Imaging the Brigham City Fault Segment Using Electrical Resistivity Tomography Techniques

Alex Barker
Utah State University

Follow this and additional works at: https://digitalcommons.usu.edu/phys_capstoneproject

Part of the Physics Commons

Recommended Citation
https://digitalcommons.usu.edu/phys_capstoneproject/22

This Report is brought to you for free and open access by the Physics Student Research at DigitalCommons@USU. It has been accepted for inclusion in Physics Capstone Project by an authorized administrator of DigitalCommons@USU. For more information, please contact digitalcommons@usu.edu.
Imaging the Brigham City Fault Segment Using Electrical Resistivity Tomography Techniques

Alex Barker

Under the direction of

Tony Lowry

Utah State University
Abstract:

Geologic faults are a result of rock structures that have given away to tectonic compression, extension, or lateral tension. Because of a fault’s propensity to slip and cause earthquakes, they are of major concern to any populated area near by. The Wasatch Fault is a result of extensional stress that runs the entire length of Utah from north to the south. It has been analyzed and broken up into several segments. By stratigraphic analysis, scientists have been able to estimate when each of these segments has last experienced a rupture. Out of all the segments that make up the Wasatch Fault, the Brigham City segment has not experienced movement for the longest period of time. Scientists have estimated that this segment will be the next segment to slip and cause an earthquake. This fault segment is of great interest to the surrounding scientific population. It is the goal of this experiment to successfully image the fault using Electrical Resistivity Tomography.

Theory:

Electrical Resistivity Tomography (ERT) is a geophysical technique for imaging subsurface structures from electrical impedance measurements made at the surface, or by electrodes in one or more boreholes. It is based on the response of the earth to the flow of electrical current. This technology can be used to obtain "snapshot" images of relatively static subsurface conditions for site screening or characterization. Different subsurface materials have different resistivity. When an electrical current is passed through the ground and two potential electrodes record the resultant potential difference between them, we can obtain a direct measure of the electrical impedance of the subsurface material. This experiment will deal with measurements made at the surface.

A variety of well-known subsurface materials have been analyzed for their electrical impedance separately in labs. Impedance data of some of these materials can be seen in figure 1. By measuring the electrical properties of the subsurface, a 2-D cross-section of the subsurface is extrapolated and interpreted qualitatively and quantitatively in terms of a lithological and/or geohydrological model. In the shallow subsurface, the presence of water controls much of the conductivity variation. Measurement of resistivity is, in general, a measure of water saturation and connectivity of pore space. A low resistivity measurement tends to be an indication of the presence of water, while a high resistivity measurement is more likely to indicate unsaturated soil or rock.
Resistivity measurements are associated with varying depths relative to the distance between the current and potential electrodes in the survey, as seen in figure 2. The further apart the electrodes are spaced, the deeper the penetration.
Figure 3 shows a current dipole in the middle of transmission (I) followed by a series of potential dipoles (V), which measure the resulting voltage gradient at each station along the line. Moving the current dipole down the line completes subsequent measurements. The resulting image plots the apparent resistivity with depth, which is then contoured using a program called RES2DINV.

The color-contoured image displays the distribution of apparent resistivity values and associated gradients within the area of interest. In order to convert the apparent resistivity data to true resistivity, the data are inverted. Figure 4 displays an example of a measured apparent resistivity pseudosection at the top, followed by a calculated apparent resistivity pseudosection, and resulting in the inverted true resistivity 2D section. The numbers presented at the bottom of the inverted section display goodness of fit criteria used to assess the accuracy of the calculated resistivity model. Note that the surface elevations must be accounted for in the final model due to changing topography. Also note that this is not a representation of the data taken at the Brigham City Fault segment. This is only an example of what the data should look like after analysis.
**Procedures:**

A list of the scientific equipment used for the experiment is as follows:

- SuperSting R1 IP Resistivity Meter
- 28 steel stakes
- 7 cable components with 4 electrodes each
- Data cable connecting laptop to SuperSting
- 12 Volt Battery
- AGISS Admin Program
- RES2DINV Program

The location for experimentation was chosen along the base of the Wasatch Mountain Range within Brigham City. Ease of transport of scientific equipment as well as authorization of land use from the city was taken into consideration when choosing a location. Finding the Brigham City Fault itself proved to be much harder than anticipated. With the direction of many local residents, the fault was located. Figures 5 and 6 show the experimental site.

