9

A New Method of an Active Electromagnetic Induction and a Seismic Monitoring in Oil Saturated Media

9

A New Method of an Active Electromagnetic Induction and a Seismic Monitoring in Oil Saturated Media

Olga Hachay[1], Oleg Khachay[2], Andrey Khachay[2]

[1]Institute of Geophysics, Ural Branch of Russian Academy of sciences, Amundsen str. 100, Yekaterinburg, 620016 Russia. E-mail: olga.hachay@yandex.ru.

[2]Ural Federal University, Yekaterinburg. Russia, E-mail: khachay@yandex.ru.

Summary

That chapter is devoted to new ideas of developing a new method of an active electromagnetic induction and a seismic monitoring in oil saturated media. It contains theoretical algorithms for modeling the elastic waves propagation in a hierarchic structured media with porous inclusions saturated by some fluids (oil or water). It presents the results, obtained by the electromagnetic method, related to the structure, and the disintegration zones, which are cracks in the rock massif. The question of self-organization of these cracks, which occur by an outer force action, had been researched. The information about that crack zones and their state is very needed for forecasting the oil outworking from the deposit. It allows the development of the outworking strategy. All experimental data had been developed in real massifs, in mines or boreholes on oil deposits. The chapter also contains a new processing method of seismic monitoring data, which are obtained on real oil boreholes.

9.1 Introduction

The processes of oil gaseous deposits outworking are linked with the moving of polyphase multicomponent media, which are characterized by no equilibrium and nonlinear rheological features. The real behavior of layered systems is defined by the complicated rheology moving liquids and the structural morphology of porous media (Hasanov and Bulgakova, 2003). It is urgently needed to account those factors for a substantial description of the filtration processes. Additionally, we must also account the synergetic effects. That allows suggesting new methods of control and management of complicated natural systems, which can research these effects. Thus, our research is directed to the layered system, -which is a complicated hierarchic dynamical system-, from which we have to outwork oil. By developing a mathematical model of a real object, we need the quality as a priori information as for the use of the active and passive monitoring data obtained during the well operation. The solution on inverse problems has a large significance for oil industry, because the oil layer covers the set of natural systems, which can not be directly investigated as a whole. Researches of the last years showed that in the evolution of dynamical systems, which cover the oil objects, the nonstabilities, the factors: the nature, the theory of the self-organization and the synergetics, play a significant role. That information about their phenomenon is only obtained using monitoring data, which are sensitive to the hierarchic structure (Hasanov and Bulgakova, 2003).

Let us consider three sequential appeared processes, which lead to exceeding of ultrasoning processes by vibration influence on the layers (Hachay and Drjagin, 2010a, b). First: transfer the weak harmonic oscillations of the bottom layer to the collector blocks. Second: appearance of blocks micro oscillations in the fluid flow by a high pressure, which leads to pressure pulsations in the liquid and to the irregularity of the flow in cracks. Third: generation of resonant block elastic oscillations, which produce ultrasonic oscillations.

The mechanism of transferring the oscillations of the initial low frequency latitude wave consists of exciting the collector layer as a whole. The transfer of transverse oscillations by inclined wave falling on the layer and the transfer of the shear stresses depend on the material capacity, which supports the cracks between the blocks. Thus, if the material is water, the transverse oscillations do not go through the bottom layer into the oil layer. If the material in the crack is viscous, the shear oscillations will influence on the neighbor blocks and initiate microscopic horizontal displacements and rotations. Mathematical methods for modeling the propagation of different geophysical wave fields through heterogeneous media with hierarchic inclusions play a significant role in constructing new methods of the oil saturated medium monitoring.

9.2 Modeling of Seismic Field for Hierarchic Heterogeneous Media

Let us consider an algorithm of sound diffraction on 2-D elastic heterogeneity with hierarchic structure, located in the j-th layer of n-layered medium (Hachay, 1994; Hachay and Khachay, 2008). If by transition on the next hierarchic level, the axis of two-dimensionality does not change and only the geometry of the section of embedded structures change, then we can write the iteration process of modeling of the seismic field (case of generating only longitudinal wave).

$$\begin{aligned}
&\frac{(k_{1jil}^2-k_{1j}^2)}{2\pi}\iint\limits_{S_{Cl}}\varphi_l(M)G_{Sp,j}(M,M^0)d\tau_M+\frac{\sigma_{ja}}{\sigma_{jil}}\varphi_{l-1}^0(M^0)-\\
&-\frac{(\sigma_{ja}-\sigma_{jil})}{\sigma_{jil}2\pi}\oint\limits_{Cl}G_{Sp,j}\frac{\partial\varphi_l}{\partial n}dc=\varphi_l(M^0)\quad by\,M^0\in S_{Cl}\\
&\frac{\sigma_{jil}(k_{1jil}^2-k_{1j}^2)}{\sigma(M^0)2\pi}\iint\limits_{S_{Cl}}\varphi_l(M)G_{Sp,j}(M,M^0)d\tau_M+\varphi_{l-1}^0(M^0)-\\
&-\frac{(\sigma_{ja}-\sigma_{jil})}{\sigma(M^0)2\pi}\oint\limits_{Cl}G_{Sp,j}\frac{\partial\varphi_l}{\partial n}dc=\varphi_l(M^0)\quad by\,M^0\notin S_C
\end{aligned}\tag{1}$$

$G_{Spj}(M,M^0)$ - the source function of seismic field for the involved problem, $k_{1jil}^2=\omega^2(\sigma_{jil}/\lambda_{jil});$ - index *ji* signs the membership to the features of the medium into the heterogeneity, *ja* - out of the heterogeneity, λ - is a constant of Lameux, σ -the density of the medium, ω- the cycle frequency, $\vec{u}_i=grad\varphi_i;$ *i*=1,…*j*, *ji*,…*n*, index l =1,…*L*-number of the hierarchic level. If on some hierarchic levels, the structure of the local heterogeneity is divided. On any heterogeneity, the integrals in the formula (1) are taken into account on all heterogeneities. In our algorithm, we consider the case, when the physical features of heterogeneities are the same, and only the boundaries differ.

The iteration process covers the modeling of the response of transition from the previous hierarchic level on the next level. Inside each hierarchic level, the integral-differential equation and the integral-differential representation are calculated as it is written in the papers (Hachay, 1994; Hachay and Khachay, 2008).

Similarly to that case, we can write the same process for modeling of elastic transversal wave distribution in the n-th layer medium with 2-D hierarchic structure of an arbitrary morphology.

$$
\begin{aligned}
&\frac{(k_{2jil}^2 - k_{2j}^2)}{2\pi}\iint_{S_{Cl}} u_{xl}(M)G_{Ss,j}(M,M^0)d\tau_M + \frac{\mu_{ja}}{\mu_{jil}}u_{x(l-1)}^0(M^0) + \\
&+\frac{(\mu_{ja}-\mu_{jil})}{\mu_{jil}2\pi}\oint_{Cl} u_{xl}(M)\frac{\partial G_{Ss,j}}{\partial n}dc = u_{xl}(M^0) \quad by\, M^0 \in S_{Cl} \\
&\frac{\mu_{jil}(k_{2jil}^2 - k_{2j}^2)}{\mu(M^0)2\pi}\iint_{S_{Cl}} u_{xl}M)G_{Ss,j}(M,M^0)d\tau_M + u_{x(l-1)}^0(M^0) + \\
&+\frac{(\mu_{ja}-\mu_{jil})}{\mu(M^0)2\pi}\oint_{Cl} u_{xl}(M)\frac{\partial G_{Ss,j}}{\partial n}dc = u_{xl}(M^0) \quad by\, M^0 \notin S_{Cl}
\end{aligned}
\qquad (2)
$$

$G_{Ss,j}(M,M^0)$ - the source function of seismic field for the involved problem, $k_{2jil}^2 = \omega^2(\sigma_{jil}/\mu_{jil})$; μ - is a constant of Lame.

