

Geophysical Characterization of a Proposed Street Extension in Cape Girardeau, Missouri

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ABSTRACT

Electrical geophysical techniques were used to survey the site of a proposed extension of Independence Street between Mount Auburn Road and Farrar Drive in Cape Girardeau, Missouri. Three electrical resistivity profiles with electrode spacings of 5, 10, and 20 feet were conducted over the entire length of the proposed road extension utilizing Wenner array. The resistivity profiles identified areas of low and high resistivity measurements. There are two sharp increases of resistivity at approximately 250 and 570 feet from Farrar Drive and two slight increases of resistivity at 150 and 500 feet from Farrar Drive. These sharp increases are flanked by low resistivity readings which may indicate faulted structures or elevated bedrock features under the survey area. These resistivity profile measurements were followed by 2-D resistivity imaging measurements using the dipole-dipole and Schlumberger configurations. The surveys were performed using the Sting R resistivity survey system. Three dipole-dipole resistivity imagings were conducted on the west, central and eastern portions of the site followed by one rollalong profile line using Schlumberger configuration over nearly the entire length of the site. There is a good similarity between the two methods results and the Wenner profiles. There are three prominent areas of high resistivity extending from the surface to the bottom of the exploration depths. These high resistivity readings may indicate faulted structures or elevated bedrock features under the survey area. The 2-D imaging profiles show a general decrease of resistivity from the surface to the saturated alluviums and weathered top of the bedrock followed by a resistivity increase at depths. These resistivity results will be utilized by the city of Cape Girardeau during the planning and development of the utility lines and street extension.

INTRODUCTION

The city of Cape Girardeau plans to expand Independence Street between Mount Auburn Road and Farrar Drive (Figure 1). The length of the proposed street expansion is approximately 800 feet (244 meters). As part of the pre-construction process, the city engineer wanted to conduct a geophysical survey to characterize the subsurface of the site. Due to cultural noise, the DC resistivity method was selected for the subsurface investigations instead of other geophysical methods. The application of DC resistivity to geotechnical problems and site characterization is well documented in literatures (Aristodemou, 2000, Burger, 1992, Carpenter et al., 1991; El-Hussain *et al.*, 2000; and Meju, 2000). The DC resistivity involves introducing an electrical current into the ground via two electrodes, measuring the resulting potential via two potential electrodes, and calculating the apparent resistivity of the subsurface (Burger, 1992). The main objective of the survey is to determine whether or not subsurface faulting exists under the site.

The geophysical instrument used in the survey is the Sting R earth resistivity meter together with the traditional 4-electrode cables and Swift multi electrode cables and smart switches. Resistivity survey lines were conducted over nearly the entire length of the proposed extension of the street. Three profile measurements were conducted manually using Wenner array on February 6, 2000. Resistivity imaging (2-D) profiles using the Swift multi electrode system utilizing dipole-dipole and Schlumberger configurations were conducted on April 30 and May 4, 2000. Figure 1 shows the proposed street extension and the survey investigation lines. The interpretations have been made utilizing Microsoft Excel, 2D inversion program RES2DINV, and the Surfer Golden software.

