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The Possibility of Electroprospecting Methods in the Assessment of Subsurface Humidity and Groundwater Flow in a Landslide Area

Nodar D. Varamashvili, Jemal K. Kiria, Avtandil G. Tarkhan-Mouravi, Nugzar Ya. Ghlonti

Ivane Javakhishvili Tbilisi State University, Mikheil Nodia Institute of Geophysics

ABSTRACT

Electrical prospecting is a branch of geophysical methods that studies electromagnetic fields of various nature. The purpose of electroprospecting is to determine the electromagnetic characteristics of the geological environment (resistance, conductivity, polarization, etc.), from which we can draw conclusions about the structure of the studied area. Electrical study can be divided into two groups: passive and active methods. The first of them is called natural electric field methods, and the second - artificial electric field methods. The materials presented in our paper were obtained by the method of resistance (vertical electric sensing) and the method of natural electric field. The article presents a study of rock humidity and the possible existence of underground water flows.

Key words: *Electroprospecting, vertical electrical sounding (VES), natural electrical field*

Introduction

Electroprospecting (Vertical Electrical Sounding)

In electroprospecting (resistance method) is used artificial power source. The electricity reaches the ground through the power electrodes and the difference between the arised potentials is measured by the receiving electrodes on the earth surface. If the environment is homogeneous, the resistance method gives us true conductivity, which will not depend on the configuration of electrodes and the position of electrodes on the surface of the earth, since the true conductivity is a constant. In electric resistivity imaging (ERI) electric currents are injected into the ground and the resulting potential differences are measured at the surface, yielding information about the distribution of electrical resistivity below the surface. Finally this gives an indication of the lithological and structural variation of the subsoil (since resistivity depends on sediment porosity and pore water). 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 (1,2,3,5). This is because water has a low resistivity and electric current will follow the path of least resistance. Increasing saturation, increasing salinity of the underground water, increasing porosity of rock (water-filled voids) and increasing number of fractures (water-filled) all tend to decrease measured resistivity. Increasing compaction of soils or rock units will expel water and effectively increase resistivity. In environment ΔV, and therefore impedance ρ should be dependent on the configuration and location of electrodes, as secondary fields influence on the primary field [2]. Therefore, the measured ρ value in nonhomogenous environments is called an apparent resistivity and is signed as ρa. The coefficient of reaccount for uneven environment depends on the configuration of electrodes. Different configurations of the electrodes are used according to the type of problem. In our tasks we used the Schumerberger method. Receiver MN electrodes are fixed in the center of the device, while the distance between the current AB electrodes increases gradually [3].

