Abstract. The results of laboratory studies made on rock samples and models are given in the work. Samples were exposed to mechanical loading by means of press. The method of free relaxation of absorption current has been applied. Curves of the dependence of the decrement of absorption current on time have been obtained at different values of mechanical stress. The curves are not characterized by one, but a number of relaxation times-short and long. Short times changes are pronounced at the increase of stresses, but long relaxation times increase greatly. It is evident that the increase of relaxation times is connected with the formation of micro-cracks in the sample. The formation of the main crack leads to the streak decrease of long relaxation time. Thus relaxation times of absorption current characterize the change in the system of cracks. The results of the investigations can be applied in the development of new methods of natural studies in seismology.

Introduction

One of actual problems in geophysics is studying a process of destruction of rocks and changes of the geophysical fields observable during the formation of cracks. In a zone of preparing destruction there is a complex intense condition which leads to the generation and germination of cracks. In such zones significant anomalies of various geophysical fields are expected to develop. Fast and slow relaxation processes in electric fields at deformation of rocks are studied poorly. Practically mechanisms of occurrence of polarizability in complex stress conditions are not studied. In a number of works (A.V. Ponomarev and G.A. Sobolev) it was marked that the change of a seeming resistance is an effective precursor of preparing destruction of a file of rocks. However till now completely there are not clear the nature of anomalies and places of the most probable displays. Especially intensive processes of variations of resistance can develop close to nonhomogenities where there are the strongest concentration of pressure. The purpose of the given work is reception of the new information on polarizability of rocks, revealing of possible mechanisms of occurrence and a relaxation of charges in laboratory experiments.

Methods

Rocks can be presented as an imperfect dielectric with losses in parallel connected resistance and capacity. The general current arising under the action of an electric field, it is possible to present it as the sum defined by the formula:

$$I = I_3 + I_0 + I_a,$$

where $I$ - general current through the dielectric, $I_3$ - current of charge, $I_0$ - residual current, $I_a$ - current gradually weakening in due course. It is named reversible current of absorption, and the phenomenon of its occurrence - dielectric absorption (Sidorov, V.A.). Falling off of a current in due course can be described by means of a set of exhibitors and to present by the formula:

$$I_a = A_0e^{-\frac{t}{\tau_1}} + A_1e^{-\frac{t}{\tau_2}} + \ldots + A_ne^{-\frac{t}{\tau_n}},$$

Thus, when studying a current of absorption ($I_a$) it is necessary to measure the rate of recession of the curve of polarizability. This method is known as a method of free relaxation of a current of absorption in absence of an external circuit (Sidorov, V.A.).

For studying recession of a current of absorption from natural (pirophillit, sandstone, and others) and modeling (concrete) materials, different samples were made (fig.1). Samples of the rectangular form were
made by the size 10x7x5 cm. Models of large-scale samples (fig. 1d) reached the size 200x70x50 cm. Cores had the sizes: height: 6-7 cm, diameter: 5 cm.

For loading we applied the press of 50 ton (Troitsk). Within 1-2 days before loading the measurements of background curves of recession of a current of absorption were spent at F=0, and average curve $I_a = f(t)$ was under construction. In cycles loading measurements were carried out at stages of constant loadings, and before the measurement the sample or model were exposed to constant pressure within 3-4 minutes. The same process was repeated at other loading. On a surface of samples from pirophillit, limestone, and sandstone, measuring electrodes MN were fixed which were established in a stratified zone of lamination and a predicted zone of concentration of pressure. In the top and bottom parts of the sample there are current gauges A and B made of graphite paste; transitive resistance of contact to the sample was less than 2 kOm for models from concrete.

![Fig. 1. Models. a - a core, b - a sample of the rectangular form, c - a sample of the rectangular form with concentrators, d - a large-scale sample from concrete.](image)

The model from concrete with the additive of a graphite dust was applied. In this case, the influence of a mineralization on the behavior of electric parameters was studied at loading. On large-scale model process of a relaxation of a current of absorption in a zone of asperity of blocks was studied at development of a condition of instability (Fig. 1d). On this sample in the work of R.A. Lementueva, V.I. Ponjatovskaya, E.I. Irisova, and V.A. Popov variations of various geophysical fields were investigated. In the given work it is experimentally shown that the process of a relaxation of current $I_a$ is possible to study in a local site of the large-scale sample, in the case of break of asperity with the movement of the fault.

Samples were humidified and contained 3 - 5 % of moisture. That provided a condition of rocks close to the natural one.
Studying of electric processes was spent on the equipment described by Komarov, V.A. for method of caused polarization (ВП). The scheme of measuring installation presented in fig. 2, includes: MSVP device (Bobrovnikov, L.Z., L.I. Orlov, and V.A. Popov), batteries, the switchboard of a current, ballast resistance (Rk) and milliampermeter (mA). Gauges M and N (of “Radelkis”) were fixed to lateral surfaces of the sample by means of plugs from plexiglas. The stability of own potentials of electrodes is 0.1 - 0.2 mV.

![Fig.2. Scheme of measurements.](image)

The technique of supervision consists in the following. In the beginning natural electric potentials (ΔU₀) between each pair of gauges N-M₁ and N-M₂ have been measured. Then through the sample an impulse of the stabilized current (I) runs of duration of 15 s with an amplitude 20 mA. At the passing of the impulse of current potentials ΔU were registered between the same pairs of gauges.

