Development of an alternative method for the teaching of the electric walk technique

Luan Viana dos Santos, Universidade Federal dos Vales do Jequitinhonha e Mucuri
Jackeline Cabral, Universidade Federal dos Vales do Jequitinhonha e Mucuri
Élida Corrêa, Universidade Federal dos Vales do Jequitinhonha e Mucuri
Carlos Henrique Alexandrino, Universidade Federal dos Vales do Jequitinhonha e Mucuri*

This paper was prepared for presentation during the 15th International Congress of the Brazilian Geophysical Society held in Rio de Janeiro, Brazil, 31 July to 3 August, 2017.

Abstract

The use of geophysical methods has been increasing in the last years, with applications in several areas, such as water prospection and mineral identification. The teaching of the techniques is given in a practical way, through field activities. However, some universities do not have the ideal conditions to perform these activities. This project, developed by Hydro Engineering students, elaborated an alternative and efficient system to allow geophysical practices, especially electric walking, in universities with few resources, as the UFVJM, where this project was performed.

Introduction

Geophysics, according to the Brazilian Society of Geophysics (SBGf), is the study of the interior of the Earth through procedures performed on its surface. Different from Geology, where studies of rocks are made through the collection and analysis of samples taken in an intrusive way, geophysical methods investigate the subsurface through the principles of physics.

Studies of earthquakes, tsunamis, tectonic plate movement, water and mineral prospecting, engineering problems and geological mapping are some of the applications of geophysics (Federal University of Pará - UFPA). The importance of this science and its wide range of applications means that the knowledge of geophysical methods is of extreme importance for several professionals, in addition to geophysicists, geologists, archaeologists and engineers.

For this reason, numerous universities include in their grades disciplines that aim to teach principles of geophysics as well as some of the most popular methods and techniques in this science. Unfortunately, in many cases, teaching is restricted to theoretical concepts due to the difficulty of teaching methods in the field, for logistical, economic, climatological and even didactic reasons, lack of adequate equipment and timeliness.

Like any other practical procedure, understanding the operation of geophysical methods becomes less efficient when the studied techniques are not practiced. The search for teaching alternatives then becomes essential for students and universities.

The students of the discipline Geophysical Methods for Underground Water Prospection (EHD121), based on the reality lived at the Federal University of the Jequitinhonha and Mucuri Valleys (UFVJM), are aware of the difficulty of practicing the geophysical methods in the field. Under orientation of the professor Dr. Carlos Henrique Alexandrino, it was developed a simple and easily replicated system that makes possible the teaching of geophysics, in particular the technique of electric walking (CE), for students of the next semesters and of other universities that face similar situations.

Method

Aiming to improve the teaching of geophysical methods, specifically the electric walking technique (EC), in schools and universities, a simple and effective system has been developed that can be used to perform the required procedures without visits and fieldwork.

The relationships between electric current, electric potential and geometric arrangement of the electrodes in the field allow to calculate the real or apparent resistivity in subsurface.

The factors that most affect soil resistivity are: mineralogical composition; porosity; Water content; Amount and nature of the dissolved salts.

The work consisted of the use of the electro resistance method in a box containing layers of different materials such as crushed rock, salt and soil layers and a rock fragment.

The soil was removed by the students on the Campus with the help of the student who added the rest of the materials. On the box were placed lines as ways of dividing it into measurements (exemplified in figure 1).

Eight vertical lines and four horizontal lines were inserted. Three depths were determined for performing the calculations. Two electrodes are inserted at the first meeting points of the horizontal and vertical lines, which are fixed and have the function of measuring the current.

The system consists of a sturdy plastic box with dimensions of approximately 52 x 41 x 20 (width x length x height, in cm), where different types of materials were deposited in order to simulate the different layers of the soil. Sand, gravel, water, terrain and a stone of considerable size were arranged in an organized manner to form layers that could be identified through the EC technique. The procedures necessary for the accomplishment of CE were previously taught to students through theoretical classes and use of free simulators to better understand the processes. The necessary materials were provided, being a voltage generator, an ammeter and a voltmeter, then the standard procedures of the CE were performed, seeking to measure the apparent resistivity in the greatest possible number of points, for greater efficiency of the results.

With the values obtained, the necessary mathematical manipulations were done using LibreOffice software and a spreadsheet with the apparent resistivity values at several points was elaborated. The worksheet was later worked on the free software Surfer, eighth version, in order to generate the field arrangement maps where the apparent resistivity of each area of the system can be observed.