That algorithm for modeling of two types of seismic waves distribution, in the matrix massif of the oil deposit and in the interblock space of the oil deposit, can be used as an approximate for interpreting the data of borehole seism-acoustic monitoring, and it can formulate the requirements to the system of monitoring data for organizing a control influence on the oil layer. Very often, we deal with a situation, when the porous oil saturated inclusion is inside an elastic inclusion, and as a whole, it is a hierarchic construction imbedded in a N-layered medium. We shall write now the system of 2-D seismic modeling in an acoustic approximation.

9.3 Modeling of a Seismic Field in an Acoustic Approximation for Hierarchic Two Phase Heterogeneous Media

This part of the chapter is devoted to develop new integral equations for 2-D seismic field in a dynamical variant and to joint analysis of integral equations for a 2-D seismic field in the frame of the model of a local hierarchical inclusion with a porous oil saturated inclusion and a pure elastic local hierarchic inclusion for the case when the parameter Lame μ=0, in the inclusion and in the host medium. In that case, the dynamical seismic problem can be considered independently for the case of a longitudinal wave and for the case of a latitudinal wave distribution. The received results can be used for the choice of criterions of joining seismic methods for researching high complicated two phase media.

9.3.1 The Problem of a Sound Diffraction on a 2-D Porous Oil Saturated Heterogeneity Located in the J-th Layer of N-layered Medium

This problem shall be solved, using the approach which is cited in the papers (Kupradze, 1950; Hachay and Khachay, 2011; Hachay and Khachay, 2013). The mass forces Φ is assumed as a potential located in the first layer of the n-layered medium. The plane *XOY* coincides with the upper plane of the first layer, z=0. The axis *OZ* is directed vertically down. The surface of the 2-D heterogeneity of arbitrary section S_0 is directed along the axis *OY*. By setting μ=0 in each layer S_i, the first equation from the equations system for the direct seismic dynamical problem (Kupradze, 1950), is transformed to such a form:

$$\begin{gathered} \Delta\varphi_i + k_{1i}^2\varphi_i = -2\pi f_i(M); \\ \vec{u} = grad\varphi; \; f_i(M) = \frac{\sigma_i}{2\pi\lambda_i}\Phi_i; \end{gathered} \tag{3}$$

where $i=1,\ldots n$, $\Phi_i=\Phi$ by i=1, by $i\neq1$ Φ_i=0. According to (Kupradze, 1950; Hachay and Khachay, 2011; Hachay and Khachay, 2013), the wave number in the i-th layer is equal to:

$$k_{1i}^2 = k_1^2 = \omega^2\frac{\sigma_i}{\lambda_i}; \tag{4}$$

where ω-cycle frequency, σ_i, λ_i - density and coefficient of Lame of the *i*-th layer of the *N*-layered medium. Let consider the porous fluid saturated inclusion (water or oil) is located in the *J*-th layer of the *N*-layered elastic medium. According to Frenkel (1944), if the liquid phase will stay in equilibrium, it must be equally stressed in all points of the porous space by a hydrostatic pressure p_2. That pressure must also have an effect on the embedding medium, and its deformation must lead to a changing of the phase volume V_1 and pores V_2 in the same ratio:

$$\frac{\Delta V_1}{V_1} = \frac{\Delta V_2}{V_2} = -\frac{1}{K_0} p_2 \tag{5}$$

K_0-true module of compressibility of the phase. In the same ratio, the whole macroscopic volume of the medium varies too. For not moving the liquid in the porous inclusion, according to Frenkel (1944), the system (1) can be written after simple transformations as such:

$$\begin{aligned} &\Delta\varphi_i + k_{1i}^2 \varphi_i = -2\pi(f_i(M) + \psi); \\ &\vec{u} = grad\varphi;\ f_i(M) = \frac{\sigma_i}{2\pi\lambda_i}\Phi_i;\psi = (1-\chi-\frac{K}{K_0})p_2; \end{aligned} \tag{6}$$

$$\psi = \begin{cases} \psi(M)\ by\, M \in S_0 \\ 0\ by\, M \notin S_0 \end{cases} \tag{7}$$

$K = \lambda$ -module of overall compression by μ=0, χ - porosity. Let us introduce such marking: $\tilde{k}(M) = k_{1i}$ - wave number in the layered medium S_i, *i=1,…,n* and

$$K(M) = \begin{cases} k_{1ji}\ \ by\ M \in S_0 \\ \tilde{k}(M)\ by\ M \notin S_0 \end{cases} \qquad k_{1ji}^2 = \omega^2 \frac{\sigma_{ji}}{\lambda_{ji}}; \tag{8}$$

The index *ji* indicates the features of the medium inside the heterogeneity S_0.

In the common case, in the arbitrary layer S_i or inside the heterogeneity S_0, the equation (6) taking into account the relations (4), (7), and (8), will be of the form:

$$\Delta\varphi_i + k_{1i}^2 \varphi_i = -2\pi(f_i(M) + \psi); \tag{9}$$

The boundary conditions in the media without discontinuities, which are the vertical component of the vector of displacement or components of the stress tensor, are continuous, according to Kupradze (1950). And on the boundaries L_i, they have the form:

$$\begin{aligned}
&\frac{\partial\varphi_i}{\partial z} - \frac{\partial\varphi_{i+1}}{\partial z} = 0\Big|_{z\in L_i}; \left(\frac{\partial\varphi}{\partial n}\right)_{ji} = \left(\frac{\partial\varphi}{\partial n}\right)_{ja};\\
&\left[\sigma_i(\omega^2\varphi_i + \Phi_i)\right] - \left[\sigma_{i+1}(\omega^2\varphi_{i+1} + \Phi_{i+1})\right] = 0\Big|_{z\in L_i};\\
&\left[\sigma(\omega^2\varphi + \Phi + \alpha p_2)\right]_{ji} = \left[\sigma(\omega^2\varphi + \Phi)\right]_{ja};\\
&\left[\sigma(\omega^2\varphi + \Phi)\right]\Big|_{z=0} = 0;
\end{aligned} \tag{10}$$

The index ji - identifies the values σ, φ, Φ on the boundary of heterogeneity from the inner side, ja - from the outer side of the heterogeneity, which is located in the j-th layer, L-boundary of the layer, with index i - from the side of the i-th layer, and with index i+1 - from the side of (i+1)-th layer, $\alpha = 1 - \chi - \frac{K}{K_0}$, according to (6).