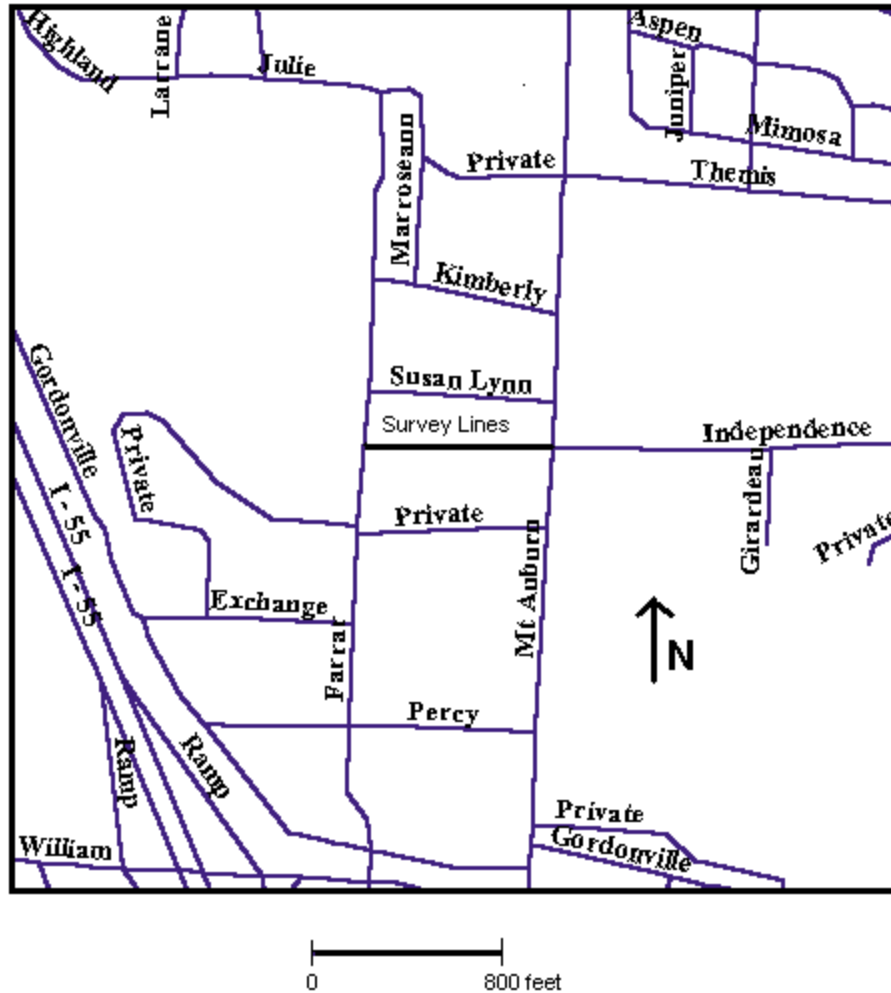


Figure 1. Map showing the study area and the location of the resistivity survey lines. The thick black line is the proposed extension of Independence Street.

GEOLOGICAL SETTING

The survey area is north of the Mississippi Embayment and west-southwest of the Illinois basin on the eastern flank of the Ozark uplift. The underlying rock strata have a regional northeast dip of 2 to 4 degrees, but local dips of 90 degrees have been recorded. The survey area is located on rolling topography, with the western side of the site lower than the eastern side.

In this area, there are 14 formally recognized Paleozoic formations ranging in age from lower Champlainian (Ordovician) to Lower Devonian. There is a blanket of surficial deposits ranging from 0 to 35 ft (excluding Mississippi River alluvium). The rocks of the area are the result of marine sedimentary processes, and consist of shale, limestone, dolomite, quartz sandstone, clay, and chert. The recognizable formations, in ascending order, are the Joachim Dolomite, Pecatonica Formation, Plattin Formation (this formation includes the Decorah Formation), Kimmswick Formation (includes the Cape Limestone), an unnamed shale unit, Thebes Sandstone, Orchard Creek Shale, Girardeau Limestone, Sexton Creek Limestone, McClure Limestone, Moccasin Springs Formation, and the Bailey Formation.

The area is extensively faulted, with approximately 165 faults noted. Most are considered normal faults, but there is the possibility some have resulted from strike-slip movement. The faults are suggested to be as recent as Holocene (McCracken, 1971).

