

Exercise 4

Electrical Resistivity Tomography

During the field campaign SS2015, electrical resistivity tomography (ERT) datasets were collected among 3 profiles to characterize the location of a fracture zone.

We will work with 2 profiles collected at the north and south part of the fracture zone, both crossing the fracture zone. Datasets are located in the folder (***.raw data***)

The first profile was collected by means of two roll-along surveys:

- USB1 (the first half of the survey)
- USB2_ (the second part of the survey)

There were 24 electrodes overlapping between USB1_ and USB2_. The data in both surveys were collected with 4 different configurations:

- USB#_1 - normal configuration dipole-dipole skip0
- USB#_2 - reversed configuration dipole-dipole skip0
- USB#_3 - normal configuration dipole-dipole skip2
- USB#_4 - normal configuration dipole-dipole skip4
- USB#_5 - normal configuration gradient

For the second profile (south) we used ONLY gradient configurations, but data were collected with roll-along surveys, each one with an overlap of 24 electrodes with the previous one.

- USB6_1 first part of the roll along
- USB6_2 second part of the roll along
- USB6_3 third part of the roll along
- USB6_4 fourth part of the roll along
- USB6_5 fifth part of the roll along
- USB6_6 sixth part of the roll along

For the inversion we will use CRTomo, developed initially by Kemna¹.

- 1) First we need to convert the data into the format required for CRTomo. Such format is based on the following:
 - a. The first line should state how many measurements you have
 - b. The line 2 to the end should be present the measuring protocol given by the current electrodes (C1 and C2), the potential dipole (P1 and P2) and the measured resistance (R in ohm).

Such as:

C1*10000+C2 P1*10000+P2 Resistance

Note: before closing please remove all readings with resistances <0 (there are not negative resistances) – check that the number of measurements defined in line 1 is right

- c. Give an adequate name to the file, given by numbers and characters, but avoid symbols. - It is recommended to save all files in the CRtomo format in a separate folder. Note: you can give any extension to the file (for instances .crt)

** For an example look at the folder: ./crt/USB1_1.crt

- 2) The second step is to describe the settings for the inversion:
 - a. The file CRtomo.cfg contains all the settings for the inversion.
 - i. Use a text editor to open the file CRTomo.cfg
 - ii. The first thing is to modify **line 2 and line 3** for defining the adequate Finite Element (FE) grid to run the inversion. The grid is based on the geometry of the survey. For the exemplary field (./crt/USB1_1.crt), the grid we will use is:
 1. ./FEgrids/48e_5m.elm – this file contains the location of each node for the finite element (**line 2**)
 2. ./FEgrids/48e_5m.elc – this file contains the number of the nodes which are used as electrodes (C1, C2, P1 P2 from the .crt file) – **line 3**
 - iii. The next step is to define the path and name of the file containing the measurements in the CRTomo format – line 4

¹ Kemna, A., 2000, Tomographic inversion of complex resistivity – theory and application: Ph.D. thesis, Ruhr-University of Bochum.

1. For the case of the example, the proper path and file name is **./crt/USB1_1.crt – line 4**
- iv. The next step is to define the path (folder name and location) for writing the inversion results from the inversion. Please be sure to create a folder with this name and in the location. The path and name of the folder is going to be defined in **line 5**
1. For the example we can use for instances **./inv1/USB1**
- v. The next step is to modify the smoothness (Glättung) in the inversion. The smoothness is defined in **line 13** and **line 14**. The smoothness could be defined as
1. 1:1 that refers to the same smoothness in x and y direction. In such case the images would look for models with no preferential smoothness (Glättung). Set a **value of 1 in line 13** and a **value of 1 in line 14**
 2. 10:1 refers that the smoothness in x direction is 10 times bigger than in the y direction. It means we search for models with horizontal layering. Set a **value of 10 in line 13** and a **value of 1 in line 14**. You can also define the value in line 13 as any number >1
 3. 1:10 refers that the smoothness in x direction is 10 times smaller than in the y direction. It means we search for models with vertical changes (faults?). Set a **value of 1 in line 13** and a **value of 10 in line 14**. You can also define the value in line 14 as any number >1
- vi. The next step is to define the error accepted in the inversion (how good should the inversion try to fit the data). If you define the error present in your data, then you can stop the inversion faster (for noisy datasets) or later (for very clean datasets) referring on how close the inverted model should reproduce the data. If the data is noisy, you may want to avoid fitting too much in the inversion to avoid fitting the noise (so-called over-fitting), but you don't want to define such a large error, such that the inverted model lacks of contrasts due to an underfitting. The error in the data is given by two terms:
1. Line 19: the relative error. This value represents a percentage value (%) and is mainly affecting high resistance values ($R > 1$). Typically you could assume a value of 1% for very clean datasets, a value of 5% for medium levels of noise and 10% for noisy datasets.