After switching-off of current I = 20 mA potentials of the caused polarization (ΔUₚ) were measured in 0.25, 0.5, 1, 2, 7, 11, and 22 s. Laboratory installation allowed registration of potentials in time of 1 upto 100 sec. And by that limits of registration (t → 200 sec) extended. It is visible that the process of recession of a current of absorption Iₐ = I₀exp (-Δt/τ) is characterized for various relaxations times (1, 2, .. n).

The quantitative estimation of the observable phenomenon in an interval (Δt) can be received

\[ \ln I_a = \ln I_0 - \frac{\Delta t}{\tau} \]

Having defined the time of relaxation, it is possible to speak about a degree of polarizability of environment, because it is known that \( \tau = RC \), \( C \sim \varepsilon \), \( \varepsilon \) — dielectric permeability of environment.

**Results**

Curves of recession of a current of absorption depending on loading for various samples are shown in fig. 3. The analysis of experimental data shows that curves of reduction of a current of absorption in due course, received at various mechanical pressure have an expotential appearance. As the received curve in half-logarithmic scale, is also similar to an exhibitor (instead of a straight line), we observe a number of processes of relaxation with various τ. In the received dependences of a current of the absorption presented in fig. 3a, b, c, d, it is possible to allocate conditionally fast and slow processes of relaxation. The first time of relaxation is defined, when \( I_a \) falls down in-e-time. In the field of “slow” (τᵢ ≥ 20s) delay of relaxation was observed at increase of loading (F). At change of F (MPa) τᵢ increased or decreased, depending on variation of loading on the sample.
Fig. 3.
Curves of recession of a current of absorption depending on time at various loadings for various samples. 

- **a** - rectangular sample from pirofillit, 
- **b** - rectangular sample from limestone, 
- **c** - model from the concrete mixed with a graphite dust, 
- **d** - sample from concrete with concentrators of pressure; 

1 - state before loading, 5 - state after loading.
The change of loading $F_{\text{max}}$ up to 0, both $\tau_1$ and $\tau_2$ decreased (“fast” and “slow” relaxations). The stated laws of behavior of curves are well visible in fig. 3a (the sample from pirophilit) and 3b (the sample from limestone). Similar dependences have been observed for cores from sandstone. Curves are presented of model from the concrete mixed with a graphite dust (fig. 3c) and with concentrators of pressure (fig. 3d).

![Fig. 3e](image)

Fig. 3e. Attenuation of a current of absorption depending on time of large-scale model from concrete.

Characteristics of the curve $I_a$ for these models constructed in half-logarithmic scale is similar for pirophilit, however constants of time $\tau_1$ and $\tau_n$ of the relaxation are less and after loading removal ($F\rightarrow 0$) it is almost a straight line.

Development of a status of instability in zone of modeled break as shown in the experiments [Lementueva, R.A., V.I.Ponjatovskaya, E.I.Irisova, and V.A. Popov], is in a direct communication with the process of accumulation of deformations under the influence of a tension and structural changes in the environment. It, in turn, is reflected in the character of dependence $I_a = f(t)$.

Experiments with large-scale model from concrete are presented in fig. 3e. In fig. 3e results of recession $I_a$ for one pair gauges $N - M_1$ are presented. At occurrence of a local break in asperity it is visible that there is an accelerated process of relaxation $I_a$ (Fig. 3e, curve 2). However loading increase (curve 3) results in increase of time of relaxation. Durability of asperity in this time interval has increased because of a congestion destroyed parts of the material in the fault. Failure of asperity with advancement on a break is characterized by a curve 4 with character change exponent dependences at the point $t = 11s$. Current $I_a$ falls down at first very slowly and curve — 4 shows that the state before of destruction of asperity is characterized by the big times of relaxation. Thus, as well as in the previous experiments, in a local deformable zone at modeling of a status of instability in a fault occurrence of big times of relaxation before the asperity failure is noted. There is a long steady polarization.
Conclusions

Results are presented of research of electrophysical characteristics of rocks under the influence of mechanical loadings on samples. The applied method of free relaxation of a current of absorption has allowed us to reveal the basic distinctions in behavior of a current of absorption $I_a$ at micro- and macrodestruction of samples and models of rocks and at development (in model from concrete) statuses of mechanical instability in the environment. Relaxation time ($\tau_n$) is a key parameter of process of an establishment and disappearance of volume polarization of rocks. On the basis of the resulted schedules acceleration of process of relaxation can testify to the occurrence of considerable infringements in the environment of rocks. Occurrence of big times of relaxation testifies that in a deformation zone there is an essential destruction, or the beginning of the main crack is formed. The constant relaxation $\tau$ in the absorption current is the characteristic of environment in the given time interval and can be used for the description of polarizability of rocks in various stages of loading. Definition $\tau_i$ on a curve constructed in half-logarithmic scale, allows us to calculate in each time interval times $\tau_n$ relaxations $I_a$. The received results, probably, will promote understanding of the processes which are taking place at destruction of rocks and for improvement of techniques of geophysical measurements.

Acknowledgements

The work was partly supported by the grant RFFI № 06-05-64888-a.

References