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On study of the geodynamic processes by geoelectrical methods.

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Abstract: Electrical methods with artificial generators are widely used in geophysical prospecting (electrical prospecting). Last decades electrical methods were applied for investigation of geodynamic phenomena for the purpose of prediction of different catastrophes: earthquakes, landslides, karsts etc. (geodynamic electric method - GDEM).
There exists the principal difference between electrical prospecting and GDEM. In the first case absolute values of geoelectrical parameters are measured, in the second case small time-space variations of geoelectrical parameters instead of the absolute values are measured.
Change in rock mass state results in distortions of electric field of generator. These distortions can be scalar or vector. Scalar distortions, as a rule, are connected with temperature effect, precipitations. Vector changes in geoelectrical fields reflect the processes of origin and development of inhomogeneity. These vector changes of an electric field are the subject of our investigations. A special measurement procedure and the special equipment are required for the solution of this problem.
The results gained by authors in the course different field and laboratory investigations are introduced in the present paper. The special method of the active geoelectric monitoring was used in all experiments.

Keywords: Geoelectical Monitoring; Dynamic components; Equipotential lines.

1. INTRODUCTION

The aim of our investigations is to study changes of stress-deformed state of medium by the method of active geoelectric monitoring. Using the system of emitting electrodes and electrical generator we can create initial electric field $\overline{E}_1$ in medium. Due to changes of stress conditions in medium time-space character of its inhomogeneity medium will be changed. In this case initial field $\overline{E}_1$ will be changed by the value $\Delta\overline{E}$

$$\overline{E}_2 = \overline{E}_1 + \Delta\overline{E} \qquad (1)$$

where $\overline{E}_2$ – field in the changed medium, $\Delta\overline{E}$ – difference field.
It is possible to consider $\Delta\overline{E}$, as the field of some dummy source, which corresponds to multiplicative function of inhomogeneity and real energy source and is connected with them spatially and quantitatively. Difference field $\Delta\overline{E}$ includes component, orthogonal to initial field E_1. These ideas became the basis for development of measurement procedure.

2. MEASUREMENT METHODS

The following requirements are necessary for measurement of dynamic components of geophysical parameters by a geoelectric method.

- Method shall provide maximal sensitivity to difference field $\Delta\overline{E}$ and minimal sensitivity to field $\overline{E}_1$.
- It is necessary to ensure low sensitivity to temperature, precipitations etc. Otherwise it is necessary to install electrodes on considerable depth.
- Correct choice of the relative position in the system source - inhomogeneity- sensor shall ensure the given directional diagram. It will allow to control the chosen object (the active fracture, for example) or to detect position of the new inhomogeneities.

The first and the second requirements are satisfied, if measuring electrodes are located on equipotential lines of initial field $\overline{E}_1$. In this case the initial potential difference between measuring electrodes MN is equal to zero. Noise factors, uniformly distributed throughout the area (temperature, precipitates, air pressure etc.), cause scalar variations of the field $\overline{E}_1$. In this case the shape of equipotential lines does not vary and $\Delta\overline{E}$ is equal to zero.
The third requirement is satisfied by installation of measuring electrodes along the beam coming from a dummy source.
Electrical installations with location of measuring electrodes on equipotential lines of field $\overline{E}_1$ are termed as the equipotential.installations. They can have different configuration. We often used three-electrode installation with two mutually orthogonal pairs of meaeuring electrodes («three-electrode equipotential two-dimentional installation»). Measuring pairs M_1 N_1 and M_2N_2 were located on equipotential lines of emitting electrode A. The second emitting electrode B was on the considerable distance.