The stakes were laid out perpendicular to the fault line with 2-meter wide spacing. Each stake was hammered in perpendicular to the ground until firm. The electrodes were firmly attached to the stakes and special care was taken to insure proper conduction between the two. Using a preset program within the SuperSting, data was collected at the touch of a button. Setup and take down time was estimated to be around three hours.
Figure 5: Aerial view of experimental site

Figure 6: The Brigham City Fault Scarp and experimental site
The electrodes were set up in a traditional Wenner Array fashion with constant spacing between measurements as shown in figure 10.

Once the data is collected, the following lists important step-by-step procedures for turning data collected from the SuperSting R1 IP into an inverted tomographic profile.
• Open the AGISS Admin program.
  o This program allows you to convert STG file format into DAT format.
• Press the ‘connect’ button to have the SuperSting connected to the Laptop.
• The right window that appears contains all the files that the SuperSting has on it. Right click on the file you want and hit ‘read file’.
• Name the file and save it.
• Now you need to convert STG to a DAT format. There is a ‘Convert’ button on the top right. Press this button when you have your file ready.
• Now disconnect the laptop by pressing the ‘disconnect’ button at the top right.
• Now open the RES2DINV.EXE program
• Click ‘File’ in the desktop bar on the top left
• Select ‘Read Data File’.
• Select the file you just uploaded
• Click ‘OK’ twice.
• Click on the ‘Edit’ option in the desktop bar
• Select ‘Exterminate Bad Data Points’.
• A graph should appear.
• Select ‘Print’ from the menu at the top left
• Select ‘Save Screen as BMP file’.
• Name your newly altered file once more
• Click ‘Save’ and then ‘OK’.
• Select ‘File’ in the desktop bar again
• Select ‘Read Data File’
• Choose your file and select ‘OK’
• Click on the ‘Inversion’ tab in the desktop bar
• Select ‘Least Squared Inversion’.
• You should see a 2D profile of your experimental area
  o Blue represents low resistivity while red represent high resistivity

Results:

Despite not having a full set of data, an incomplete apparent resistivity pseudosection of the Brigham City Fault Segment was successfully pieced together using Excel. The pseudodepth of penetration was calculated to be at 9.3 meters based on the equation: 0.5167*a, where ‘a’ is the spacing between the 1st and 7th electrode.

Figure 11: Apparent Resistivity of the Brigham City Fault Segment
Conclusion:

Comparing the table of the resistivity of different subsurface materials to the pseudosection constructed in figure 11, the following materials match the resistivity specifications:

- Anthracite
- Hematite
- Dolomite
- Limestone
- Sandstone
- Conglomerates
- Slate
- Quartzite
- Marble
- Schist
- Gabbro
- Basalt
- Diorite

Considering the vast range of impedance measurements that could be possible, the area surveyed seemed to be relatively uniform. Measurements ranged from 1100 Ohm-meters to just over 8400 Ohm-meters. Note that the resistivity measurements are not congruent to the impedance level of water in any part of the area tested. Deposits of gravel, particularly if unsaturated, have high resistivity. Steeply dipping faults may be located if there is sufficient resistivity contrast between the rocks on the two sides of the fault.

There is an anomaly of particular interest starting at the mid-upper left corner, and ending eventually in the mid-lower right corner. This particular string of data indicates an area of
impedance much higher than the surrounding rock. This could be a promising indication of the snapshot of a fault.

The original goal of the experiment called for three separate measurements spanned out over five weeks. Data, unfortunately, could not be collected on two of these occasions due to technical difficulties involving the meter itself. Had it been collected, comparison of the three data interpretations could have ruled out any ambiguity of fault imagery.

References:


