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Effects of the Natural Earth Currents on the Electric Potential Distribution on the Surface due to Underground Structure

By

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Abstract

So far spontaneous polarization method of prospecting is mainly used for finding an oxidizing ore body. This method is, however, also useful for predicting the subsurface structure. In any case interpretation requires careful consideration to affecting factors for simpleness of the method. Among them is the probable disturbance in the distribution of potentials on the surface of the earth by the earth current flowing through the top layer affected by the subsurface topography of the bed rock, no matter the current being telluric or electrochemical. In this paper are given a few examples showing such effects caused by subsurface topography which can be considered as two dimensional problem. Potential profiles obtained by model experiments are described.

Introduction

The self-potential method of prospecting is a useful one for exploring ore deposit and underground structure. The sources of potential are usually caused by a differential oxidation between one part of the body and another, mainly due to the difference in aeration of the soil near the surface and the deeper part. According to the present knowledge, the mechanism of generation of spontaneous polarization must be attributed to many causes, physical and chemical. Some of them are well explained, but others insufficiently. Among them are (i) oxidation and reduction of the ore body, (ii) difference in pH of the underground water around the ore body, (iii) filtration potential accompanied by the flow of water through pore space in rock or soil, (iv) difference in ionic concentration, (v) heterogeneity due to alteration or difference of rock, (vi) membrane potential of rocks, (vii) potential due to adsorption of special ions, (viii) polarization by earth current. Other probable causes are those of radioactive origin and those affected by meteorological factors.

The writer does not intend to make discussion on these problems in this short article, but to call attention on the fact that in any case in nature, there is no field where no earth current exists, and therefore, in the interpretation of the results of measurement at the surface of electric potentials over the surveyed area, the effect of the earth current caused by the subsurface topography or structure on the potential distribution must be taken into consideration. With this aim, some examples will be offered in the followings.

General Principle

For simplicity of explanation, let us consider two-layer case in which the second layer, usually the bed rock, being assumed as practically non-conductive, and also the underground structure can be dealed with as two-dimensional problem. If the thickness of the homogeneous overburden layer is kept constant, the electric potential along the earth's surface caused by the earth current flowing horizontally in the layer decreases linearly in the direction of the current as shown in Fig. 1-a. In the case of the increasing thickness towards or against the current direction, the gradient of the potential-drop decreases or increases respectively as shown in Fig. 1-b and Fig. 1-c.

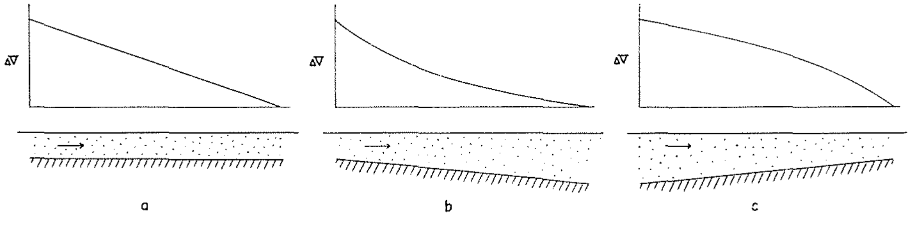

Fig. 1. Electric potential distribution along the surface due to the horizontal current in the surface layer in relation to the inclination of the bed rock and the direction of the current (the arrow), the bed rock being assumed to be non-conductive.

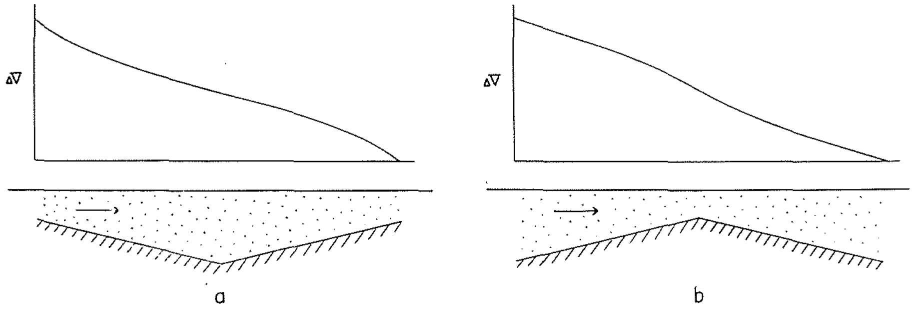

Fig. 2. Electric potential distribution along the surface due to the horizontal current in the surface layer across subsurface valley (a) and ridge (b).