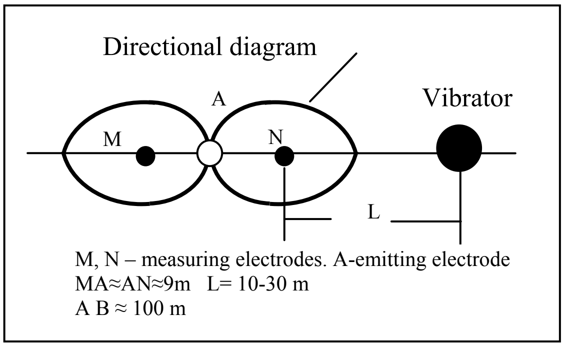

Figure 1. The experiment plan

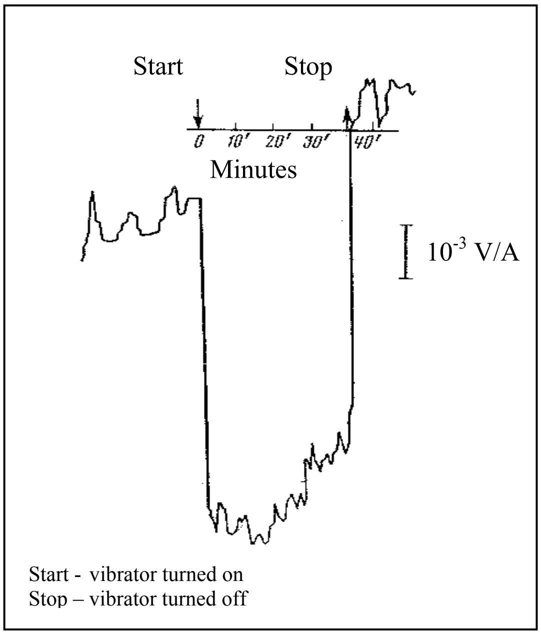

Figure 2. Result of experiment with vibrator

3. RESULTS OF EXPERIMENTS

3.1 Field Experiments with the Seismic Vibrator

Scheme of experiment is shown in Figure 1.
The used measurement instrument was the electrovariometer (EV). This device was designed for long-term continuous automated measurements of variations electrical parameters of rocks [A.N. Bogolubov et al., 2002].

EV consists of the generator, measuring unit, emitting electrodes AB and one or several pairs of measuring electrodes MN. The generator connected with the Earth through AB electrodes emits a low-frequency signal (73 Hz), the measuring unit receives active and reactive components of voltage between measuring electrodes (Re U_{MN} and Im U_{MN}). One pair of measuring electrodes MN was oriented in direction of the vibrator. The second pair of measuring electrodes was installed orthogonally the first one (it is not shown in Figure 1).

The result of one experiment (modification Im U_{MN}) is shown in Figure 2. Frequency of the vibrator was 4 Hz, a time of work was 40 minutes. Im U_{MN} value was normalized to generator current I_G. Im U_{MN}/I_G value was changed by $5.9*10^{-3}$ V/A after vibrator was turned on (Start) and was recovered after vibrator was turned off (Stop). Re U_{MN}/I_G value was changed in the same way. Polarity of the effect in all experiments remained invariable; the dependence on vibrator frequency was not detected. The signal on orthogonal pair MN was not detected.
These results were the consequence of inhomogeneous, reversible medium change under the influence of the vibrator. We believe that it is the complex of changes of stress condition and electrical conductivity of medium under the influence of elastic vibrations This problem needs the further investigation.

3.2 Natural experiments

During several years we conducted field observations in seismically and landslide active regions using the three-electrode equipotential installation. As field experiments have shown, this method allows to decrease co-phased electrical interference by three orders of magnitude in comparison with Venner installation. The influence of the near-surface layer conductivity caused by temperature change was decreased by two orders and more. A direct effect of precipitation was not detected.

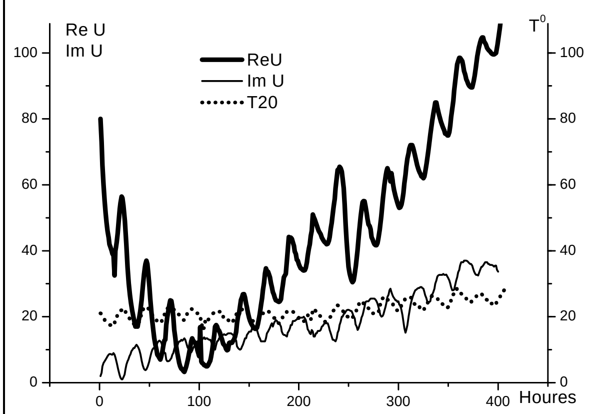

Figure 3. Synchronous measurments of Re U_{MN}, Im U_{MN} and soil temperatures

During the observations, quasiperiodic oscillations (“equipotential line breathing”) with the main periods of approximately 24, 12 hours were registered. Amplitudes of the oscillations with different