DATA ACQUISITION AND ANALYSES

Data Acquisition

The Sting R earth resistivity meter together with the traditional 4-electrode cables and Swift multi electrode cables and smart switches were used in the data collection. Initially, three profiles with electrode spacings of 5, 10, and 20 feet were conducted using Wenner array configuration. Resistivity data for these profiles was collected manually using 4 electrodes. A Swift Smart Electrode cable consisting of 28 switches and cable segments were connected together for the 2-D resistivity imaging. Since it was not obvious which array type (dipole-dipole or Schlumberger) would return the best data the two different arrays were recorded on the same initial layout. A total of 28 electrodes were placed at 3-meter intervals along the survey line. The STING meter was prepared with one user defined measurement program for the Schlumberger method and the built-in dipole-dipole program for the dipole-dipole method. The measurements were automatically recorded by Sting using the loaded program for the Schlumberger method utilizing the rollalong technique. Similarly, the dipole-dipole measurements were taken using the built-in Dip-Dip program for a total of three different segments along the survey line. The rollalong technique was not utilized for the dipole-dipole measurements even though the measurements overlap in some parts of the line. The first electrode location of Wenner profiles, Schlumberger profile, and the first dipole-dipole profile was at 52 feet (16m) from Farrar Drive. The location of the survey lines is shown in Figure 1.

Data Analyses

The apparent resistivities of Wenner configuration profiles were plotted using the Microsoft Excel spreadsheet. The apparent resistivity of the dipole-dipole and Schlumberger measurements were inverted using the RES2DINV software package (Loke and Barker, 1996). A detailed outline of the inversion approach can be found in the RES2DINV manual. The objective of the inversion is to get realistic set of physical model parameters that can adequately produce the given set of field observations. The fit between the measured data and the model response is assessed by the root-mean-square fit function. Surfer for Windows was used for the apparent resistivity presentation for comparison with the inverted data.

RESULTS AND INTERPRETATIONS

Figure 2 shows the Wenner array Profile lines. The three profiles show lateral resistivity changes in near surface materials. The top profiles (5 and 10 foot spacing) show several high resistivity segments two of which show sharp resistivity increase. The area with sharp resistivity increase may be interpreted as faults or elevated bedrock topography. In the bottom profile (20 feet spacing), while the areas of high resistivity still discerned, the resistivity values decrease compared to the values in the top profiles due to resistivity averaging of the bedrock and overburden materials. The subsurface structures causing this resistivity change can be interpreted as graben features.

The Schlumberger imaging results are presented in Figure 3. The top plot in Figure 3 is a Surfer presentation of the raw apparent resistivity data while the bottom three plots are the results from the RES2DINV inversion model package. Areas of high resistivity are shown on both the Surfer plot and the pseudosection/inverted model plots. Several zones of high resistivity (sand, gravel, or near surface solid bedrock) and low resistivity (clay, fractured/weak zones of bedrock) can be identified. These areas can be interpreted as elevated bedrock blocks located at 45 m and between 160 to 180 m from the beginning of the survey line as shown in both the pseudo and the inversion section. Low resistivity areas flanking these high resistivity areas can be interpreted as fractured/weak, clay filled zones of bedrock.

The dipole-dipole imaging data from the three profiles were combined and presented in Figure 4. There are high resistivity areas flanked by low resistivity areas at the same locations in both the Schlumberger and dipole-dipole results. The high resistivity areas may indicate solid uplifted rock flanked by low resistivity areas which may indicate areas where the host rock has been fractured and thus contains water making the area less resistive to electrical current. Several zones of low resistivity (fractured/weak zones) could be identified in both the dipole-dipole and Schlumberger data. The resulting 2-D profiles show great similarities between the two techniques. Therefore, the dipole-dipole and Schlumberger are good choices for lateral structures whereas Wenner gives high resolution near the surface but noisy data towards increasing depths. Schlumberger seems to be a good technique to use in such a study, since it gives good detail with lateral resolution, resulting in better depth penetration than the dipole-dipole method. Future soil boring may be needed to validate the resistivity results.

CONCLUSIONS

In this study, high resistivity areas and low resistivity areas were identified along the proposed stretch of Independence street extension. The high resistivity areas may indicate gravel, sand, and rock fragments laid on top of elevated solid rock. The low resistivity areas may indicate areas where the host rock has been lowered by faulting and/or fractured and thus contains water, making the area less resistive to electrical current. There are great similarities between the dipole-dipole imaging results and the Schlumberger imaging results. Future confirmatory soil boring may help validate the geophysically derived information.