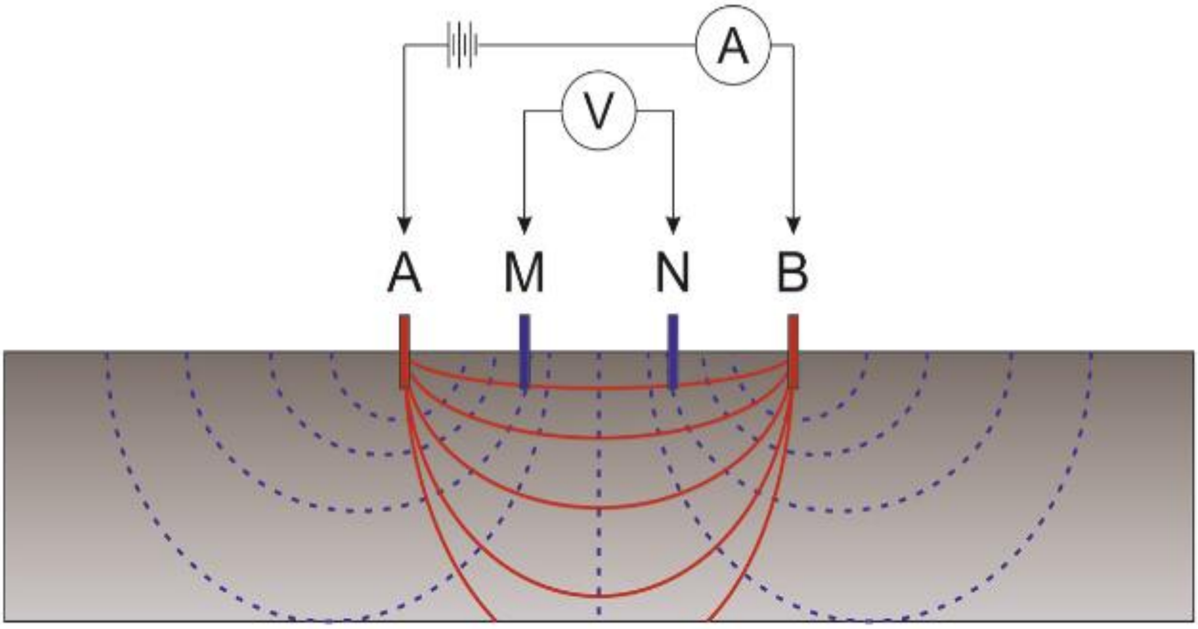

Fig.1. Schlumberger method of vertical electrical sounding

The vertical electrical sounding (VES) method relies on the fact that the greater is the distance between of current electrodes (AB), deeper penetrating the current, than from more deep layers we receivs information by measured potential on the electrode.

The works were carried out by the Italian electrometer equipment (Earth Resistivity Meter PASI 16GL-N). Data processing was done through a certified IPI2WIN program.

Electrical resistance table for some of the rocks

The name of the rock	Electrical resistivity (ohm.m)		
	min	typical	max
Clay	5	10	15
loam	10	30	50
sand clay	30	50	80
Water-saturated sands	50	80	200
Sands slightly moist	100	150	500
Dry sands	200	500	10000
Carbonate rocks weakly cracked	500	1000	5000
Intrusive rocks weakly fractured	1000	2000	10000
Bulk	30	50	500
Permafrost rocks of various ice content	500		80000
Ores minerals conductors(in mostly sulphides)	0,001		1-5

As we see from this table [2], the electrical resistance is different for different rocks that allow us to be more confident about the definition of rocks, the water content in them, and to overcome various geophysical tasks.

A study entitled slope stability analysis for landslides natural disaster mitigation by means of geoelectrical resistivity data in Gedangan of South Malang, East Java, Indonesia has been conducted [12]. The research was conducted using geoelectrical resistivity method by applying a vertical electrical sounding (VES) model and Wenner-Schlumberger configuration. From the data as a result of field data acquisition, processing and interpretation are carried out to obtain landslide parameters. By merging each vertical electrical sounding (VES) point, physical parameters will be obtained as the basis for local landslide analysis [12].

Landslide, as a geohazard issue, causes enormous threats to human lives and properties. In order to characterize the subsurface prone to the landslide which is occurred in the Tehran-North freeway, Iran, a comprehensive study focused on geological field observations, and a geoelectrical survey as a cost-effective and fast, non-invasive geophysical measurement was conducted in the area [13]. The Vertical Electrical Sounding (VES) investigation in the landslide area has been carried out by the Schlumberger array for data acquisition, implementing eight survey profiles varying in length between 60 and 130 m [13]. Electrical resistivity values above 150 Ωm indicate a basement of weathered marlstone and sand. Values between 15 and 150 Ωm illustrate a shale-content layer with outcrops in the area that is the reason for movement. The sliding surface is at a depth of about 12 m. The method used in this study is a good candidate to investigate the risk of landslides in this region and can be applied to other landslide areas where borehole exploration is inefficient and expensive due to local complications [13].

Natural electric field (NF) method

In the lithosphere, there are diverse natural electric fields that differ in their nature, nature and scale of manifestation. Among them, a special place is occupied by the electrochemical fields of natural electronic conductors, also called fields of redox or ore nature. One of the methods of electrical exploration is based on the study of fields of this type - the natural electric field method (SP method), which is used to search for and explore mineral deposits and map certain types of rocks.