Through the interpretation of the maps, one can observe and identify places where the apparent resistivity is not expected when compared to the other layers, indicating places where specific materials can be found, such as water wells or mineral mines.

The students, duly enrolled in the previously cited discipline, set up a simulation of the subsurface soil, inside a sturdy dark plastic box, so that the inner layers could not be seen.

The objective was to be able to identify the existence of the different layers in a non-intrusive way, through the EC technique, which had previously been taught to the students. A source, an ammeter and a voltmeter were used, of small dimensions and capacities, that would not be efficient used in real scale, being, nevertheless, the only equipment available in the UFVJM. In this way, students could practice the technique without the need to travel to open areas and using the existing devices.

For the execution of the electric walking technique, which aims to identify the layers of the ground horizontally, and at different depths, the box was divided into rows and columns, to better identify the points where the dipoles would be placed to supply the tension and measuring the current and voltage at the different points of the box. The division can be seen in Figure 1.

Using the above-mentioned apparatus, the current and voltage are measured at different points. To obtain the apparent resistivity, object of study of this work, it was necessary to manipulate the results through mathematical expressions, counting with the help of LibreOffice software.

Figure 1 - Paths and rows

In Figure 2, we see a representation of the operation of the EC, where the dipoles AB are responsible for measuring the voltage at the point and the dipoles MN identify the currents. The distances between AB, BM and BN are responsible for the variation of the point and depths investigated. In the study presented here, the walk was executed in two directions, left and right, to obtain more data.

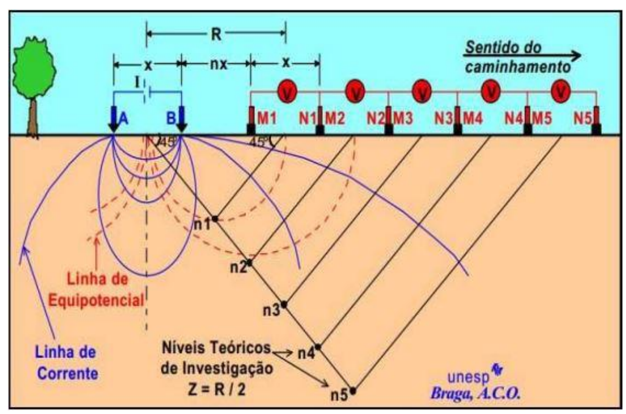

Figure 2 - Scheme of electric walk. Source: Braga - 2007

To calculate the apparent resistivity (ρa), the following expression was used:

$$p_a = K * \frac{V}{I}$$

In equation (1) K and the geometric factor, V is the electric potential difference and I is the electric current. The geometric factor K is estimated by equation (2) which depends on the arrangement of the ABMN electrodes; X =

spacing of the dipoles and n = corresponding research level, as described in equation (3). (BRAGA, 2007).

$$K = 2.\pi.G.x$$

And

$$G = \frac{1}{\frac{1}{n} + \frac{2}{n-1} + \frac{1}{n-2}}$$

Table 1 - Data (First Part)

Line	Direction ->	G	V	I	K	Pa	x(cm)	P(cm)
1	N1-AM=12	3	440	19.9	113.1	2500.5	6	6
1	N2-AM=24	12	890	19.9	452.4	20191.5	6	12
1	N3-AM=36	30	1801	19.3	1131	105537.7	6	18
2	N1-AM=12	3	391	40.1	113.1	1102.7	6	6
2	N2-AM=24	12	710	39.5	452.4	8131.4	6	12
2	N3-AM=36	30	323	37.5	1131	9741.4	6	18
3	N1-AM=12	3	378	170.5	113.1	250.7	6	6
3	N2-AM=24	12	500	168.5	452.4	1342.4	6	12
3	N3-AM=36	30	205	168.5	1131	1375.1	6	18
4	N1-AM=12	3	467	1600	113.1	33	6	6
4	N2-AM=24	12	450	1590	452.4	128.1	6	12
4	N3-AM=36	30	135	1579	1131	96.7	6	18

With this, values of apparent resistivity were obtained for points described in tables (1) and (2) for the study region. For different depths both crosswise and longitudinally, for the four lines, 12 cm apart from each other, shown in Figure 1, for three different depths, 6, 12 and 18 cm.