ACKNOWLEDGMENTS

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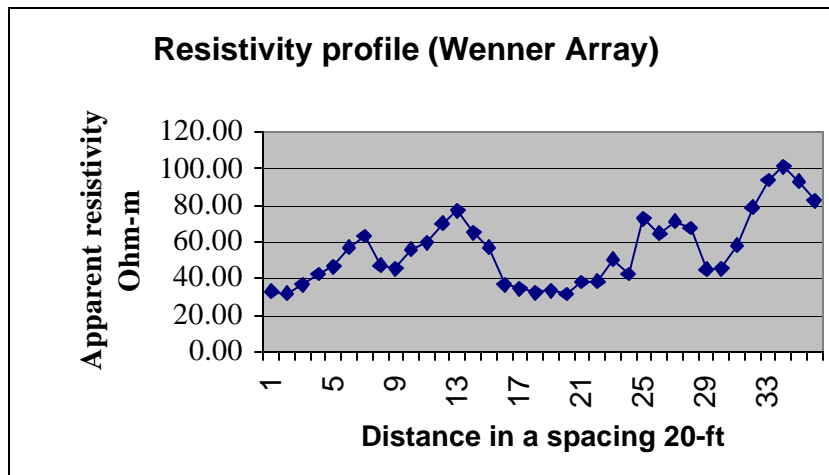
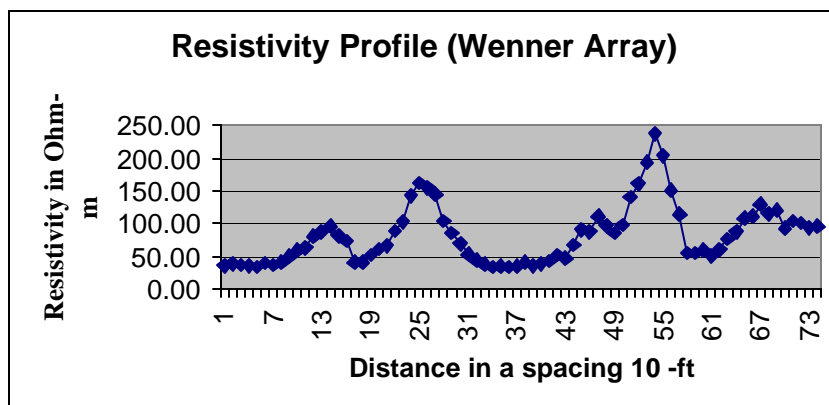