As a modification of these cases, if a ridge or valley exists under the surface layer normally to the direction of the earth current in it, the curves shown in Fig. 2 will be presumed as the distribution of the potential along the surface.

In the case that a fault with a throw existed in the bed rock, the distribution of potential becomes rather complex near the fault. Such a case is investigated by a model experiment, the method and the result are briefly described in the followings.

Model Experiments

Referring to Fig. 3, A is a sheet of moderate conductor for electric current moistened with water containing a proper amount of calcium chloride. This is composed of

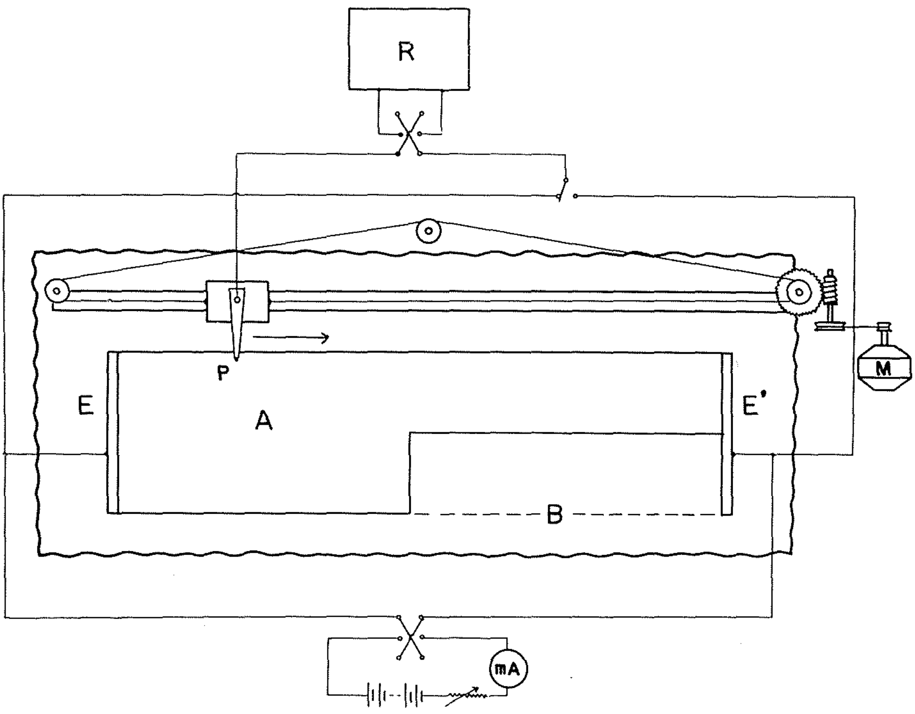

Fig. 3. Schematic diagram showing arrangement of the apparatus used in the model experiment.

A : Filter paper moistened with water containing $CaCl_2$
B : Insulator board
E, E': Current electrodes
M: Electric motor
P : Moving electrode
R : Recorder

two sheets of filter paper for use in chromatography cut in shape after being put crosswise one upon another to avoid anisotropy due to probable lineation of the paper. B is a board of insulating material on which the former is spread closely to leave no air bubbles between them. Thus A represents the surface layer and B the bed rock. On the both ends of A are placed the electrodes which supply the constant current, and along the top of A the potential with respect to one electrode is measured with a potentiometer. In practice, in order to avoid difficulties which can be expected in making use of a double commutator and a potentiometer, a direct current was used. As the current electrode a brass rod of square cross-section (1×1 cm), preferably gold-plated, was used. With the total current of $1 \sim 2$ mA, the polarization was found unremarkable, that is, one tenth at most. In several minutes its change became almost negligible and the current could be taken as constant during a run which usually required less than one minute. The potential between either current electrode and a moving potential electrode driven by a small electric motor at a constant speed was recorded utilizing the Electronic Polyrecorder Model EPR-2T.