The self-potential method enables non-intrusive assessment and imaging of disturbances in electrical currents of conductive subsurface materials. It has an increasing number of applications. Laboratory investigations undertaken, the inverse problem and seismoelectric coupling, and concludes with the application of the self-potential method to geohazards, water resources and hydrothermal systems [8].

Landslides present a latent danger to lives and infrastructure worldwide. Often such mass movements are caused by increasing pore pressure. The electrical self-potential (SP) method has been applied in a broad range of monitoring studies. When fluid flow is involved the most relevant source of SP is the streaming potential, caused by the flow of an electrolyte through porous media with electrically charged internal surfaces [9].

The trigger factor of landslide in Pasanggrahan, Indonesia is the increase of water content in the slope and the slip plane. The slip plane began to actively to turn on when the rainy season arrives. The infiltration of rainwater into slopes as an avalanche trigger can be detected by Self Potential (SP) method. SP measurements were performed to determine changes in subsurface water flow [10].

The major factor that triggered the landslide is the combination of the heavy rainfall and the existing weak zones. The electrical resistivity and self-potential profiling are invaluable tools for providing subsurface information in landslide investigation [11].

Fig. 2. Dry unpolarizable electrodes for self potentials measurement - PMS 9000

In the natural electric field method, two methods of observation are used: the gradient method and the potential method. When using the gradient method, the potential difference between adjacent points of the profile is measured. This method is indispensable in cases where it is not possible to use long wires, for example, in settlements or in areas of intense industrial interference. On the other hand, measurements by the gradient method are often accompanied by the accumulation of a large error, and the results require additional processing. The most commonly used and simplest for processing is the shooting of the EP according to the potential scheme, when one electrode is fixed, and using the second identical electrode, the potential difference between the fixed electrode and the rest points of the space is measured.

Measurements of the natural electric field were carried out by means of non-polarizable electrodes of French production (Unpolarizable electrodes for self potentials measurement - PMS 9000).

Field measurements and processing methods

Electroprospecting works. On March 29, 2021, on the landslide located on Machavariani street, electroprospecting works were carried out using the method of vertical electric sounding. Measurements were performed with modern Italian (PASI GL-15N) equipment. The measurement was performed at two points (Fig. 3). The data was processed using the certified program IPI2Win.

The first measurement was made near the landslide tongue, on Machavariani Street (Fig. 3). The measurement was performed by the vertical electrical sounding, with Schlumberger method. The maximum distance between the current electrodes was 100 meters. The corresponding vertical electrical sounding (VES) curve is presented in Fig. 4. The figure shows the curve obtained as a result of resistivity measurements in black, the theoretical curve in red, and the layers, separated by inversion method, in blue. The analysis of the imaginary curve allows us to assume that the clay layer starts from a depth of about 25-30 meters. This result is in some agreement with the results obtained by carotage of wells in the vicinity of VES point.

Fig. 3. Positioning of vertical electrical sounding points in landslide body areas.