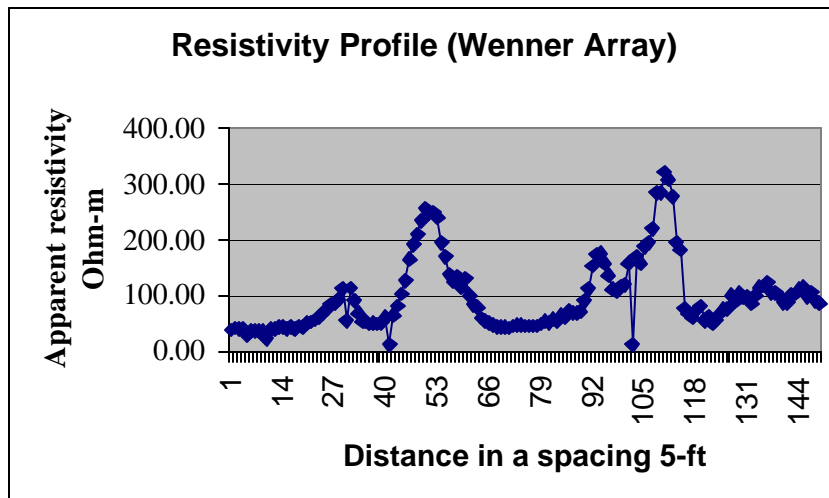
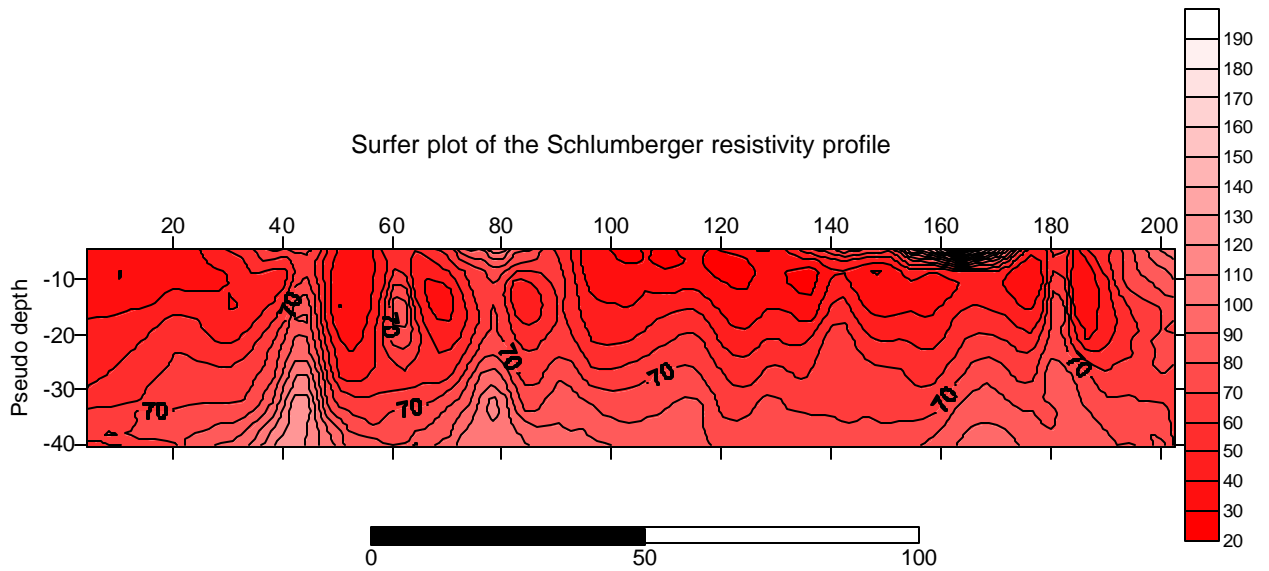
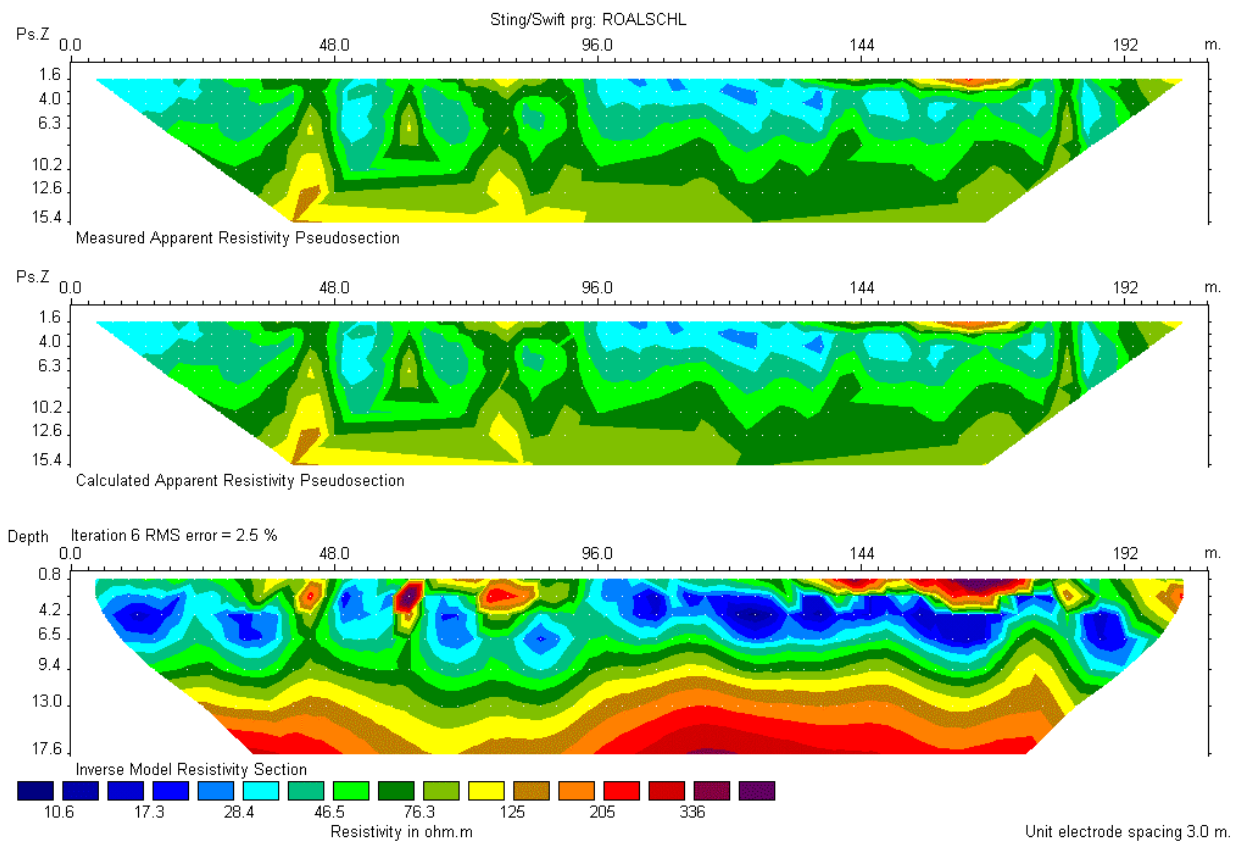