As examples, the results obtained by such an experiment are shown in the followings; the cases of subsurface valley (Fig. 4), ridge (Fig. 5) and vertical escarpment (Fig. 6) of the bed rock which is assumed to be non-conductive. It is noteworthy that the effect due to buried escarpment is more remarkable on the side of the larger thickness of the overburden than on that of the smaller one.

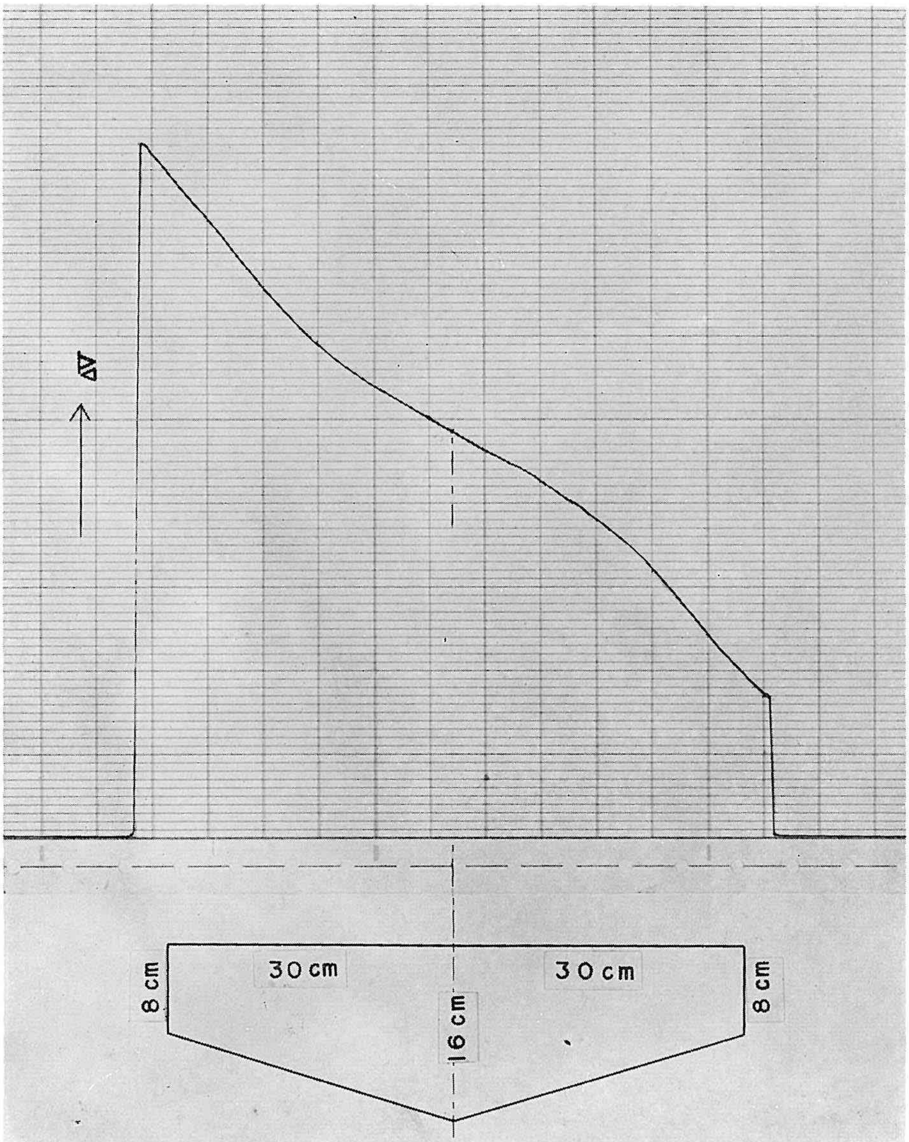

Fig. 4. Trend of electric potential obtained by the model experiment corresponding to that along a traverse across subsurface valley.