According to Kupradze (1950), the conditions of damping on infinity, have the form:

$$r\, grad\, \varphi_i = O(1),\ r\left(\frac{\partial\varphi_i}{\partial r} - \mathrm{i}k_1\varphi_i\right) = o(1) \tag{11}$$

$$\text{Let: } \tilde{\varphi}_i = \varphi_i - \varphi_i^0, \tag{12}$$

where i=1,…j,ji,…,n, φ_i^0 - the potential of the normal seismic field in the layered medium by absent heterogeneity: $\varphi_{ji}^0 = \varphi_i^0$ and

$$\Delta\varphi_i^0 + k_{1i}^2\varphi_i^0 = -2\pi f_i(M); \tag{13}$$

$$\begin{aligned} &\frac{\partial\varphi_i^0}{\partial z} - \frac{\partial\varphi_{i+1}^0}{\partial z} = 0\Big|_{z\in L_i};\\ &\left[\sigma_i(\omega^2\varphi_i^0 + \Phi_i)\right] - \left[\sigma_{i+1}(\omega^2\varphi_{i+1}^0 + \Phi_{i+1})\right] = 0\Big|_{z\in L_i}; \end{aligned} \tag{14}$$

The functions φ^0 and $\frac{\partial\varphi^0}{\partial n}$ on the contour of the heterogeneity are continuous. The algorithm of a normal field calculation by sound diffraction, in the layered medium by an arbitrary excitation source in a dynamical variant, is written in the papers (Khachay, 2006 a, b), $\tilde{\varphi}_i$ - the potential of the seismic field anomaly, which, as it can be shown by taking into account (4,6,9,12), satisfies the equation:

$$\Delta\tilde{\varphi}_i + K^2(M)\tilde{\varphi}_i = -(K^2(M) - \tilde{k}^2(M))(\varphi_i^0 + \alpha p_2); \tag{15}$$

and the boundary conditions:

$$\begin{aligned} &\frac{\partial\tilde{\varphi}_i}{\partial z} - \frac{\partial\tilde{\varphi}_{i+1}}{\partial z} = 0\Big|_{z\in L_i};\ \left(\frac{\partial\tilde{\varphi}}{\partial n}\right)_{ji} = \left(\frac{\partial\tilde{\varphi}}{\partial n}\right)_{ja};\\ &\left[\sigma_i\omega^2\tilde{\varphi}_i\right] - \left[\sigma_{i+1}\omega^2\tilde{\varphi}_{i+1}\right] = 0\Big|_{z\in L_i}; \end{aligned} \tag{16}$$

On the contour of the heterogeneity, the following relation is established:

$$[\sigma\tilde{\varphi}]_{ja} - [\sigma\tilde{\varphi}]_{ji} = (\sigma_{ja} - \sigma_{ji})(\varphi_j^0 + \alpha p_2) \tag{17}$$

The source function of a seismic field $G_{Sp}(M,M^0)$ is defined as a solution of such a boundary problem (Hachay and Khachay, 2011; Hachay and Khachay, 2013):

$$\Delta G_{Spi} + \tilde{k}^2 G_{Spi}(M,M^0) = -2\pi\delta(M - M^0); \quad (18)$$

And the boundary conditions satisfy:

$$\begin{gathered} \frac{\partial G_{Sp,i}}{\partial z} - \frac{\partial G_{Sp,i+1}}{\partial z} = 0\Big|_{z\in L_i}; \left[\sigma\omega^2 G_{Sp}\right]\Big|_{z=0} = 0; \\ \left[\sigma_i\omega^2 G_{Sp,i}\right] - \left[\sigma_{i+1}\omega^2 G_{Sp,i+1}\right] = 0\Big|_{z\in L_i}; \end{gathered} \quad (19)$$

Functions $G_{Sp}(M,M^0)$ and $\frac{\partial G_{Sp}(M,M^0)}{\partial n}$ are continuous on the contour of the heterogeneity. Let us use the Green formula (Kupradze, 1950) for the functions $\tilde{\varphi}_i$ and $G_{Sp}(M,M^0)$ for each layer of n-layered medium by $i \neq j$:

$$\begin{gathered} \int_{L_i} (\tilde{\varphi}_i \frac{\partial G_{Sp,i}}{\partial n} - G_{Sp,i} \frac{\partial \tilde{\varphi}_i}{\partial n}) dl_i - \int_{L_{i+1}} (\tilde{\varphi}_{i+1} \frac{\partial G_{Sp,i+1}}{\partial n} - \\ - G_{Sp,i+1} \frac{\partial \tilde{\varphi}_{i+1}}{\partial n}) dl_{i+1} = \begin{cases} 2\pi\tilde{\varphi}_i(M^0)\, by\, M^0 \in S_i \\ 0\, by\, M^0 \notin S_i \end{cases} \end{gathered} \quad (20)$$

By $i=j$:

$$\int_{Lj_i} (\tilde{\varphi}_j \frac{\partial G_{Sp,j}}{\partial n} - G_{Sp,j} \frac{\partial \tilde{\varphi}_j}{\partial n}) dl_j -$$
$$- \int_{L_{j+1}} (\tilde{\varphi}_{j+1} \frac{\partial G_{Sp,j+1}}{\partial n} - G_{Sp,j+1} \frac{\partial \tilde{\varphi}_{j+1}}{\partial n}) dl_{j+1} + \tag{21}$$
$$+ \oint_{C_{ja}} (\tilde{\varphi}_{ja} \frac{\partial G_{Sp,j}}{\partial n} - G_{Sp,j} \frac{\partial \tilde{\varphi}_{ja}}{\partial n}) dc_{ja} = \begin{cases} 2\pi\tilde{\varphi}_j(M^0) \; by \, M^0 \in S_j - S_0 \\ 0 \, by \, M^0 \notin S_j - S_0 \end{cases}$$

C_{ja} -is the outer side of the contour of the heterogeneity C. Let us multiply by σ_i the expressions (20) and (21) and sum them with account of the boundary conditions. As a result, we shall obtain:

$$\frac{\sigma_j}{2\pi} \oint_C (\tilde{\varphi}_{ja} \frac{\partial G_{Sp,j}}{\partial n} - G_{Sp,j} \frac{\partial \tilde{\varphi}_{ja}}{\partial n}) dc =$$
$$= \begin{cases} \sigma(M^0)\tilde{\varphi}(M^0) \;\; by \, M^0 \in S_j - S_0 \\ 0 \qquad\qquad by \, M^0 \notin S_j - S_0 \end{cases} \tag{22}$$

Let us apply the Green formula to the functions $\tilde{\varphi}_{ji}$ and $G_{Sp,j}(M, M^0)$ for the inner side of the domain S_0, with account of (6), (7), (13), (14), (15-17) (18), (19), then we shall obtain:

$$\frac{k_{1ji}^2 - k_{1j}^2}{2\pi} \iint_{S_0} \varphi(M) G_{Sp,j}(M, M^0) d\tau_M -$$
$$- \frac{1}{2\pi} \oint_C (\tilde{\varphi}_{ji} \frac{\partial G_{Sp,j}}{\partial n} - G_{Sp,j} \frac{\partial \tilde{\varphi}_{ji}}{\partial n}) dc = \tag{23}$$
$$= \begin{cases} (\tilde{\varphi}(M^0) + \alpha p_2) \; by \, M^0 \in S_0 \\ 0 \; by \, M^0 \notin S_0 \end{cases}$$

Let us multiply the expression (21) by σ_{ji} and sum it with the expression (22), taking into account the boundary conditions on the contour of the heterogeneity. We obtain:

$$\begin{aligned}
&\frac{\sigma_{ji}(k_{1ji}^2-k_{1j}^2)}{2\pi}\iint\limits_{S_0}\varphi(M)G_{Sp,j}(M,M^0)d\tau_M+\\
&+\frac{(\sigma_{ja}-\sigma_{ji})}{2\pi}\oint\limits_C\varphi^0(M)\frac{\partial G_{Sp,j}}{\partial n}dc-\\
&-\frac{(\sigma_{ja}-\sigma_{ji})}{2\pi}\oint\limits_C G_{Sp,j}\frac{\partial\varphi}{\partial n}dc-\frac{(\sigma_{ja}-\sigma_{ji})}{2\pi}\oint\limits_C G_{Sp,j}\frac{\partial\varphi^0}{\partial n}dc=\\
&=\sigma(M^0)(\tilde{\varphi}(M^0)+\alpha p_2);
\end{aligned} \tag{24}$$