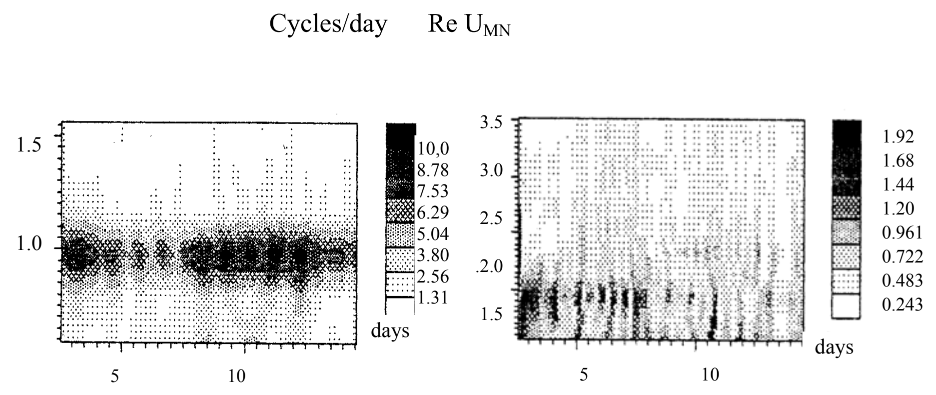

Figure 4. ST diagram of Re U_{MN}

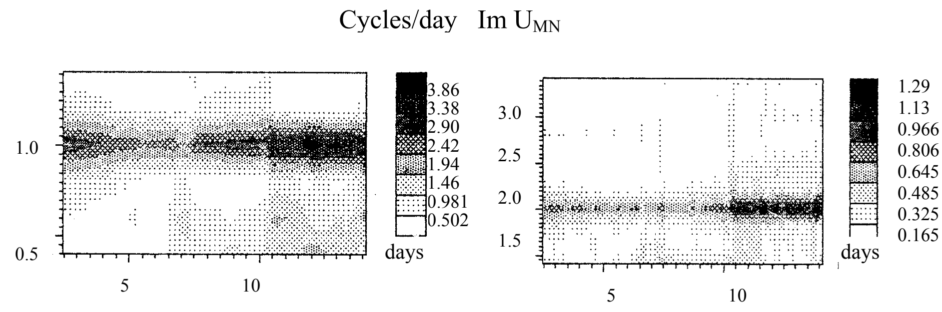

Figure 5. ST diagram of Im U_{MN}

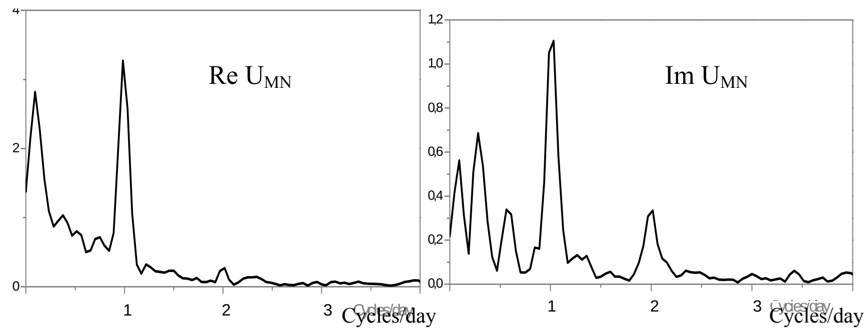

Figure 6. Spectra of Re U_{MN} and Im U_{MN}

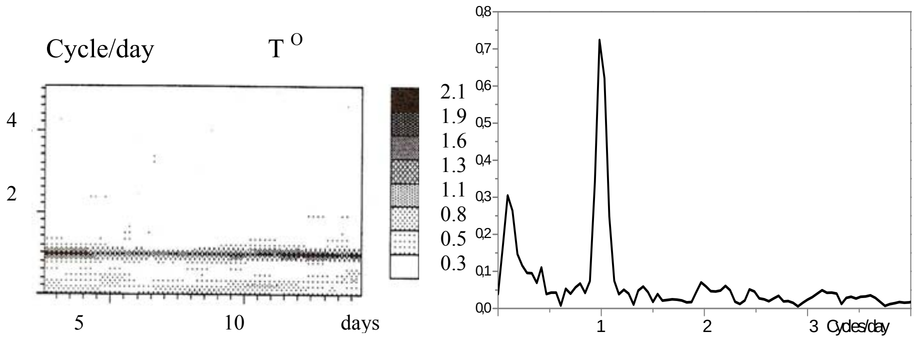

Figure 7. ST diagram and spectrum of T^{O}

periods varied in the time. This behavior (regime) corresponded to the "quiet" condition of the medium (the uppermost layer of the Earth's crust). The disastrous geodynamic events (earthquakes and landslides) were accompanied by the destruction of a "normal" trend several hours before these events. Oscillations were restored several hours after these events. . These results are presented in A. N. Bogolubov et al., [2002] and Volkova E.N. et al. [1998].