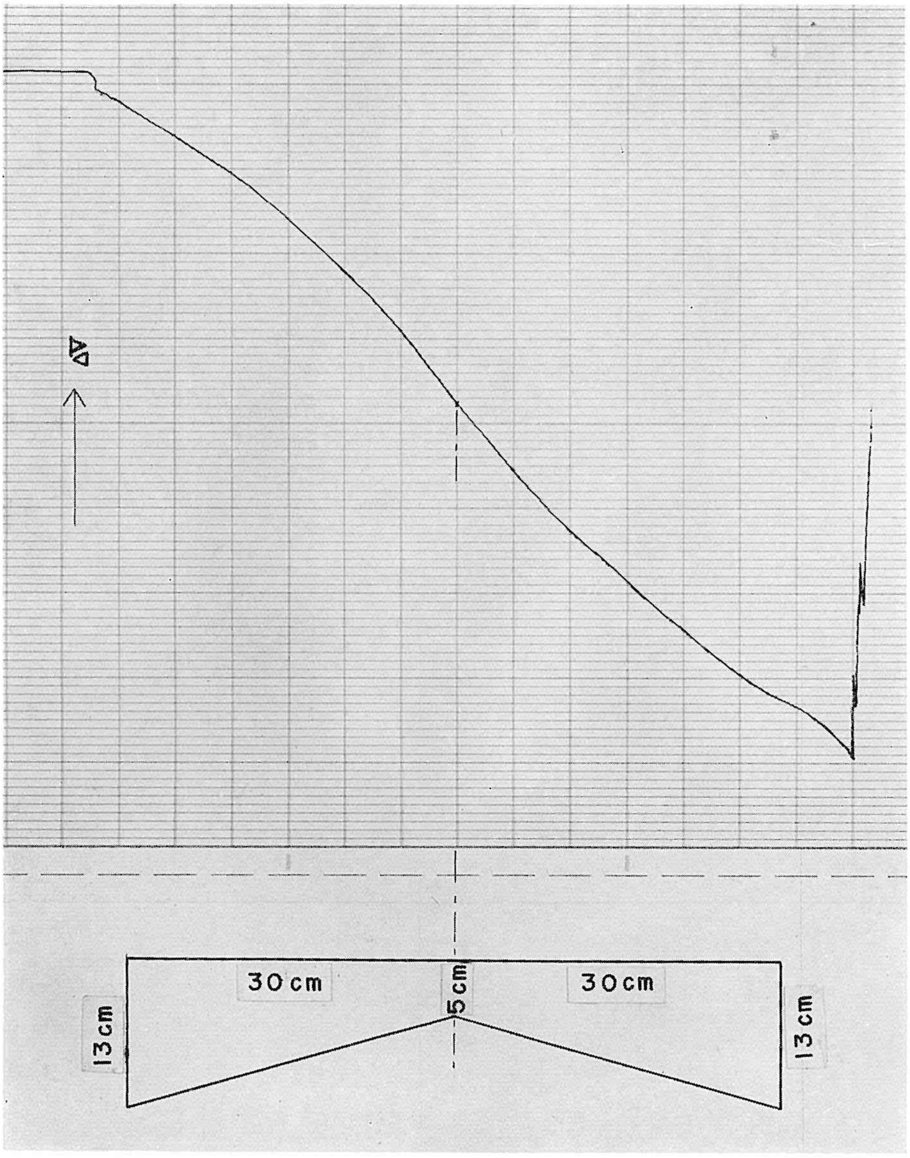

Fig. 5. Trend of electric potential obtained by the model experiment corresponding to that along a traverse across subsurface ridge.

