Application of ATEM on the Xiongan New Area Underground Space Investigation

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Abstract

The application of Airborne Time-domain Electromagnetic is developing in recent year, but investigation of underground space is rarely to see in China. An ATEM was conducted in Xiongan New area in the central part of China, which was known as one of the most complex shallow structure underground. The plan of field work, data processing method and inversion method was introduced in the paper. Two years field data and inversion results were compared to confirm the data quality. Ground resistivity method was discussed and compared in the paper. Geophysical data was collected to clarifying different kind of soil, which were used for inversion and layer distinguish. Through the research work in the area, water contained layer was mapped in the model, which can be the supplement of ground investigating work. The experience of work in the area would be useful for the underground structure investigation in the future.

1. Introduction

Airborne Transient Electromagnetic Method (ATEM) was developed fast in recent years, some good result was obtained in mining, hydrology and engineering (Liang et al., 2014;Yin et al., 2015;Wu et al., 2019). Flying platform was used to setup the device, which is off the ground and need nothing assist while flying, can minimize the disturbance of ground artificial building. A lot of application was successfully carried out in underground structure investigation(Auken et al., 2008;Barfod et al., 2016;Sridhar et al., 2017;Yi-Yuan et al., 2018;Yang et al., 2020).

The interpreting result provided important information for the designing in Xiongan New area, central part of China.From the beginning of Xiongan New area was set up, big amount of investigating work was done to serve the space arranging plan and master designing assurance. Geology, hydrogeology and underground space investigation was carried out, a lot of geophysical method was used.

We introduced the theory of ATEM and the background situation of working area, also summarized the electrical characteristic of soil layer. Data processing method and inversion method were discussed in the paper, interpreting was obtained through integrated analyzing. We summarize the underground application with ATEM in the end.

2. Atem Theory

ATEM method is an induction method obtaining data with flying platform. High power is induced into ground which is generated by electric current through a loop, we called primary field. Eddy current is generated with the induction, which leads to new electrical signal when declining, called secondary field. Electrical information of target body could be subtracted through observing the secondary field, we can describe the geological structure by the information.

ATEM method includes data obtaining, data processing, data inversion and interpreting, etc. There are some different system were used in the world, the parameter of wave form, receiver frequency etc. were quite different(Reninger et al., 2014;Barfod et al., 2016;Sridhar et al., 2017). Data of each system need to be processed and interpreted separately.

3. Survey Background

Xiongan New area is in Hebei province, central part of China. It includes Xiong, Rongcheng, Anxin country and some other town with a total area of 2000 square kilometer, the traffic is convenient through the area. The biggest freshwater lake Baiyangdian was in the area, the total area of which is 360 square kilometer. A lot of geological work was carried out in the area, such as hydrogeological evaluation, underground water pollution investigation and geothermal energy evaluation from 2016. Land subsidence and land quality parameter evaluation were carried out in the last decade.

3.1 Strata

The quaternary strata is the main aim of our work, we have a brief introduce to the Strata.

3.1.1 Holocene Series(Q_n)

The bottom surface of Q_n is 10 to 15 meter in the piedmont zone, and it increased to 20–25 meter in the east. Main material came from Diluvial-alluvial and lacustrine deposit. Lithology characteristic is grey mild clay and mild sand soil in the upper part, grey muddy mild clay in the middle, yellow-grey fine and silty sand in the lower part. The particle size in alluvial fan is bigger, sand and sand gravel are the main rock.

3.1.2 Upper Pleistocene(Qp3)

The bottom surface of Qp3 is 40 to 50 meter in the piedmont zone, increases to 60 meters in the east. The thickness of the deposit is 40 to 50 meter. Lithology characteristic is mild clay, mild sand soil with different particle size of sand, sandstone is found in the piedmont zone.

3.1.3 Middle Pleistocene(Qp2)

The bottom surface of Qp is less than 20 meter in the piedmont zone, the biggest depth is lower than 180 meter in the east, which has an average thickness 80 to 140 meter. Lithology characteristic is mild clay, clay mixed with sand and sandstone. Several calcified layers were found in the upper or top of layer.

3.1.4 Earlier Pleistocene(Qp1)

Qp1 has a thickness of 200–260 meter on the top of Tertiary. Its bottom depth is less than 60 meter in the piedmont zone, and lower than 380–400 meter in the east. The deposit contains clay, mild clay mixed sandstone, which has very complex particle size distribution.

3.2 Electrical characteristic

We obtained 36 drills with logging data, the depth of which is less than 200 meter. Resistivity value of different type of soil was classified, including water-contained sand, clay and silt etc. layers with similar resistivity value was combined into one group. The characteristic of soil resistivity help us setting up the parameter for the inversion and the interpreting (Fig. 1).

Resistivity value of different soil was classified according to the quaternary strata uncovered in the drill. Lithology characteristic can be distinguished into four group, which are clay, mild sand, medium sand and coarse sand. The resistivity value is 10 to 20 Ω.m in different group, sometimes even bigger. The target body can be distinguished by ATEM, which help us setup the three dimensional electrical structure. After interpreting the structure, we can obtain the space distribution of strata. We summarized the resistivity value characteristic in below.