Let us use the equality (Kupradze, 1950):

$$\begin{aligned}
&\frac{(\sigma_{ja}-\sigma_{ji})}{2\pi}\oint\limits_C(\varphi^0(M)\frac{\partial G_{Sp,j}}{\partial n}-G_{Sp,j}\frac{\partial\varphi^0(M)}{\partial n})dc=\\
&=\begin{cases}(\sigma_{ja}-\sigma_{ji})\varphi^0(M^0)\,by\ \ M^0\in S_0\\ \qquad 0\,by\ \ M^0\notin S_0\end{cases}
\end{aligned} \tag{25}$$

Then, the expression (22) with account of (23) can be rewritten in such form:

$$\begin{aligned}
&\frac{(k_{1ji}^2-k_{1j}^2)}{2\pi}\iint\limits_{S_0}\varphi(M)G_{Sp,j}(M,M^0)d\tau_M+\frac{\sigma_{ja}}{\sigma_{ji}}\varphi^0(M^0)-\\
&-\frac{(\sigma_{ja}-\sigma_{ji})}{\sigma_{ji}2\pi}\oint\limits_C G_{Sp,j}\frac{\partial\varphi}{\partial n}dc=(\varphi(M^0)+\alpha p_2)\ \ by\,M^0\in S_0\\
&\frac{\sigma_{ji}(k_{1ji}^2-k_{1j}^2)}{\sigma(M^0)2\pi}\iint\limits_{S_C}\varphi(M)G_{Sp,j}(M,M^0)d\tau_M+\varphi^0(M^0)-\\
&-\frac{(\sigma_{ja}-\sigma_{ji})}{\sigma(M^0)2\pi}\oint\limits_C G_{Sp,j}\frac{\partial\varphi}{\partial n}dc=\varphi(M^0)\ \ by\,M^0\notin S_0
\end{aligned} \tag{26}$$

Thus, that allows obtaining the solution of the integral-differential equation and defining the distribution of the potential for the displacement vector inside the heterogeneity. Using the second integral-differential representation, we can define the potential of the displacement vector in an arbitrary layer. Then, using the expression (1), we calculate the distribution of the displacement vector in the arbitrary layer.

9.3.2 Comparison of Algorithms of a 2-D Modeling of the Seismic Field for the Cases of an Elastic and a Porous Liquid Saturated Inclusion in a N-layered Medium

Let us compare the obtained expressions for the solution of diffraction of the seismic field in a frame of a geometrical model but with different physical features of the inclusion. In our previous research (Hachay and Khachay, 2011), we expressed the system of integral-differential equations for the case of elastic inclusion in N-layered medium by:

$$\begin{aligned}
&\frac{(k_{1ji}^2 - k_{1j}^2)}{2\pi} \iint_{S_0} \varphi(M) G_{Sp,j}(M, M^0) d\tau_M + \frac{\sigma_{ja}}{\sigma_{ji}} \varphi^0(M^0) - \\
&-\frac{(\sigma_{ja} - \sigma_{ji})}{\sigma_{ji} 2\pi} \oint_C G_{Sp,j} \frac{\partial \varphi}{\partial n} dc = \varphi(M^0) \quad by\, M^0 \in S_0 \\
&\frac{\sigma_{ji}(k_{1ji}^2 - k_{1j}^2)}{\sigma(M^0) 2\pi} \iint_{S_C} \varphi(M) G_{Sp,j}(M, M^0) d\tau_M + \varphi^0(M^0) - \\
&-\frac{(\sigma_{ja} - \sigma_{ji})}{\sigma(M^0) 2\pi} \oint_C G_{Sp,j} \frac{\partial \varphi}{\partial n} dc = \varphi(M^0) \quad by\, M^0 \notin S_0
\end{aligned} \tag{27}$$

The names of variables in (27) are the same, as in (26). By comparing (27) and (26), we notice that it is a difference in the structure of the free term in the integral-differential equation for the inner problem. Thus, it is evident that this will reflect on the difference of the solution for these two models. However, the existence of the porous inclusion does not change the wave number for the considered problem of the longitudinal wave distribution for two different medium models. That makes evident the no informative kinematic characteristics of the longitudinal waves for the identification of a porous liquid saturated inclusion.

9.3.3 Modeling of a Sound Diffraction on a 2-D Elastic Heterogeneity of a Hierarchic Type with an Inside Porous Inclusion, Located in a N-layered Medium

Let us consider a sound diffraction on a 2-D elastic heterogeneity with a hierarchic structure, located in the *j*-th layer of a *n*-layered medium (Hachay and Khachay, 2013). If by passing from one to another hierarchic level, the 2-D axis does not vary and only the geometries of the sections of the nested structures vary, we can develop an iteration process for the modeling of the seismic field (the case of the distribution of longitudinal wave only).

The idea, which was developped in the paper (Hachay and Khachay, 2013) for the solution of the direct problem for the 2D case of the distribution of the longitudinal wave through a local elastic heterogeneity with a hierarchic structure located in the *J*-th layer of the N-layered medium, is extended to the case, when a porous liquid saturated inclusion will exist on the *L*-th hierarchic level.

$$\begin{aligned}
&\frac{(k_{1jil}^2 - k_{1j}^2)}{2\pi}\iint_{S_{Cl}}\varphi_l(M)G_{Sp,j}(M,M^0)d\tau_M + \frac{\sigma_{ja}}{\sigma_{jil}}\varphi_{l-1}^0(M^0) - \\
&-\frac{(\sigma_{ja}-\sigma_{jil})}{\sigma_{jil}2\pi}\oint_{Cl}G_{Sp,j}\frac{\partial\varphi_l}{\partial n}dc = \varphi_l(M^0), M^0 \in S_{Cl} \\
&\frac{\sigma_{jil}(k_{1jil}^2 - k_{1j}^2)}{\sigma(M^0)2\pi}\iint_{S_{Cl}}\varphi_l(M)G_{Sp,j}(M,M^0)d\tau_M + \varphi_{l-1}^0(M^0) - \\
&-\frac{(\sigma_{ja}-\sigma_{jil})}{\sigma(M^0)2\pi}\oint_{Cl}G_{Sp,j}\frac{\partial\varphi_l}{\partial n}dc = \varphi_l(M^0), M^0 \notin S_{Cl}
\end{aligned} \tag{28}$$

where $G_{Sp,i}(M,M^0)$ - the source function of seismic field, which coincides with the function of the expression (18-19), $k_{1jil}^2 = \omega^2 (\sigma_{jil} / \lambda_{jil})$ - the wavenumber for the longitudinal wave, in the provided expression the index *ji* indicates that the features of the medium belong to the inside space of the heterogeneity, *ja* - out of the heterogeneity, *l*=1…*L-1* - the number of the hierarchic level, $\vec{u}_l = grad\varphi_l$, φ_l^0 - the potential of the normal seismic field in the layered medium in the absence of a heterogeneity of the previous rank, if *l*=2…*L* $\varphi_l^0 = \varphi_{l-1}$, if *l*=1, $\varphi_l^0 = \varphi^0$, these functions coincide with a corresponding expression suggested by Hachay and Khachay (2013). If by passing on the next hierarchic level of 2-D, they do not vary and only the geometry sections of embedded structures vary. Then analogously to (Hachay and Khachay, 2013), we can develop an iteration process for modeling the seismic field (case forming of longitudinal wave). The iteration process pertains to modeling the displacement vector by passing from previous hierarchic level to the next level. Inside each hierarchic level, the integral-differential equation and the integral-differential representation are written for the potential, which is used for defining the displacement vector (28). If *l*=*L*, inside the heterogeneities from the previous hierarchic level, the porous liquid saturated inclusion occurs. In that case, the system (28) with account of (26) can be written in such a form:

$$
\begin{aligned}
&\frac{(k_{1jil}^2 - k_{1j}^2)}{2\pi} \iint_{S_{0l}} \varphi_l(M) G_{Sp,j}(M, M^0) d\tau_M + \frac{\sigma_{ja}}{\sigma_{jil}} \varphi_{l-1}^0(M^0) - \\
&- \frac{(\sigma_{ja} - \sigma_{jil})}{\sigma_{jil} 2\pi} \oint_{Cl} G_{Sp,j} \frac{\partial \varphi_l}{\partial n} dc = (\varphi_l(M^0) + \alpha p_2), M^0 \in S_{0l} \\
&\frac{\sigma_{jil}(k_{1jil}^2 - k_{1j}^2)}{\sigma(M^0) 2\pi} \iint_{S_{0l}} \varphi_l(M) G_{Sp,j}(M, M^0) d\tau_M + \varphi_{l-1}^0(M^0) - \\
&- \frac{(\sigma_{ja} - \sigma_{jil})}{\sigma(M^0) 2\pi} \oint_{Cl} G_{Sp,j} \frac{\partial \varphi_l}{\partial n} dc = \varphi_l(M^0), M^0 \notin S_{0l} \quad by\ l = L
\end{aligned}
\qquad (29)
$$

If l=L+1 and on the next level the heterogeneity is again elastic, for the following of the iteration process we can use again the system (28). Very often, we deal with a situation of solid oil deposits, where they are outworked in mines by mining technologies. Here, we are going to show the use of an electromagnetic method to control the morphology of the zones of the disintegration in the holes. By providing mining works in a high stressed rock massif, the man-made seismicity becomes evident, therefore the problem of its forecasting and prevention attracts much attention in all the countries with a developed mining industry. The near-term forecasting plays a significant role, but till now the developing of a method which allows to define quantitative criterions for the warning system is a large problem as in mining and in seismology (Yegorov and Redkin, 2001). Using the idea of physical mesomechanics, which includes the synergetic approach for analyzing the state changing of a rock massif of a different matter content, that problem can be solved by monitoring methods, which can research a medium with a hierarchical structure (Panin et al., 1995; Hachay, 2007). The medium changing, which leads to near-term precursors of dynamical events, can be explained in a frame of a conception of a self-organized criticality (Klimontovitch, 2002; Olemskoy and Kaznelson, 2003), for which the main factors are the heterogeneity and nonlinearity. In the frame of the Siberian Mining Institute, a new direction of massif state research is developed and named as nonlinear geomechanics (Kurlenja and Oparin, 1999). But in our opinion, we can achieve more success using together geomechanical and geophysical methods, which are based on a medium model as a model of a stratified block structure with hierarchical inclusions. Moreover, if we are also interested in the evolution of that structure, we need to use complex geophysical methods, which have a sufficient resolution of revealing of the origin and the decay of the self-organized structures (Hachay, 2007). For the first time by using the planshet electromagnetic method, which was elaborated in the Institute of geophysics of

Ural Branch of Russian Academy of Sciences we could in the frame of natural investigations realize the idea of revealing of the disintegration zones in the rock massif and organize the monitoring of their morphology (Hachay et al., 2003a; Hachay, 2003b). That method covers to geophysical methods of non destroying control. It differs from other tomography methods by a system of observation and methods of processing and interpretation, which are based on the conception of three staged interpretation (Hachay et al., 2001).

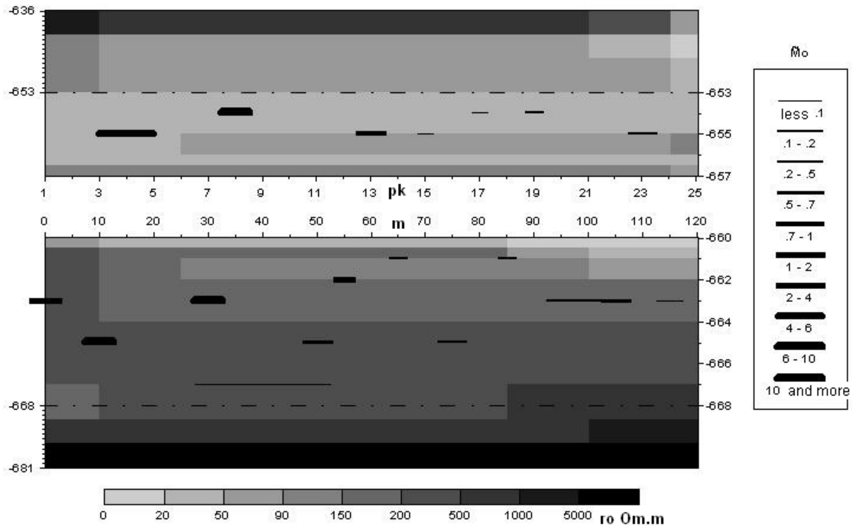
9.4 A New Method of Revealing of the Disintegration Zones in the Near Hole Space of Rock Massif of Different Matter Content

For the first time the phenomenon disintegration zones around the underground holes was described in the paper (Shemjakin et al., 1986), which was later on registered as a discovery (Shemjakin et al., 1992). The research of the morphology and the migration dynamics of these zones has a great significance by outworking deep located deposits, in which dynamical events occur. Significant devices for its research are geophysical methods. In addition to the the information about the structure and medium state, obtained from the geophysical data by their interpretation in the frame of the model, which is an approximation to the real medium, it is needed to be choosen from the class of physically and geologically proved. As it was shown in the paper (Sadovskiy et al., 1987), for geological medium describing as a rock massif with its natural and man-caused heterogeneity, the discrete model as piece-block medium with included heterogeneities of less rank, than the block is meaningful. As it had been shown in the paper (Sadovskiy et al., 1987) a simple sum of measured geophysical parameters can lead to violent conceptions of the medium structure and its evolution. A set of papers from the Institute of Physics of the Earth RAS had been devoted to research the development of a hierarchical block medium model on the quality level (Sadovsky et al., 1987; Rodionov et al., 1989). Significant roles have the papers of academician V.N. Strachov, which are devoted to developing a new interpretation theory for gravitation and magnetic fields for a discrete structure of the medium; the main conception is published (Strachov, 1993, 1994). It must be marked, that for research of the structure details of discrete hierarchic media, a larger resolution has geophysical fields, which depend as on space coordinates, as on time or frequency-that are-seismic and electromagnetic fields. Moreover, the use of controlled sources achieve the field focusing. Our planshet method for an electromagnetic induction research in a frequency-geometrical variant is now widely used also for an underground (mine) variant. It allows to provide volume geophysical research in massifs, by man-caused influence (Shemjakin et al., 1992; Hachay and Novgorodova, 1999). Let us consider these experiments in details. As an excitation source we used the field of a vertical magnetic dipole on frequencies: from 5 to 80 kHz. We provided measurements of the modules of three alternating magnetic field components (vertical $|Hz|$ and two horizontal: along the hole $|Hr|$ and across the hole $|H\varphi|$) in the frame of planshet system of observation (in wide profile array variant) with the step 5m and length 60-80m (in dependence from the geoelectrical features of the researched massif. The excitation source is located at the beginning of the array and it is moving systematically with the array through 15 m along the hole. For each array and fixed frequency ω two interpretation parameters are defined by such formulas: $\rho_{eff.}(r)=\omega r^2(|Hz|/|Hr|)/\pi$ and $\delta(r) =(|H\varphi|/|Hr|)100\%$. These data present an information base for data for further interpretation, which is realized during three stages (Hachay and Novgorodova, 1997). On the first stage geoelectrical parameters of the one-D section are defined for each array after a previous filtration of data $\rho_{eff.}(r)$ with account the condition : $\delta(r)<A$, where A - is a level of filtration (Hachay and Novgorodova, 1997) of $\rho_{eff.}(r)$ values . The interpretation of the first stage is provided in a frame of layered model: n layers over the hole and n layers under it. Then we shall calculate the average parameters of the section with account of overlapping for the whole profile or for some planshet. As a result we obtain the distribution of a specific resistivity in the per hole space up and down from the hole for each point of observation.