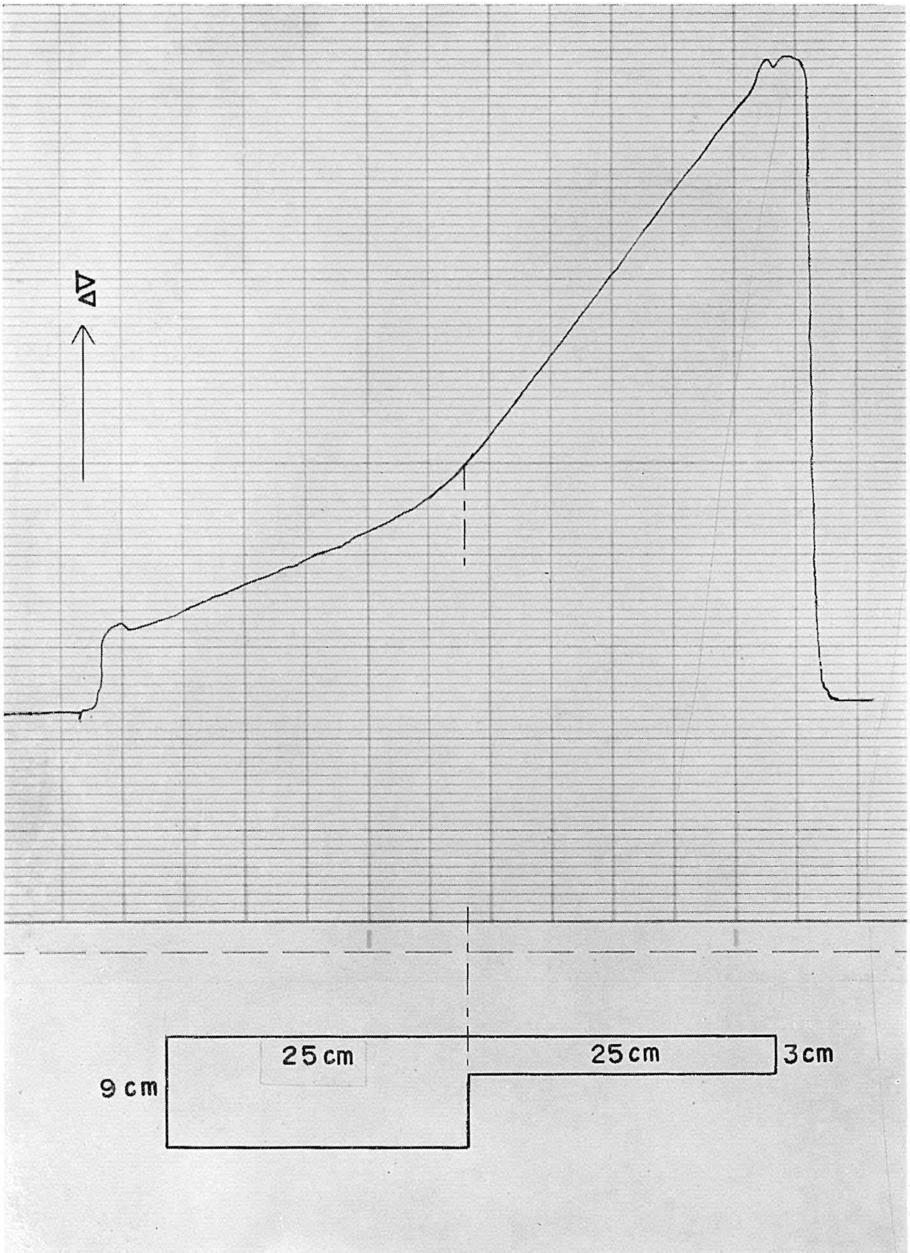

Fig. 6. Trend of electric potential obtained by the model experiment corresponding to that along a traverse across subsurface escarpment.