1. Clay, silt clay and clay mixed with sand has the lowest resistivity value, the value range is from 14 to 24 Ω.m.
2. Silt, fine silty sand etc. resistivity value is little higher, the value range is from 26 to 36Ω.m.
3. Fine sand, medium-fine sand etc. resistivity value range is from 42 to 60Ωm, which has a difference around 20Ω.m.
4. Medium coarse sand, coarse sand, dry sand has the highest resistivity value, the value range is from 60 to 120Ω.m.

4. Survey Method

The AeroTEM-IV Time domain airborne TEM system was used to collecting data. Two years survey data was obtained to study the geological structure of the Xionan New area. In order to get the best data, flying altitude was strictly obeyed during survey. For safety consideration, some artificial construction such as tower and power line was avoid with safe altitude. The direction of survey line is 320 degree, which is vertical to the main fault of the area (fig2.). Part of the survey line was designed to make infill survey.

4.1 Data processing

High density data samples and more assist information was obtained in the ATEM acquisition system, which required more space for data storage. Multiply information should be processed during data processing. The field data of AeroTEM system include electromagnetic, GPS data, radar altimeter and imaginary data etc.

The first step is preprocessing. There are different ways to process data, but some basic step is the same, such as data gating, filter etc. (Vrbancich, 2012;Reninger et al., 2014). Database was merged after data stacking, gating, filter and leveling etc. Then data will be checked in database software, also be trimmed out of the survey boundary. Finally, it will be imported into a software called Geoprobe. The software was developed by China Aero Geophysical Survey & Remote Sensing Center for Natural & Resources (AGRS). Quality control and different kinds of report table could be obtained from Geoprobe software. Interface and low quality data will be analyzed in the processing stage. Survey database would be acquired after eliminating bad data, and it can be used in inversion in the next step.

In order to study the noise data characteristic of field data, we enumerates an example dataset. Fig 3a shows a normal distribution of decay curve without noise, which obeys the rule of decay very well, can reveal the structure underground well. Fig 3b shows decay curve with noise point, those points will have a big affection to the inversion result. It needs some methods to eliminate the bad data point before inversion.

Since we obtained the data in two years, the situation of underground would changes largely. An estimation should be done to study the affection of environmental difference. We chose two repeat line survey each year, the inversion results were used to evaluate the difference. From the inversion results (fig4) we can see that the resistivity model changed a little on the boundary, both data can reveal the structure well. So, we used two years data to improve the model quality.

4.2 inversion

Data inversion was carried out in Workbench software. We carried out noise data evaluation and elimination, artificial interfere remove, data restack etc. Remote sensing information were used to confirming the noise data, some other inversion method was also chose for parallel compare. Inversing result was constrained with drill information, which can strongly improve the accuracy. With the assist of drill data, it can be well merged with ground base hydrogeology result. Tie line and survey line data inversion result was used to check the stability of the whole survey. Constrain method can provide a reliable images of the subsurface(Auken et al., 2008).

First we study single line in the survey. Fig 5 showed the relationship between amplitude and receiver height for field data, the value of electrical responds decreased rapidly as height increase (Fig 5a). Beside, amplitude has relationship with distribution of low resistive body, bury depth etc. It can be as a proof on interpreting low resistive body in the last (Fig 5b).

In order to check the equivalence with ground base electronic work, we survey a line strict along a high density resistivity method profile. The inversion result of ground base method is shown in fig 6a, a high resistive body was distinguished in the profile. Due to the density of survey point, the model shows the continuity is poor. Fig 6b shows a continuity high resistive body, the body disappears in7500 meter consisting with fig 6a. Through the two figure we may find that they all got the abnormal body, and have difference on continuity. The ATEM can describe more detail than ground base electromagnetic method.

4.3 Interpreting

According to the geology record obtained before, ground water in the area is contained in loose rock. The characteristic of stability, hydraulic properties, present situation of exploration in aquifuge or weak aquifer was studied in the former work. Aquifer can be distinguished into two system, phreatic water to micro artesian water and artesian water(Gu,2000).

A result of previous research was involved, which shows that aquifer in part of the area is differ than others. Father study was not carried out due to lack of funding and technique restriction. The resistivity distribution in space shows the existence of an abnormal in the aquifer.

The survey area and study area were presented in fig 7, which is in the southwest of Baiyangdian Lake. There are four plane graph was drawed to interpreting the aquifer distribution (fig 8), fig 8a shows there are some low resistivity value area which were disconnected, it becomes bigger in fig 8b, the body turned to decrease in fig 8c, almost disappear in fig 8d. We can conclude that the low resistivity body continuity is well, only some small body is isolated. It exist from a depth of 40 meter to 130 meter, which is supported by the drill information obtained in the earlier years.

Hydraulic data provides us information that the low resistivity layer is an aquifuge, water sample test show that it contains higher salt. We can conclude that the water consisting system is combined in the area, but the system can get hydraulic connection around the aquifuge.

Overall, the low resistivity body is mainly clay, combined with sand in part of the body, which is a poor water consisting body.

A boundary with 30Ωm was calculated to describe the aquifuge with salt water underground(fig 9). It has a long distance from southeast to northwest, mainly distributes in the depth from 50 to 140 meter. The study give us a more detail position of the aquifuge, and it correct the depth data obtain before.

5. Conclusion And Disscussion

We have shown the advantage of ATEM method to distinguish at regional scale underground resistivity variations in Xiongan New area. It is a useful tool to understand spacial distribution in geology complex area, and it can describe more detail information than other geophysical method in the situation. Artificial interference could be decreased in the method.