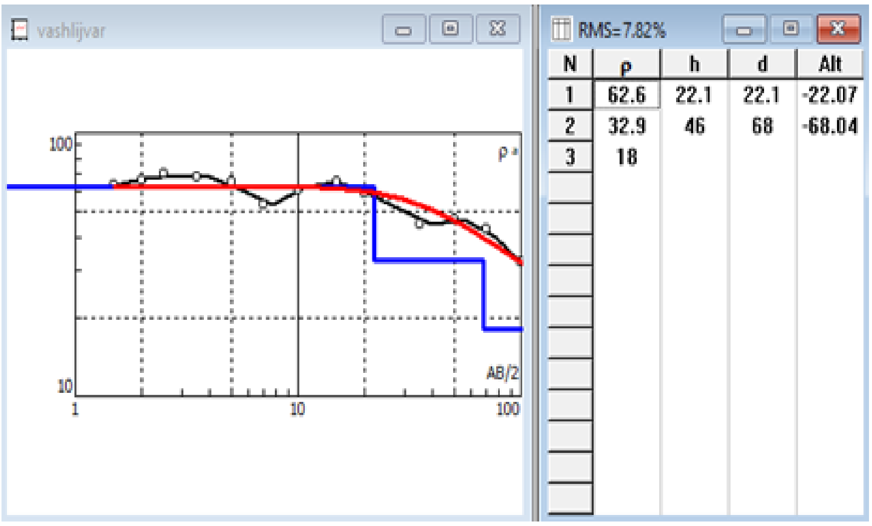

Fig. 4. Vertical electrical sounding curve obtained as a result of measurements near the landslide tongue.

The second measurement was made on the landslide body, about 500 meters away from the first point (Fig. 5). The measurement was also performed using the vertical electrical sounding method with Schlumberger extension. The maximum distance between the current electrodes was 250 meters.

The corresponding vertical electrical sounding curve is presented in at Fig.5. Potentially humidity layers are separated on the VES. However, the analysis of the vertical electrical sensing curve allows us to assume that the entire investigated underground space is characterized by high humidity, which may indicate the inflow of water from certain areas.

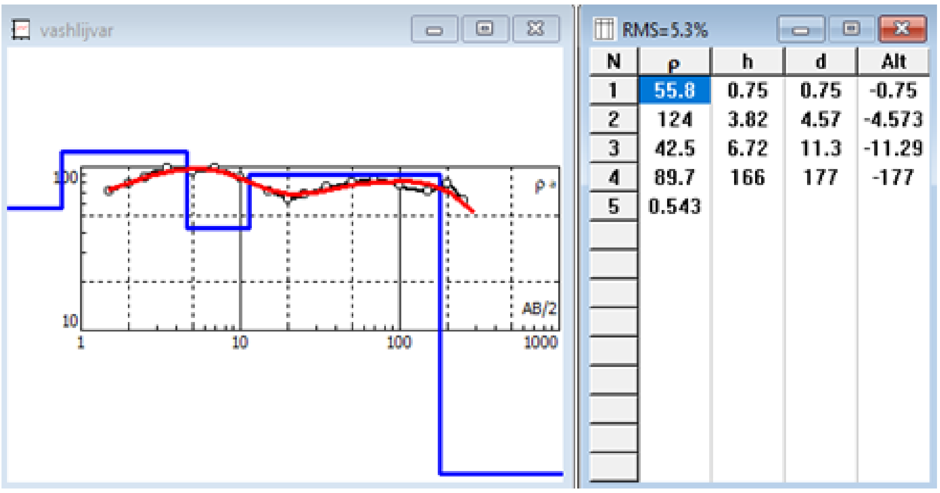

Fig. 5. Vertical electrical sounding curve obtained as a result of measurements on the landslide body.

Works of natural electric field. The measurement of the natural electric field was carried out in the vicinity of the second point of vertical electric sounding (vashlijvari2) (Fig.3). The measurement was carried out by method of the potential (Fig.6). One electrode was fixed stationary in the center of the circle, while the other electrode, connected to it by a 25-meter cable, moved around the circle at a 90-degree angle step. The potential difference was measured on each step. Measurements of the natural electric field allow determining the presence and direction of groundwater flow. From the asymmetry of the diagram, it can be assumed that there is movement of underground water. By analyzing the presented diagram (Fig.7), the direction of groundwater flow can be assumed. Most likely, the movement of underground water flow occurs in the direction of small to large potential difference.