Figure 2: Resistivity profiles over the site with different electrode spacing. The x-axis is the reading number, which should be multiplied by electrode spacing to get distance.



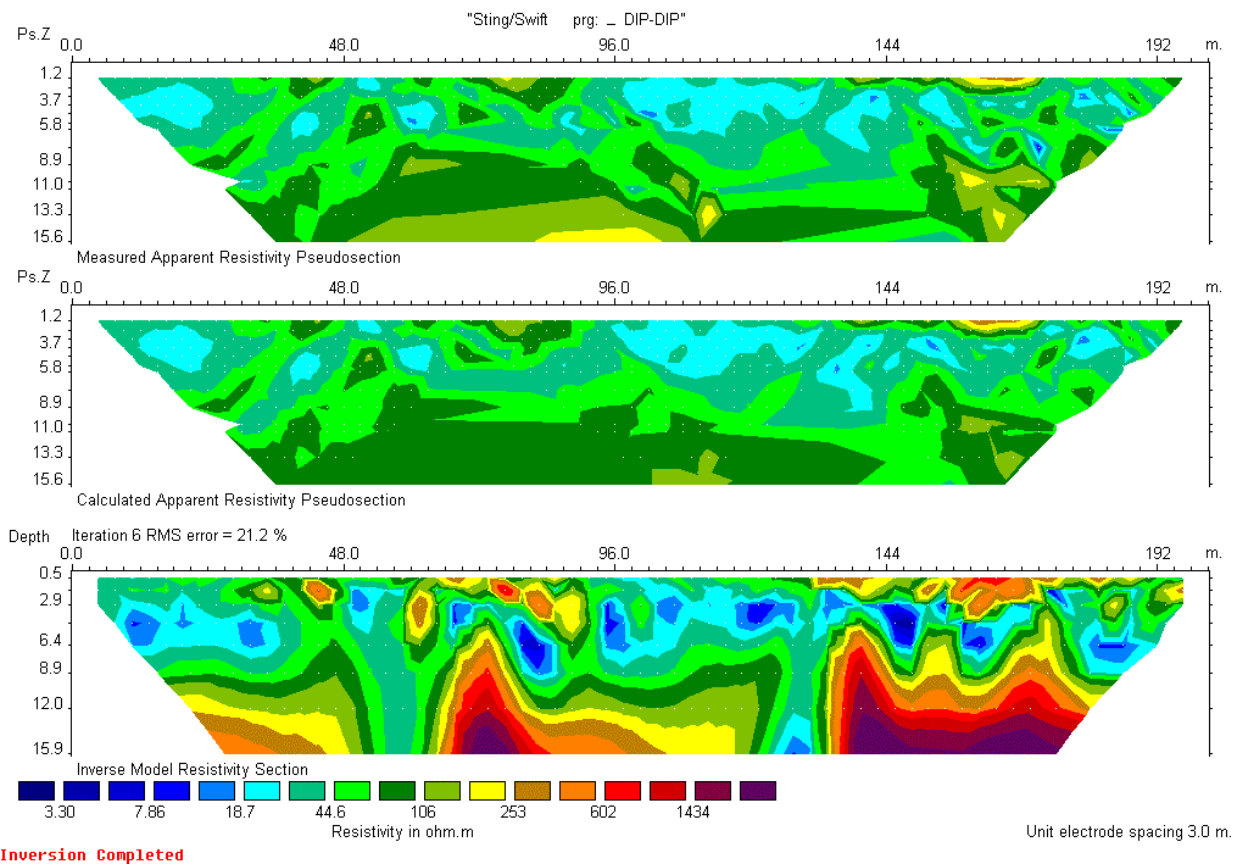
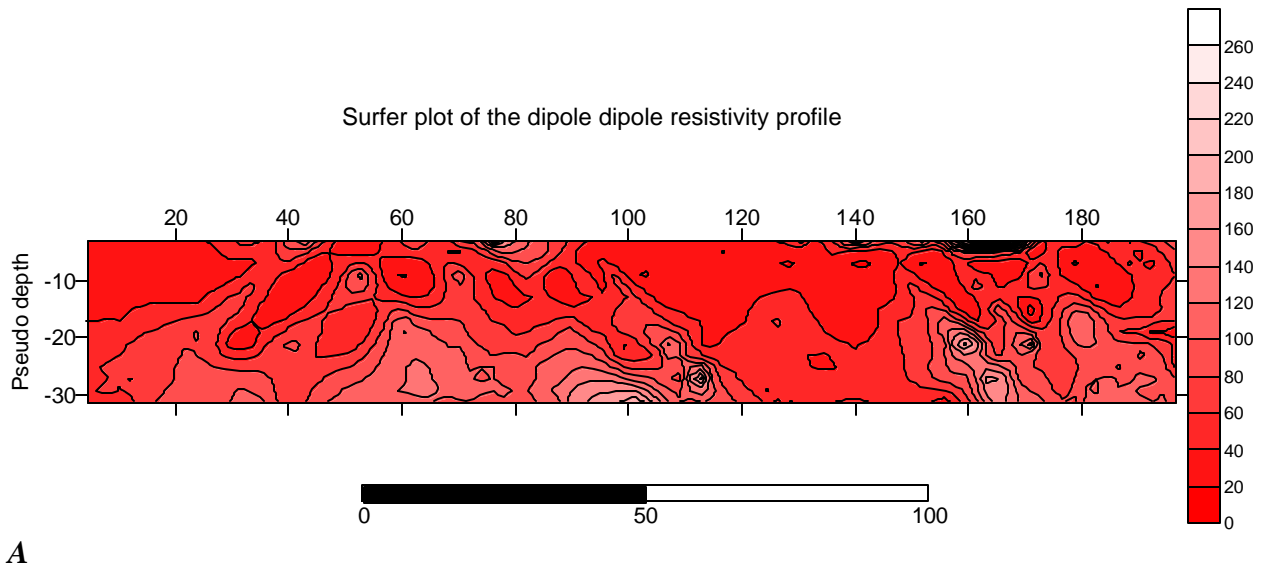
A



Inversion Completed

B

Figure 3. **A)** Surfer plot of the Schlumberger resistivity profile. **B)** Measured and predicted data together with the resistivity inversion model for the roll along Schlumberger resistivity profile.



B

Figure 4. **A**) Surfer plot of the dipole-dipole resistivity profiles (combined). **B**) Measured and predicted data together with the resistivity inversion model for the dipole-dipole resistivity profile.

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