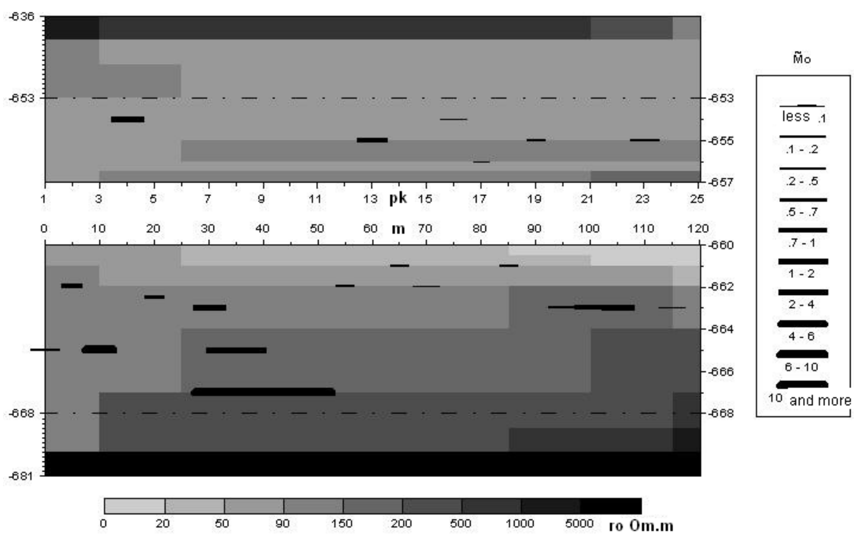
Then, the second stage is fulfilled in the frame of the algorithm, which allows to determine the geometrical characteristics of the conductive intrusions and their sum equivalent moments which are proportional to the ratio of the difference between the conductivity in an imbedded medium and in the intrusion to the conductivity of the imbedded medium. Here according to (Strachov, 1993, 1994), the approximate principle for alternating electromagnetic fields is used. The initial model of the inclusion is used as current lines of finite length. The average parameter of geoelectrical heterogeneities, which is defined as average value of δ in each point of the profile, located along the hole by this type of sources is approximated. We are solving the minimization problem of the standard deviation (residual) of the experimental curve of an average parameter of geoelectric heterogeneity from the theoretical (Hachay and Novgorodova, 1997). The location of the sources of excitation remains the same as it was by the realization of the first stage. The current lines are located directly either under the profile down from the hole, or above up the profile. Thus, we can define the described above parameters of these current lines, the fitting is provided in a semi-automatic regime: the changing of sought parameters during the fitting process is assigned interactive. The procedure finishes, when the residual becomes less of the given value. The absolute value of the residual is controlled by the given fitting accuracy of the experimental value of the average parameter of geoelectric heterogeneity in extreme points. Mathematically speaking, that procedure is realized by a computational algorithm and a program. Thus, using the results of the first and second stage of interpretation we can construct the 3-D geoelectric model of a researched place of a geological medium.

That developed approach for alternating electromagnetic fields was extended on the case of a dynamical seismic with an active source of excitation in a frame of joined three staged conception of an electromagnetic and a seismic interpretation (Hachay et al., 1999a). That method also allows researching the heterogenic medium in the frame of discrete-hierarchic model, distinctive from the widely used seismic methods, based on a kinematic approach. A new complex volume research electromagnetic induction and seismic (in dynamical variant) method allows to construct a volume geoelectrical and elastic model of rock massif structure. In different mines of deposits of different matter content with use of such method it had been revealed disintegration zones of rock massifs. It had been developed criterions, which allow to provide the sorting of these zones of zones of hidden cracks and contact (different module) zones, which had been confirmed by geologic and geomechanical data (Hachay et al., 1999b; Hachay and Novgorodova, 2000). The high accuracy of that approach is ensured by the use of the volume system of observation in a frame of holes located on different levels. The distribution of zones of local heterogeneities and its morphology into the mine space is the significant information for safe outworking of the deposit. Let us consider results of 4 cycles of the electromagnetic monitoring of the Tashtagol's mine massif, which was provided during 2000-2003 years in some holes, located on four horizons. Here we shall consider results of monitoring of ort 4, horizon -210, because in that hole additional repeated measurements during every year cycle of measurements had been provided. So, it is possible to analyze the structure of the massif during different time intervals. In the sections (fig. 1 a-c), obtained in the year 2002, we can see, that even during a small time interval

(1 week) the migration of the zones of the local heterogeneities and its intensity has more significant results.



a



b

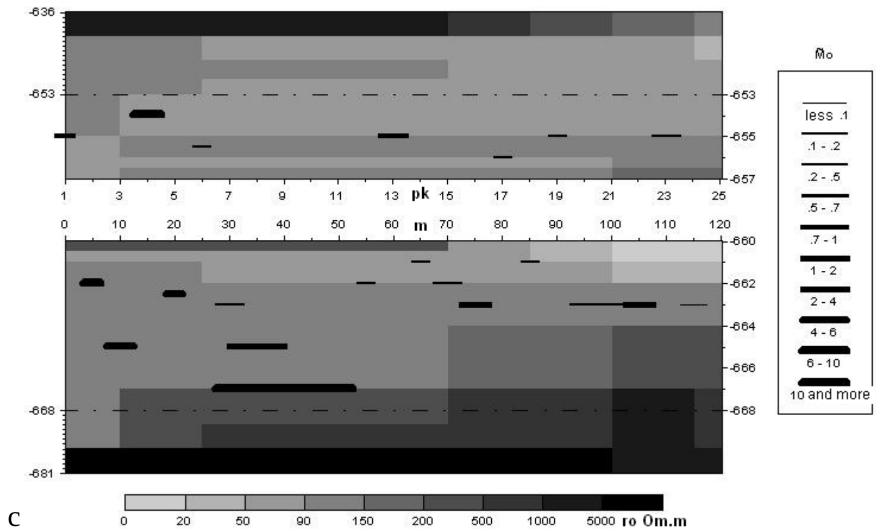


Figure 1. *Geoelectric sections of the massif from the 4-th ort, horizon -210, Tashtagol mine, 2002, frequency 5 kHz, three cycles of measurements.*

Reference designations: $\tilde{M}_0=M_0\times L_0\times 10^3$, M_0- coefficient which is multiplied with the moment of the electrical current line, it is equivalent by field to the influence of the zone of geoelectric heterogeneities, L_0 - length of the current line in m, the resistivity of the imbedding section is given in Om.m. The vertical axis is given in m (depth in absolute marks), the horizontal axis is the length of the hole in number of pickets (pk) and in meters (m).