Table 2 - Data (Second Part)

Line	Direction <-	G	V	I	K	Pa	x(cm)	P(cm)
1	N1-AM=12	3	910	3.1	113.1	33631.3	6	6
1	N2-AM=24	12	434	3	452.4	65883.5	6	12
1	N3-AM=36	30	140	2.9	1131	54244.58	6	18
2	N1-AM=12	3	708	37	113.1	2163.9	6	6
2	N2-AM=24	12	365	42	452.4	3903.5	6	12
2	N3-AM=36	30	217	43	1131	5667.1	6	18
3	N1-AM=12	3	492	27	113.1	2060.8	6	6
3	N2-AM=24	12	325	26	452.4	5654.8	6	12
3	N3-AM=36	30	598	26	1131	26214	6	18
4	N1-AM=12	3	409	30	113.1	1541.8	6	6
4	N2-AM=24	12	418	30	452.4	6388.33	6	12
4	N3-AM=36	30	1630	29	1131	4358.4	6	18

Results

The summary results obtained for apparent resistivity are shown in Table 3.

Table 3 - Apparent resistivity

	A1	A2	B1	B2	C
LINE 1	2500.5	33631.3	20191.5	65833	79881.1
LINE 2	1102.7	2164	8131.4	3903.5	7704.3
LINE 3	2500.7	2060.8	1342.4	5654.7	13794.5
LINE 4	330.1	1541.8	128.1	6388.3	31722.8

Where A1 = Depth 1, Direction 1; A2 = Depth 1, Direction 2; B1 = Depth 2, Direction 1; B2 = Depth 2, Direction 2; And C = Depth 3, Single direction.

For each line, a map has been drawn. For speculation of the values in the other areas of the box, the Kriging interpolation method, available in Surfer software, was used. With the interpolated values, first a 'post map' was created, by command with the same name, to identify the exact points the measurements were made.

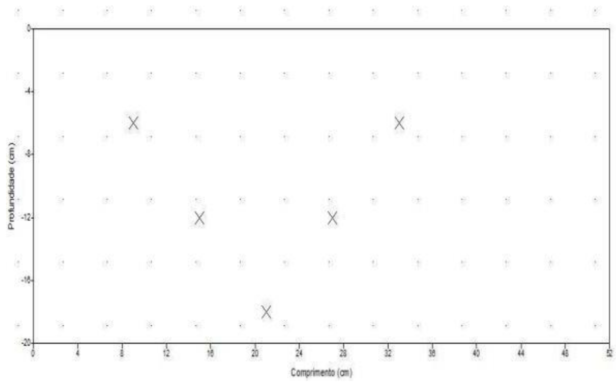

Figure 3 - Position of measurements

Afterwards, the contour map command was used to plot the contour curves obtained with the interpolation, identifying the locations of the same apparent resistivity and classifying them in color scale, being white places of lower resistivities and red where the apparent resistivity is higher.

The estimates of apparent resistivities estimated for the probe lines described in figure (2) are shown in Figures (4) to (7), we see the tendency of proportional increase of resistivity with increasing depth, with the points of Greater centralized resistivity in the deeper layers of the system. This behavior was expected due to the presence of less conductive materials, such as brittle materials, in the bottom of the box.