Finally, we may conclude that:

1. The interpreting result obtained from ATEM method can match drill and geophysical work on the ground well, and it can tell more detail information.
2. The blanked region between drills could be well studied with ATEM, which can bring us an regional interpreting result.
3. Interpreting result of interfere area and place hard to get were obtained, it is useful for the further study.

Still, a lot of steps in ATEM application need be studied now. More research work were needed to improve the investigating ability. For instance, more detail interpreting asks for improvement in data aquization, data processing and integrating information analyzing.

Declarations

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Founding

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Competing interest: No

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Figures

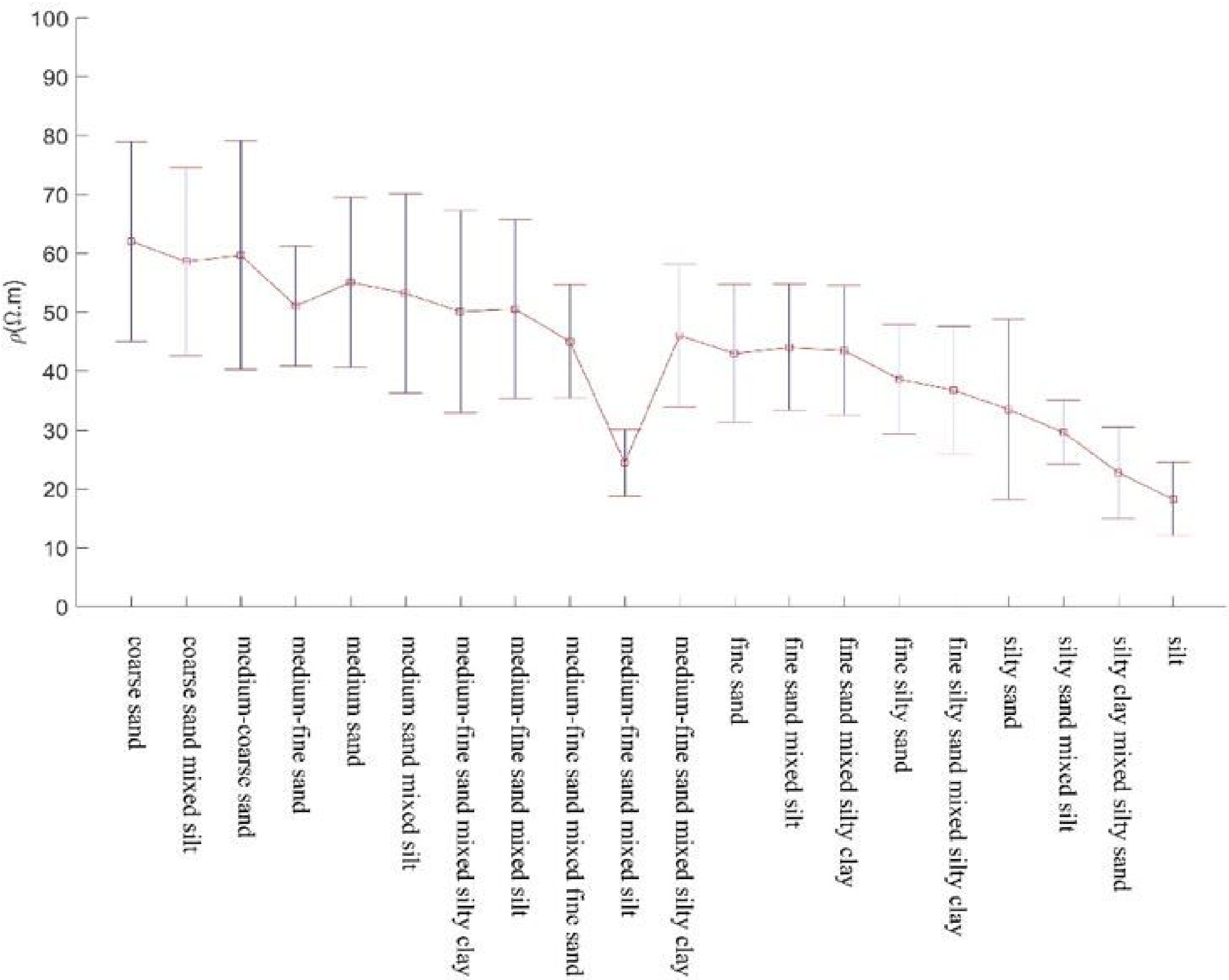

Figure 1

Resistivity value in different soil layer

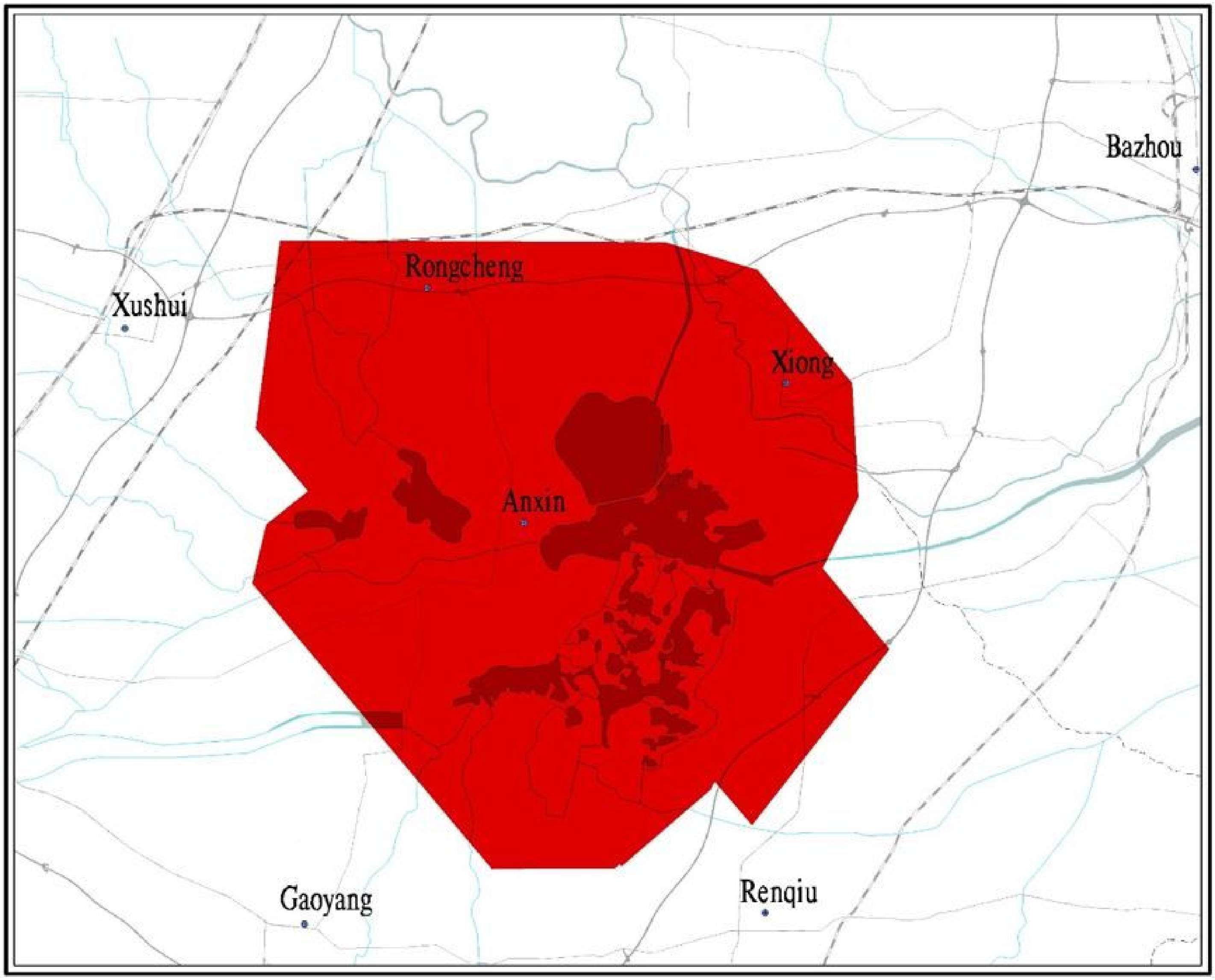

Figure 2

survey design Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

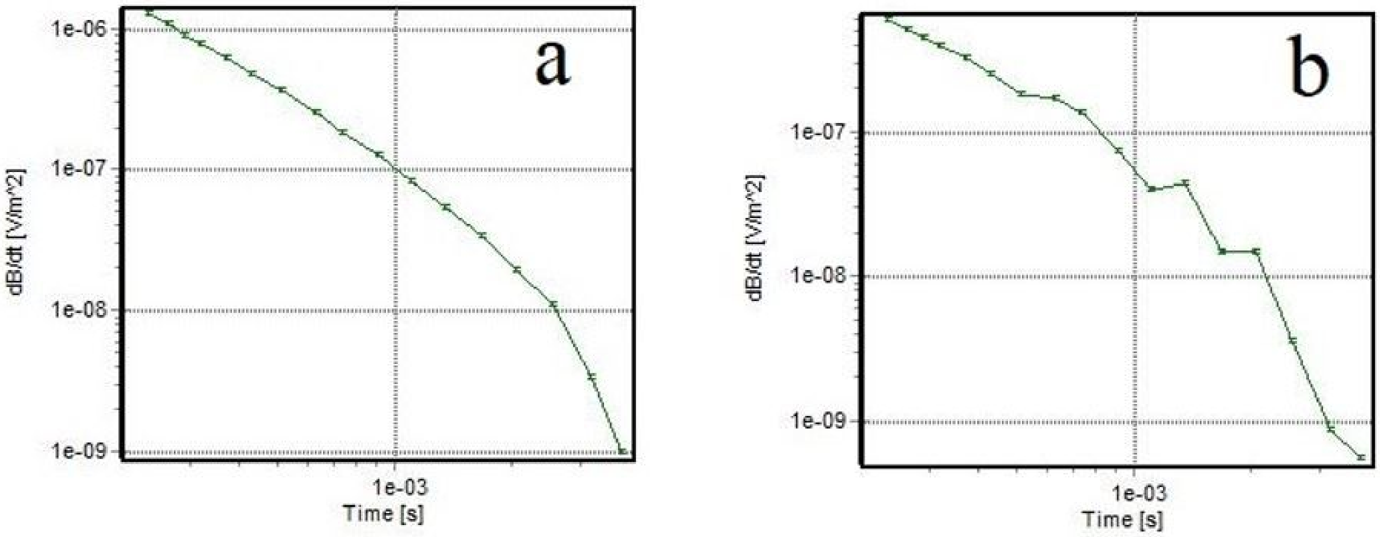

Figure 3

Single survey point electromagnetic responding curve(a, normal data. B, data with noise)