2. Line 20: the absolute value, this can be observed as the error present in each measurement (associated with the resolution of the device). This is the parameter defining the error in low resistance measurements (<1 ohm). You can select it as the lowest value in your resistance measurements (.crt file) or as 0.001 or 0.01
- vii. Check again that the path and name of files/folders in line 2-4 are correct
- viii. After modifying lines 2,3,4,5, 13, 14 , 19 and 20 – save and close file CRTomo.cfg
- ix. Double click on the file CRTomo_stable64.exe
- x. Once the black box closes you can find several files written in the folder defined in the line 5 of the CRTomo.cfg
 1. The most important for this exercise are the rho#.mag files – you can open such files with any text editor. These files show the location of the x-coordinate (first column), depth (second column) for the resolved electrical resistivity (third column). Please note that the resistivity is given in terms of the logarithm 10.
 2. Note that there is a rho00.mag to rho##.mag, with ## associated with the model obtained for each iteration, the .mag file with the largest number refers to the last iteration → the final result of the inversion
- xi. To plot the inversion routine you can use the matlab function plot_ERT.m provided in this exercise.
 1. Here you are first asked to select the proper FEgrid.elm file
 2. Then you are asked for the adequate FEgrid.elc file
 3. The you are asked to select the rho##.mag file for plotting

Tasks:

- 1) Run the inversion for the files:USB1_1 and USB2_1 assuming a smoothness 1:1 (lines 13 and 14), as well as an error of 5% (line 19) and 0.001 (line 20). Plot the inversion results. Are they consistent? Remember that there is an overlap of 24 electrodes.
- 2) Run the inversion for the files USB2_3, USB2_4 and USB2_5 with the same settings as step 1. When comparing the inversion results for each inversions, can you observe the changes in the resolution due to the different configurations
- 3) Run the inversion results for line USB2_1 defining the error parameters such as:
 - a. 10% and 0.00001 (lines 19 and 20)

- b. 0.1 and 1 (lines 19 and 20)
 - c. Compare the inversion results
- 4) Would you be able to join the files USB1_1 and USB2_1 in a single file? - remember that electrode 1 from file USB1_2 actually represents the electrode number 25 due to the 24 electrodes overlapping. Hence the last electrode of the entire array should be the number 72
 - a. Run the inversion of the file with the long profile using the FEgrid (72_5m) and a smoothing of 1:1
 - b. Run the inversion of the file with the long profile using the FEgrid (72_5m) and a smoothing of 1:10
 - c. Run the inversion of the file with the long profile using the FEgrid (72_5m) and a smoothing of 10:1
 - d. Compare the resulting images. How do you understand the results?
- 5) Compare the inversion results for the long array (72 electrodes after joining USB1_ and USB2_) for different electrode configurations dipole-dipole skip0, dipole-dipole skip2, dipole-dipole skip4 and gradient. Based on the number of independent quadrupoles and the inversions results, which one would you select for a new survey?

Protocol has to be delivered as a .pdf file on December 2.2016 by 10:00 am to the address: tugeophysics@outlook.com

*** There is an exemplary CRTomo.cfg which you can use as a reference (CRTmo_sample.cfg)