Pseudo-3D direct current resistivity for underground water surveying

Zhenwei Guo[1,2,3], Chunming Liu[1,2,3*], Jianxin Liu[1,2,3], Hua Zhou[4], Shuaijun Zhao[5,6], Haibing Li[5]
1,Key Laboratory of Metallogenic Prediction of Nonferrous Metals and Geological Environment Moni-toring （Central South University), Ministry of Education, Changsha 410083, China
2,Hunan Key Laboratory of Nonferrous Resources and Geological Hazard Exploration, Changsha 410083, China
3, Bureau of Geology & Mineral Exploration and Development of Hunan 402 Team, Changsha, 410004, China
4,School of Geosciences and Info-physics, Central South University, Changsha, 410083, China
5,Geological Environment Monitoring Station of Hunan Province, Changsha, 410007, China
6,School of environmental studies, China University of Geosciences, Wuhan, 430074, China

*Corresponding Author
guozhenwei@csu.edu.cn; lifuming001@163.com; ljx6666@126.com;

SUMMARY

The direct current (DC) resistivity method has been applied in geophysical exploration for many years. 3D DC resistivity array has also been applied for surveying since long time ago. However, due to the limitation of the topography of the surveying field, 3D array is not the efficient way to acquire the data. The 2D profiles are not effective to interpret the DC resistivity result. In this paper, we present a pseudo-3D DC resistivity array for the data acquisition. Both the synthetic data and real data cases can prove that the pseudo-3D DC resistivity array provide a better resistivity image than 2D array. Compared to the 3D array, it also can reduce the data acquisition time.

Keywords: DC resistivity, pseudo-3D, underground water

INTRODUCTION

The direct current (DC) resistivity method is a useful geophysical technique to describe the various resistivity of the earth. The electrical resistivity varies with the rock or sediment type, porosity and water situation. Traditionally, arrangements called Schlumberger array are using four electrodes for vertical soundings or horizontal profiling.

Resistivity is calculated by using the relationship between resistivity, an electric field, and current density (Ohm’s law). The assumption is where the earth is homogeneous and isotropic, so the calculated resistivity is defined as the apparent resistivity (Dobrin, 1988).

Early discussion of DC resistivity method could be found in Sumner (1976), and Sharma (1997). In order to collect the sounding and profiling data, multi-electrode array was provided to measure the data (Dahlin, 1989；2000). The dense array of data can provide more details for the resistivity interpretation.

A towed array data acquisition system has been used where a carriage of electrodes towed by a vehicle (Panissod et al., 1998). The towed array provides a fast data acquisition approach.

2D data acquisition arrays, such as Schlumberger array, pole-pole, pole-dipole and dipole-dipole arrays are using no more than four electrodes to measure the data. 3D data acquisition employs all the electrodes as the transmitters and receivers electrodes.

In this paper, we proposed a pseudo-3D DC resistivity data acquisition system, which provides a 3D resistivity cube. This pseudo-3D data array provides faster and more efficient data acquisition system than 3D data array. Additionally, the pseudo-3D data array provides more detailed information than 2D data array.

Method

The pseudo-3D array uses the transmitter electrodes in a line. As shown in Figure 1, the “Red Cross” is the location of the transmitter electrodes. The “Black Cricle” is the location of the receiver electrodes. From A_{-13} to A_{13}, the distance is 2.6 times of the width of area 6. The infinitely powered electrode is located at position 1. The transmitter equipment is located at position 3.

We assume that the coordinates (-a,-b) and (a,b) are at the corners of area 6. The coordinates of transmitter electrodes (x,y) is given as:

$$(x,y) = \begin{cases} (x,0); when\ |x| \le a \\ (a+2^i,0); when\ a < x \le (3a+1), \\ (-a-2^i,0); when - (3a+1) \le x < -a \end{cases} \quad (1)$$

where *x, y, a, i* are integers.

The neighbor distance is *c* in horizontal direction(*X*); and *d* in vertical direction (*Y*). When the distance of the transmitter line is 2.6 times of the width of the measurement area 6, the coordinate origin is assumed as the center of measurement area.

The coordinate of the transmitter is given as:

$$(X_c, Y_c) = (x \times c, y \times d) = (x \times c, 0) \quad (2)$$

The Pseudo-3D array could measure the data as pole-pole or pole-dipole way.

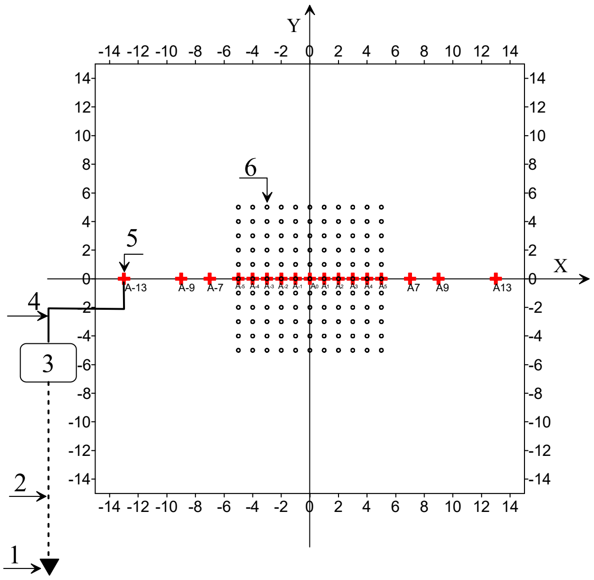

Figure 1: The observation system of pseudo-3D DC resistivity surveying

Numerical modeling and inversion results

In order to compare the 2D array, 3D array and pseudo-3D array data acquisition, we test the method by inverting the synthetic data. The area of the field is 300×300 m^2. The distance between the neighbor electrodes is 20 m. A 10 Ωm resistivity cube is embedded in the 1000Ωm formation. The side length of the cube is 100 m. It is located at （-50,-50）~（50,50）, and the top of the cube is buried at 20 m.

The inversion results are given in Figure 2, Figure 3, and Figure 4. The Figures 2, 3, and 4 show the results of 2D, 3D and pseudo-3D DC resistivity inversion.

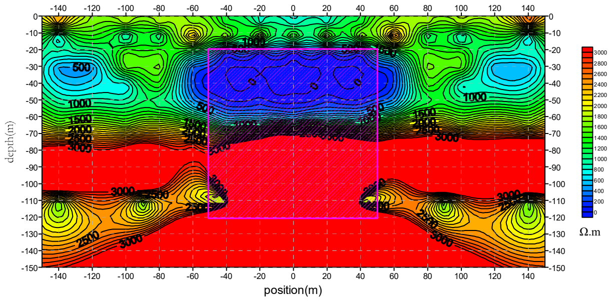

Figure 2: The inversion results of 2D DC resistivity surveying

The pink square is the position of the true model. Figure 2 shows that the high resistivity layer below 70 m as artifacts. The low resistivity anomaly is just half thickness of the real model.

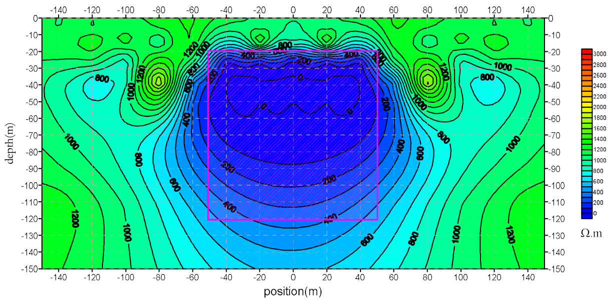

Figure 3: The inversion results of 3D DC resistivity surveying

Figure 3 shows the 3D DC resistivity inversion result. The low resistivity anomaly fits the true model well. The background resistivity is also around 1000Ωm. This result is better than the 2D case.

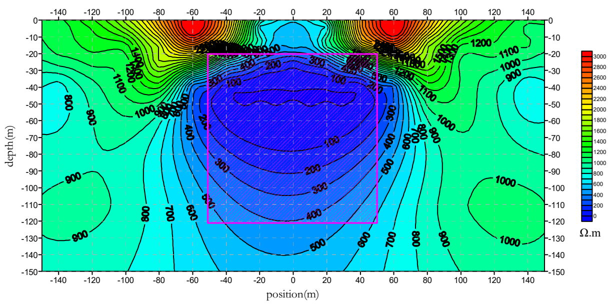

Figure 4: The inversion results of pseudo-3D DC resistivity surveying

Figure 4 shows the inversion results of the pseudo-3D DC resistivity data. The data acquisition is more efficient than the 3D case. The low resistivity anomaly is limited in the pink square. The result fits the true model not bad. However, there are two high resistivity artifacts near surface located at (-60, 0) and (60, 0). This result is also better than the image shown in 2D case.

Real data case

In this section, we are testing the pseudo-3D method on the groundwater exploration case. The field work has been done in Zixing, China.