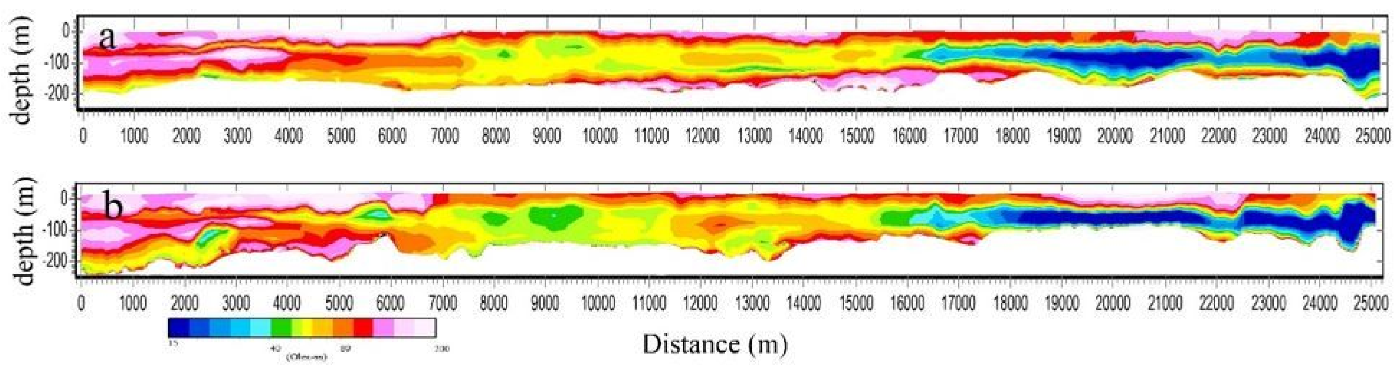

Figure 4

Two years repeat line inversion result (a, data obtained in 2018. b, data obtained in 2019)