The results of synchronous measurements Re U_{MN}, Im U_{MN} and soil temperatures at depth of 20 cm are shown in Figure 3. Spectral-time diagrams and Fourier spectra of these curves are shown in Figures 4, 5, 6 and 7. Harmonic components of intraday periodicity are detected in all series. Amplitudes of diurnal and semidiurnal oscillations for Re U_{MN} are differed several times. The amplitude of the semidiurnal oscillations Im U_{MN} is comparable with amplitude of diurnal oscillations, and it was noted early [A. N Bogolubov et all., 2002]. A temperature series contains only one dominating diurnal period.

It is most likely that variations Re U and Im U were caused by geodeformation processes.. Diurnal oscillations have both "temperature" and "tidal" origin, the semidiurnal harmonics are the result of lunisolar influence. This assumption was partially confirmed by model experiments in the lab.

3.3 Modeling experiments

The experimental equipment was designed by Dr. Victor P. Khomenko [Khomenko, 2003]. The working camera of installation (95 x 74 x 30 sm) was filled with sand. At a definite moment, after the bottom of the chamber started gradually to open, an enclosed cavity was formed in the chamber due to the sand spilling out through the partially opened bottom (the cavity did not appear on the surface of the sand).

The possibility of registration of process of formation of the enclosed vacuity was studied by the method of geoelectric monitoring in the course of these experiments. Attempts of our colleagues to make it by means of traditional geoelectric and seismic methods have failed.

We used different versions of the equipotential installations, including two-dimensional eqiupotential geoelectrical device. In some experiments the tilt-meter (НИ-3, designed at IFE RAS) was installed on the surface of the sand (Figure 8, 9).

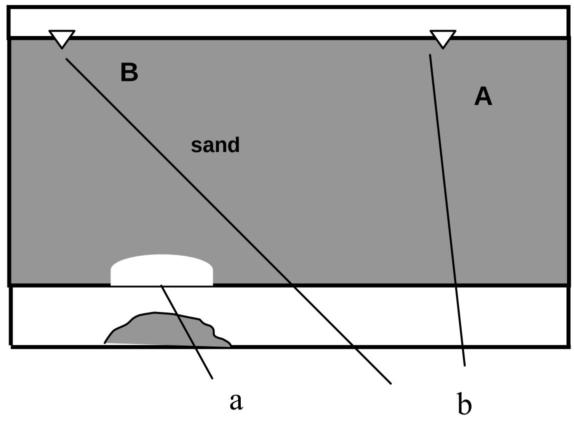

Figure 8. Location of the cavity and measuring equipment. a – cavity, b - emitting electroedes A and B

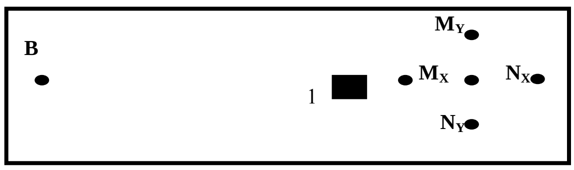

Figure 9. Location of the tilt-meter (1) and two-dimentional eqiupotential installation on the surface of the model

The formation of cavity was fixed in all experiments (more than ten experience were conducted). The typical result of experiment with 600 mm sand layer is shown in Figure 10. The background noise was measured from 0 till the moment A. A is the beginning of opening of metal bottom of model. Noise has appeared after opening of a metal bottom at this moment.

The opening in bottom of model was increased from the moment A till the moment C. Cavity (height 15 sm., width 25 sm.) appeared at the moment B. Cavity was increased at the moment C (height 18 sm., width 35 sm.). The moments of formation and increasing of the cavity were clearly registered by the measuring device.

The use of a two-dimensional eqiupotential installation allowed to define direction to cavity. The positive slope of U_{MxNx} diagram till the moment of cavity formations (moment B) was observed during experiment. The same slope was observed after a moment B.
It means, that distortion of equipotential lines of an electric field took place. We have assumed that there took place deformation of surface of model caused by continuous increase of opening in bottom of model.

This assumption was checked by synchronous electrical and tilt measurements (Figure 11).
The background noise was recorded during 10 minutes (till the moment A). After that the bottom of installation started to move apart. The positive trend was observed on both diagrams. Response to formation and development of the cavity is also observed on both diagrams. Tilt-meter data show formation of the cavity was preceded by deformation of the surface of the sand in the working camera.