Let us introduce a new integral parameter for the intensity of the disintegration zones, located in the massif down the hole:

$$S_p = \sum_i \tilde{M}_0{}^i (x, H) \tag{30}$$

where H- the researched depth of the massif, located down the hole, x-coordinate of the zone center along the hole, i- number of the zone.

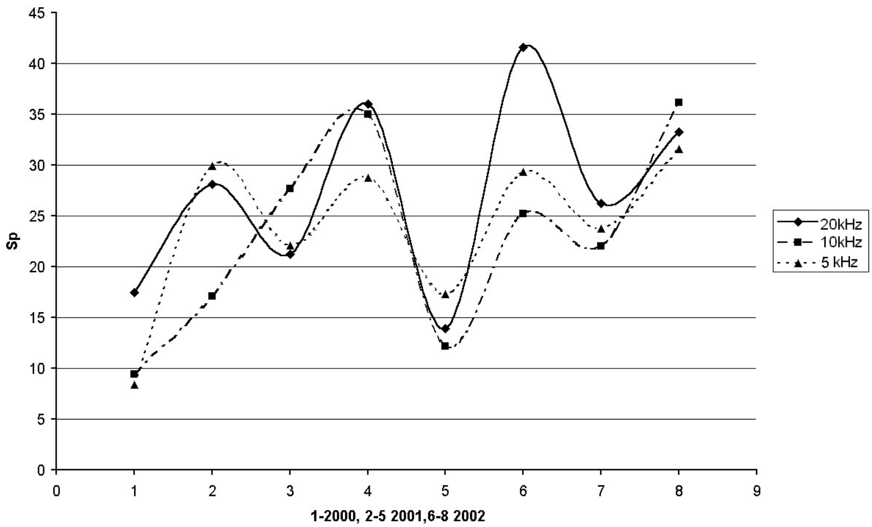


Figure 2. *Distribution of integral intensity Sp of revealed crack zones down the hole, using active electromagnetic monitoring data during 4 years, horizon -210.*

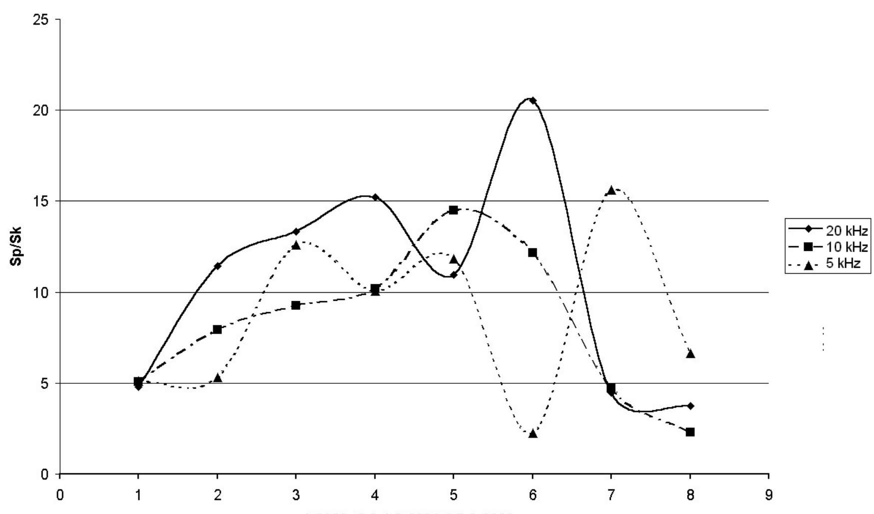


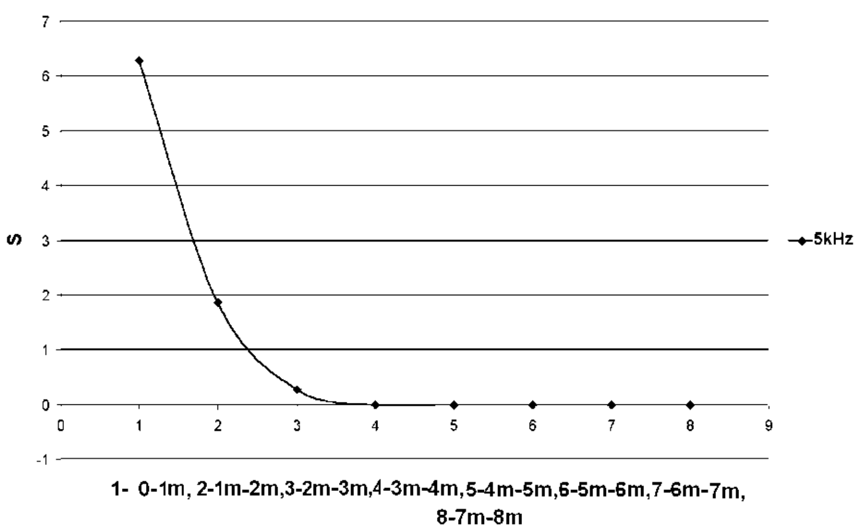
Figure 3. *Distribution of the ratio of integral intensity Sp of revealed crack zones down the hole and Sk above the hole, using active electromagnetic monitoring data during 3 years, ort 4, horizon -210.*

A good correlation of obtained results (fig.2) indicated about the change in the massif structure, located down the hole, which do not lead to its non stability. Let us introduce a function analogously (30) for a roof space of the hole:

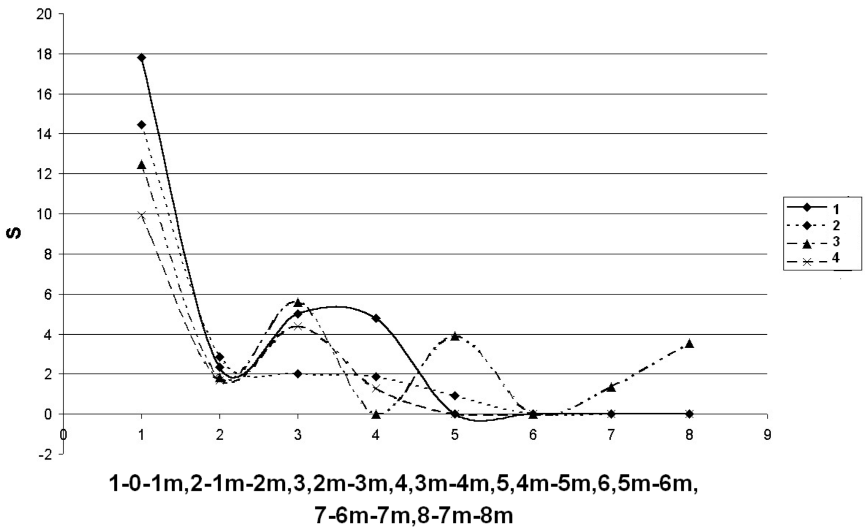
$$S_k = \sum_n \tilde{M}_0{}^n (x, H)$$

As it is seen particularly from the fig.3 there is a significant difference of the massif of the structure up and down the hole space. On the fig.3 the changes of the ratio *Sp/Sk* during 4 years of the provided research are analyzed. Three measurement cycles of observation during 2002 year show a sharp difference if the ratio behavior in dependence from frequency, that can indicate about the changing in the phase state of the massif, located into the roof hole space.