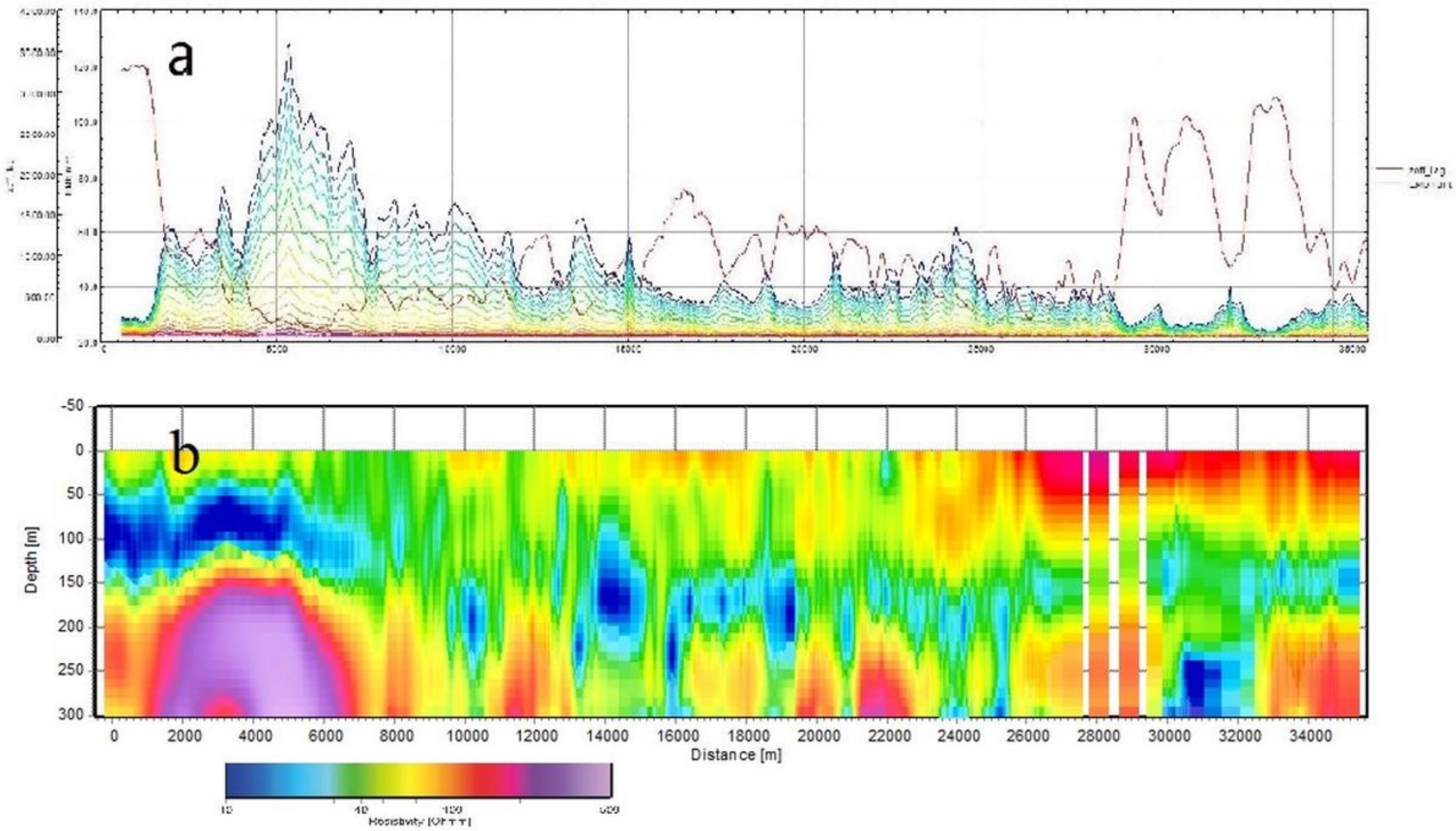

Figure 5

1490 line comparation of field data and inversion result (a,Field data with fly height; b, inversion result)

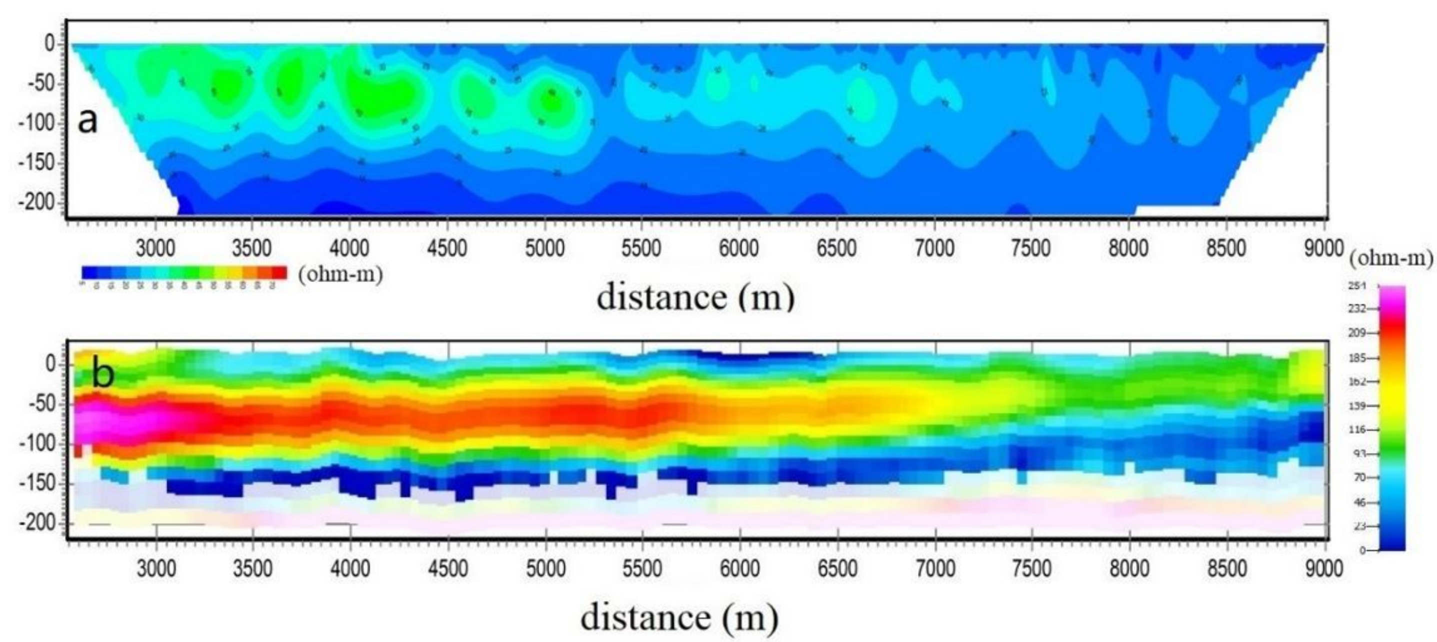

Figure 6

comparasion of ground and airborne cut (a, high density resistivity method; b, ATEM inversion)