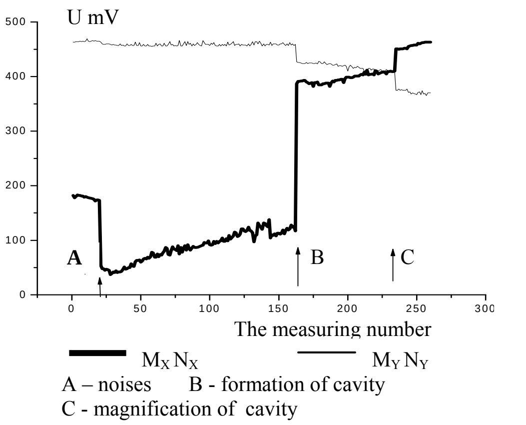

Figure 10. Detection of enclosed cavity by the two-dimensional eqiupotential installation

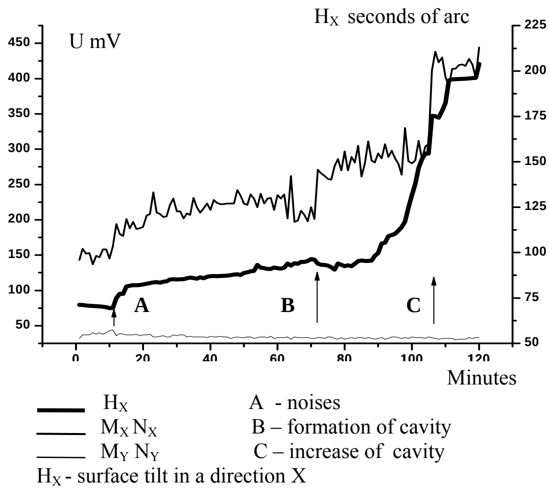

Figure 11. Synchronous measurement of an electric field and declinations of a surface of model.

4. RESUME

Investigations in the seismically and landslide active regions and model experiments show that the equipotential installations have high resolution ability and a high noise immunity.

We could compare behavior of U_{MN} during formation of cavity (Figures 10 and 11) and during work of vibrator (Figure 2). The nonreversible changes caused by formation of inhomogeneity (cavity) took place in the first case. In the second case changes of U_{MN} are similar, but reversible. So, it is possible to consider that vibrator action is equivalent to appearance of inhomogeneity, which disappears after vibrator stops working. So, experiments with vibrator and model experiments confirm that two-dimensional eqiupotential geo-electrical installation is able to register space-time development of deformational process.

Analysis of a spectral content of electrical and temperature series (Figure 3-7) confirms conclusions made in A. N Bogolubov et all. [2002] that quasiperiodic oscillations of U_{MN} are caused by temperature and tidal strains. Final inferences on nature of these oscillations could be made after further natural observations. It is necessary to carry out a cycle of continuous geoelectrical, deformational, hydrogeological, temperature and other measurements to detect qualitative and quantitative relationships between variations of physical properties.

It is necessary to pay additional attention to analysis of a low-frequency trend of temperature and electrical series (Figure 3).

Experiments with ground model shows that the presented method of the active geoelectric monitoring gives possibility of sure registration of formation of underground cavities.

The simplified measuring device was used in model experiments. Its resolution is approximately equal to 5 mV/second of arc according to data on the interval A-V, Figure 11. Resolution ability of an electrovariometer EV, which was used in natural experiments, is approximately two orders higher. It is known that amplitudes of surface tilts caused by lunisolar tides amount to 0.04 second of arc. So, surface tilts caused by lunisolar tides could be registered by the equipotential installation.

The correct choice of the relative location of the generator, inhomogeneity, and sensors (GNS) is very important for the investigation of inhomogeneity dynamics. The GNS configuration, selected with regard to features of investigated process provides the best noise cancellation and the greatest sensitivity for a useful signal, i.e., it provides a maximal signal/noise ratio.

4. CONCLUSION

In this paper we have tried to introduce maximal volume of the experimental results. The main objective of experiments was to checkout of possibilities of instrumentation and a measurement procedure.

The main requirement is to provide maximal sensitivity to dynamic components of geophysical parameters of medium. The results of field observations and model experiments demonstrate the expediency of introduced geoelectrical monitoring methods of investigation of geodynamic processes. It is necessary to investigate possibilities of different modifications of the equipotential installations for control of concrete objects.

Unfortunately volume of the paper does not allow to discuss theoretical and instrumental problems.

Evaluation of our conclusions and hypotheses will be possible after conducting of the long-term complex geophysical observations in quiet and active regions.

In our opinion, integrating of methods of active geoelectric and seismic monitoring with the methods based on mechano-elektrical transformings in rocks is very perspective.

Space-time variations of mechano-elektrical transfer function of rocks could be studies in this case. It will produce additional information.

The methods of monitoring based on analysis self-oscillation in rocks are also important for explanation. The first results have been published in Kamshilin et al., 2002.

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