Figure 5 shows the field of the groundwater exploration. In Figure 5, the three blue profiles are designed to measure the pseudo-3D DC resistivity data. The transmitter electrodes are located at the long profile in the middle. The receiver electrodes are located at the three profiles.

Figure 5. Location of groundwater exploration in Zixing.

Figure 6 shows the 2D DC resistivity inversion results of the groundwater exploration. From the resistivity image, the high resistivity anomaly is interpreted as the granite rocks. The low resistivity anomaly is below the granite rocks. However, the inversion of pseudo-3D DC resistivity shows the opposite conclusion, which is shown in the Figure 7.

Compares the two Figures 6 and 7, we can find that the Figure 7 provide a better resistivity image for the interpretation. The smooth resistivity image gives a low resistivity layer above the granite rocks. At the position of 300, the oblique structure is good for save the groundwater. Because the security reason, we design a drilling well at the position 400.

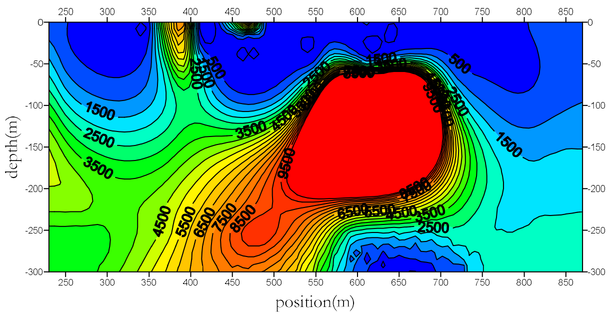

Figure 6. 2D DC resistivity inversion results.

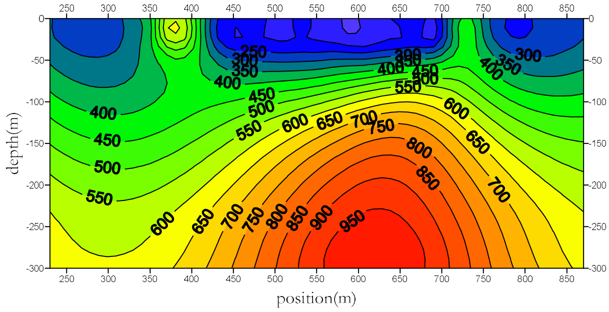

Figure 7. Pseudo-3D DC resistivity inversion results.

From Figure 7, the resistivity image gives a low resistive area between positions 0-400. A fault F1 degree 50 has been found near the 400 position. So the reason of the low resistivity area is caused by the rock fracture zone being filled with the water. The high resistivity between the positions 450-750 is caused by the Silica and Granite zone. Near the surface, the low resistivity layer is due to the sediments of the Quaternary alluvium and the river.

Based the interpretation discussed with the geologist, the decision is to drill a well at the position 400.

Figure 8. The ground water well at the 400 position.

The photo as shown in Figure 8 is given the drilling result. The groundwater is pumped from underground. The well has been drilled through the shallow granite rock layer. The fracture zone found by the drilling could be the reservoir for the underground water.

CONCLUSIONS

In this paper, we present a pseudo-3D DC resistivity array to enhance data acquisition efficiency. This pseudo-3D DC resistivity array can provide a better resistivity image from the inversion than the 2D array. Compared to the 3D array, it reduces the data collection time but provides the similar result. Both the synthetic data and the real field data show that the pseudo-3D DC resistivity array is an effective and efficient method for geophysical exploration.

ACKNOWLEDGEMENTS

The author has the financial supported by "The International Postdoctoral Exchange Fellowship Program". Project funded by China Postdoctoral Science Foundation grant number [2017M622607].

REFERENCES

Dahlin, T., (1989). The development of a cable system for vertical electrical sounding and a comparison of the Schlumberger and Offset Wenner methods. Licentiate Thesis LUTVDG/(TVTG-1005)/1-77, Lund University, 77pp.

Dahlin, T.(2000). Short note on electrode charge-up effects in DC resistivity data acquisition using multi-electrode arrays. Geophysical Prospecting, 48(1), 181-187.

Sharma, P. V. (1997). Environmental and engineering geophysics Cambridge University Press Cambridge. United Kingdom.

Sumner, J. S. (1976). Principles of induced polarization for geophysical exploration. Elsevier. Amsterdam, Netherland, 277.

Panissod C., M. Dabas, A. Hesse, A. Jolivet, J. Tabbagh, A. Tabbagh, (1998). Recent developments in shallow depth electrical and electrostatic prospecting using mobile arrays, Geophysics, 63(5), 1542-1550.