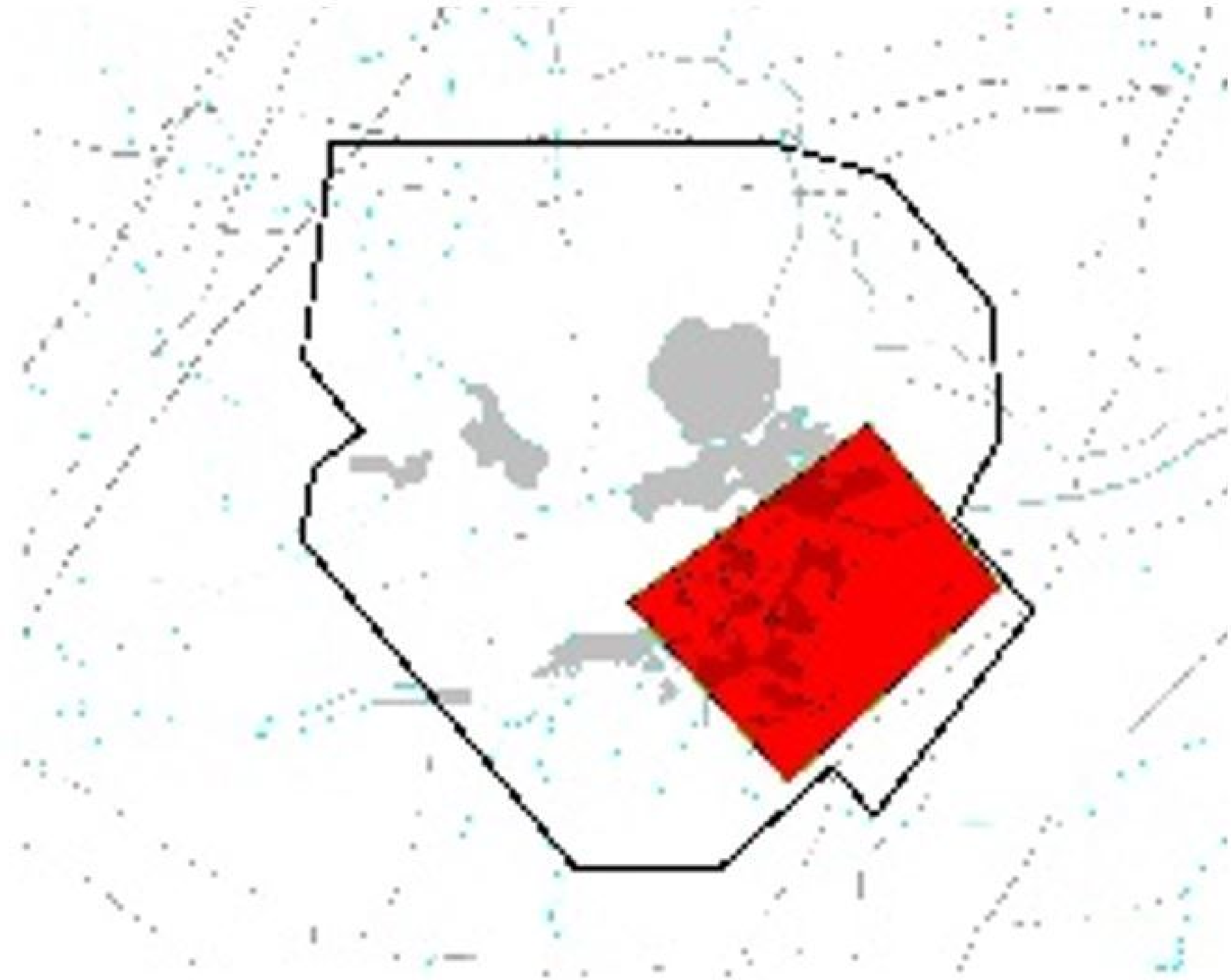

Figure 7

Area of interpreting in survey area. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

