images with the best resolution. Conversely, the inversion result shows that Wenner- γ produced images with the best resolution.

4. Conclusion

The numerical modeling using three synthetic models; block-One, dyke, and water models was carried out to compare the resolution and effectiveness of three-electrode arrays (Wenner- α , Wenner- β , and Wenner- γ) in resolving geological structures. This was achieved using forward modeling and inversion. The forward

modeling was done using RES2DMOD software and the inversion used is based on smoothness-constrained least-square inversion which was carried out with RES2DINV, the result was plotted and the APEs were calculated to measure the effectiveness of these arrays in SURFER11 software.

For block-one; Wenner- β was found to be the most suitable array compared to the three arrays for the block model. For dyke model, Wenner- γ have the best resolution with the other arrays having moderately good resolution, Wenner- α gave the highest effect value, and Wenner- γ and Wenner- β have low effect value. Finally, for the water model, the result shows that all the three-electrode arrays were able to image the feature with Wenner- β having a better resolution than that of the other arrays.

Conflict of Interest

The authors declare that there is no conflict of interest.

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