Fig. 6. Non-polarizable electrodes PMS 9000

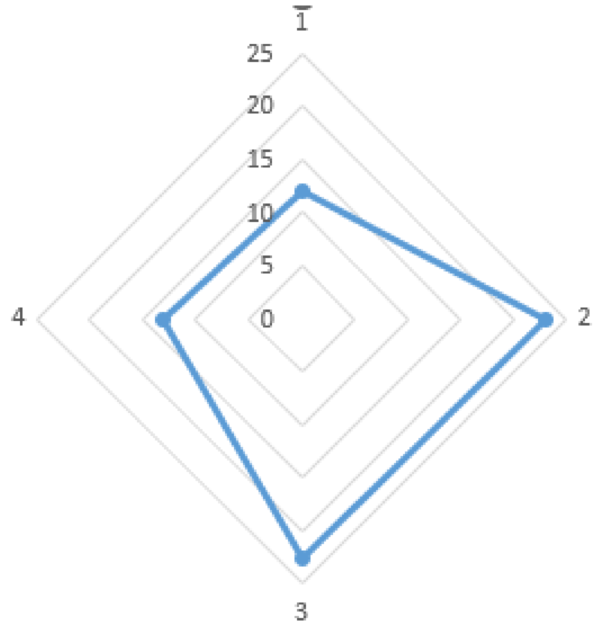

Fig. 7. Result of measurement of the natural field by circular (90° angle) rotation

Conclusion

1.Vertical electrical sounding method is effective in determining groundwater levels, lithology of subsurface and estimating moisture of the subsurface rock. Also, to evaluate the thickness of moistened areas.
2. Measurements of the natural electric field allow determining the presence and direction of groundwater flow.
3. Each of these methods has its own area of application. In the complex they complement each other and can be used for more useful information.
4. However, it should be noted that the work done is not sufficient to study the issue in depth. Further studies are needed.

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ელექტრომიების მეთოდების შესაძლებლობა მეწყრულ არეში ქვეზედაპირის დატენიანების და მიწისქვეშა წყლის ნაკადის შეფასებაში

ნ. ვარამაშვილი, ჯ. ქირია, ა. თარხან-მოურავი, ნ. ღლონტი

რეზიუმე

ელექტრომიება არის გეოფიზიკური მეთოდების მიმართულება, რომელიც სწავლობს სხვადასხვა ბუნების ელექტრომაგნიტურ ველებს. ელექტრომიების მიზანია გეოლოგიური გარემოს ელექტრომაგნიტური მახასიათებლების დადგენა (წინააღმდეგობა, გამტარობა, პოლარიზაცია და ა.შ.), საიდანაც შეიძლება გავაკეთოთ დასკვნები შესწავლილი ტერიტორიის აგებულების შესახებ. ელექტრული გამოკვლევა შეიძლება დაიყოს ორ ჯგუფად: პასიური და აქტიური მეთოდები. პირველ მათგანს ბუნებრივი ელექტრული ველის (ბევ) მეთოდებს უწოდებენ, ხოლო მეორეს - ხელოვნური ელექტრული ველის მეთოდებს. ჩვენს ნაშრომში წარმოდგენილი მასალები მიღებულია წინააღმდეგობის (ვერტიკალური ელექტრული ზონდირების) მეთოდით და ბუნებრივი ელექტრული ველის მეთოდით. სტატიაში წარმოდგენილია ქანების გაწყლიანების და მიწისქვეშა წყლების ნაკადების შესაძლო არსებობის კვლევა.

Возможности электроразведочных методов в оценке подземной влаги и подземного потока воды в оползневой зоне

**Н.Д. Варамашвили, Д.К. Кирия, А.Г. Тархан-Моурави,
Н.Я. Глонти**

Резюме

Электроразведка — раздел геофизических методов, изучающий электромагнитные поля различной природы. Целью электроразведки является определение электромагнитных характеристик геологической среды (сопротивление, электропроводность, поляризация и др.), по которым можно сделать выводы о строении изучаемой территории. Электрические исследования можно разделить на две группы: пассивные и активные методы. Первый из них называется методами естественного электрического поля, а второй - методами сопротивления. Материалы, представленные в нашей статье, были получены методом сопротивления (вертикальное электрическое зондирование) и методом естественного электрического поля. В статье представлено исследование дренирования горных пород и возможного существования подземных водотоков.