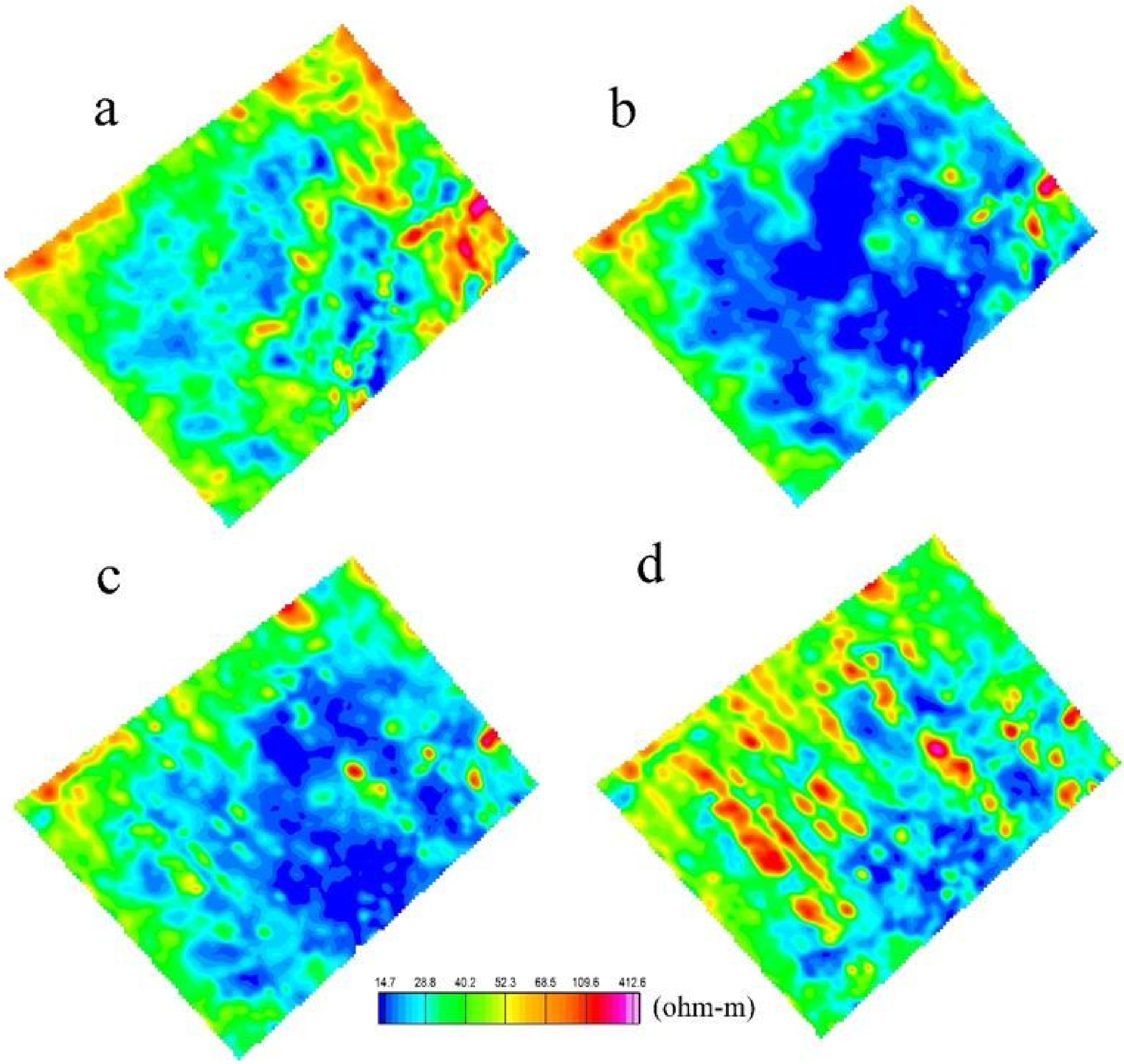

Figure 8

resistivity values in different depth (a：-60m，b：-90m，c：-110m，d：-130m)

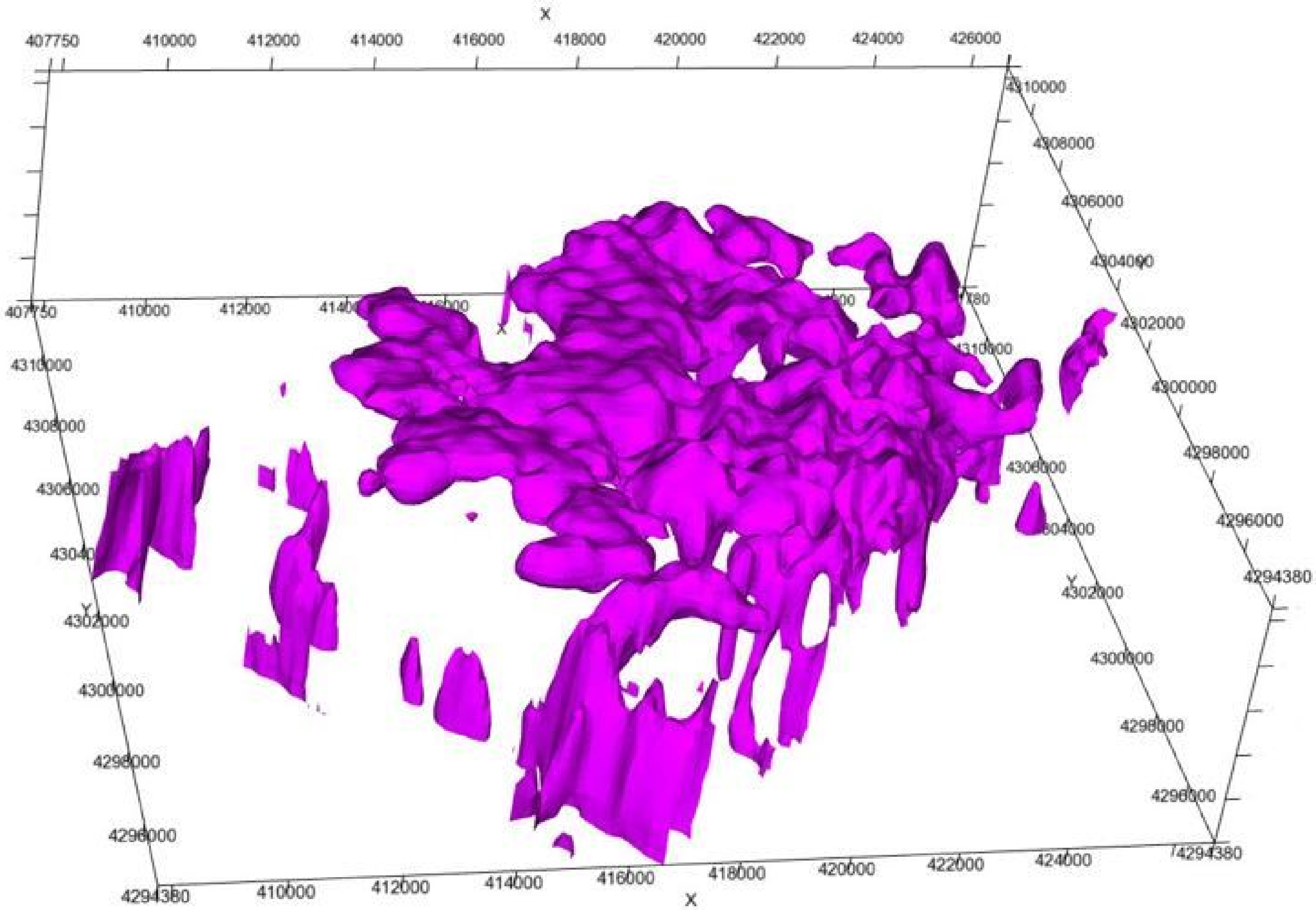

Figure 9

Low resistivity value body in 3 dimension