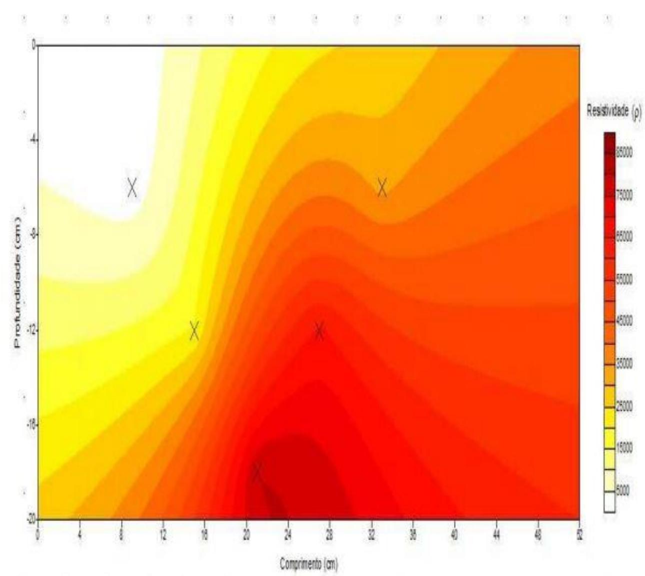

Figure 4 - Apparent resistivity - Line 1

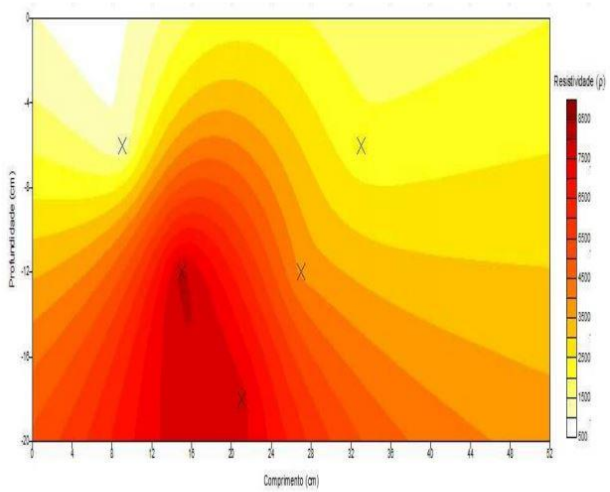

Figure 5 - Apparent resistivity - Line 2

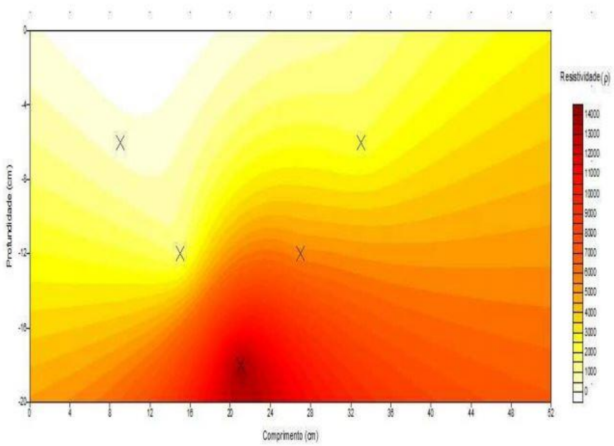

Figure 6 - Apparent resistivity - Line 3

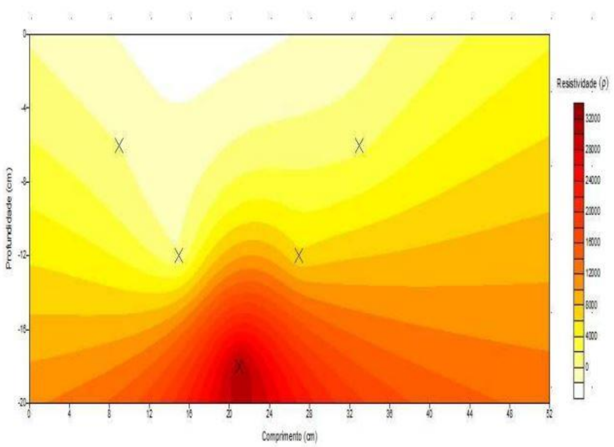

Figure 7 - Apparent resistivity - Line 4

Conclusions

The system proved to be efficient for carrying out the electric walk method without the need for field practices or the use of high-precision equipment - and cost. Through a simple and effective adaptation, the time and cost that would be required for teaching the same technique in the field was reduced.

The results obtained for the resistivity presented high variations between the different lines. This is due to the small distance between the voltage source and the meters in some of the lines. Moreover, the inexperience of students in the application of the technique is a factor that contributes to the inaccuracy of the data, but is not enough, however, to invalidate them.

In Figure 5, where the map obtained for line 2 is presented, the maximum apparent resistivity point was observed in a position different from that shown in the other lines. It was then found that this point of greatest resistivity was exactly where the largest stone had been inserted between the layers of the ground. This proves the effectiveness of the method, allowing the identification of areas of lower conductance, characteristic of non-crystalline rocks and other ores.

We have, therefore, that the system, in due proportions, is a viable substitute for occasions where field practice is impracticable for any reason, presenting acceptable results and allowing students who do not have the best equipment to also learn in a practical way to perform the geophysical technique of the electric walk.

References

BRAGA, Antônio Celso de Oliveira. 2007. Métodos Geoelétricos Aplicados. Universidade Estadual Paulista.

SBGf – Sociedade Brasileira de Geofíscia. Disponível em: http://www.sbgf.org.br/geofisica/geofisica.html. Acesso em 18 abr. 2016.

UFPA – Universidade Federal do Pará. Faculdade de Geofísica. Disponível em: http://www.geofisica.ufpa.br/index.php/oquee. Acesso em 18 abr. 2016.