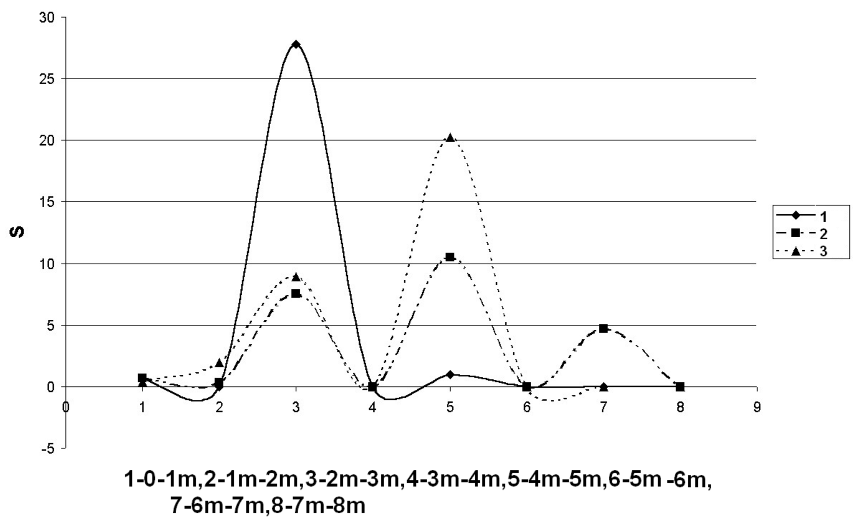
Let us analyze interpretation results data of electromagnetic monitoring for each cycle (years: 2000, 2001, 2002, and 2003) for the frequency 5 kHz. Let us divide the interval H (30) on subintervals through 1m down the contour of the hole and for each of it we can calculate the value *Spint*- the integral interval intensity of zones heterogeneity in massif, located down the hole.



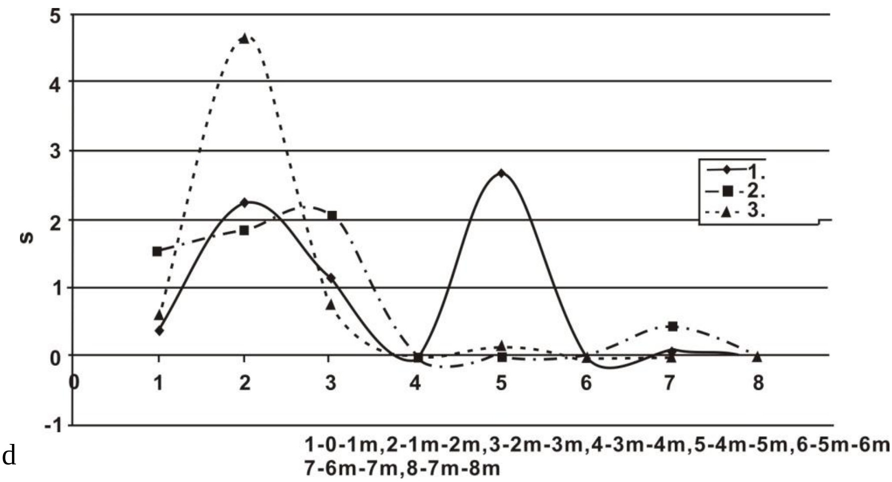
a


S
1
2
3
4
1-0-1m,2-1m-2m,3,2m-3m,4,3m-4m,5,4m-5m,6,5m-6m,
7-6m-7m,8-7m-8m

b


S
1
2
3
1-0-1m,2-1m-2m,3-2m-3m,4-3m-4m,5-4m-5m,6-5m -6m,
7-6m-7m,8-7m-8m

c



d

Figure 4. *The changing of the interval from the hole contour and integrated along the hole intensity of disintegration zones for the frequency 5 kHz. S=Spint.a - one cycle of observation in the 2000 year, b - four cycles of observation in the 2001 year, c - three cycles of observation in the 2002 year, d - three cycles of observation in the 2003 year.*

$$Spint(N,T) = \sum_{i=1}^{k_N} \tilde{M}_0^i(N,T)$$

where *N*-number of the interval, on which is divided the hole space located down the hole: *N*=1 (0-1m), *N*=2 (from1m to 2m), *N*=3 (from 2m to 3m), *N*=4 (from 3m to 4m), *N*=5 (from 4m to 5m), *N*=6 (from 5m to 6m), *N*=7 (from 6m to 7m), *N*=8 (from 7m to8m), *N*=9 (from 8m to 12m), *N*=10 (from 12m to 17m), *T*- cycles of measurements: *T*=1 (2000 year),*T*=2 (2001 year), *T*=3 (2002 year), *T*=4 (2003 year), k_N.-amount of heterogeneities extracted for the interval *N* for the whole length of the hole.

On the fig. 4a we can see the relation, which is obtained from data of 2000 year. The value *Spint* monotonously decreases down to a contour hole. On the fig.4b we can see the appearance intervals of a disintegration zones absence (2001year). That tendency is seen more obviously from analyze of data of 2002 year (fig.4c) and 2003 year (fig.4g).

Based on the previous results obtained for one point of the mine space it is interesting to analyze the identical results of four cycles of massif electromagnetic monitoring for all researched halls of the Tashtagol mine, located on four horizons on the depth from 540m to 750m for revealing the morphology of disintegration zones in the outer hole space, which is under intense man caused and a natural stress field action.

The system of many leveled electromagnetic induction frequency-geometrical researches, provided in the mine during the years 2000-2003 has such form:

Scheme 1. *The location of the profiles in the mine.*

Horizon (m)	Number of holes						
-140		3					
-210	2		4	8			
-280				8			
-350					18	19	20

Considering only the quantitative values of $Sp\,int(N,T)$ (in conventional units) for all orts according to scheme 1 for three frequencies 20, 10, 5 kHz: first group - up to 30, second group from 30 to 40, third group - from 40 to 100.

Table 1. *The classification of the rock massif state stability. First group-state stable, second group-state quasistable, third group-state nonstable.*

N	First group	Second group	Third group
1	Horizon -140, ort3	Horizon -210, ort2	Horizon -210, ort 8
2	Horizon -350, ort 20	Horizon -350, ort 18	Horizon -280, ort8
3	Horizon -210, ort4		Horizon -350, ort 19

The structure of the first massif group independently from the depth of orts location is characterized as stable and the distribution of the parameter $Sp\,int(N,T)$ is defined as stable ordered, especially it is typical for the 4-th ort, horizon -210, where had been provided repeated measurements during three years and in the year 2004 the measurements had been provided before and after mass explosions. From the other side the 4-th ort is located in the restricted crunch, and our results show its stable state. The distribution of the parameter $Sp\,int(N,T)$ for the massif of the second group is characterized by every year change its ordering in contour intervals down the hole, and by the way, there exist a frequency no agreement of its change, but the amplitude of the change is restricted. In our classification that massif state can be characterized as quasi stable.

For the massif of the third group the peculiarities of distribution of the parameter $Sp\,int(N,T)$, indicated for the massif of the second group only grow with its amplitude and the massif can be characterized as a potential no stable. In the years 2002, 2003 the most strong dynamical events had been located near 8-th orts, -210 and -280 horizons, ort 19 horizon -350 also characterizes as anomaly, where a rock shock occurred with the energetic class more than 6, in the place, indicated by the results of electromagnetic monitoring by higher average parameter geoelectric heterogeneity.

9.5 Conclusions

Thus, the received results of an electromagnetic induction monitoring allow to make such conclusions:

- Rock massif has a many ranked hierarchic structure, the research of the dynamical state and its structure can provide only with geophysical methods which are dialed on that medium model.
- The use of planshet many leveled induction electromagnetic methods with

a controlled source and a developed processing and interpretation method allows to reveal disintegration zones, which are indicators of a massif stability.

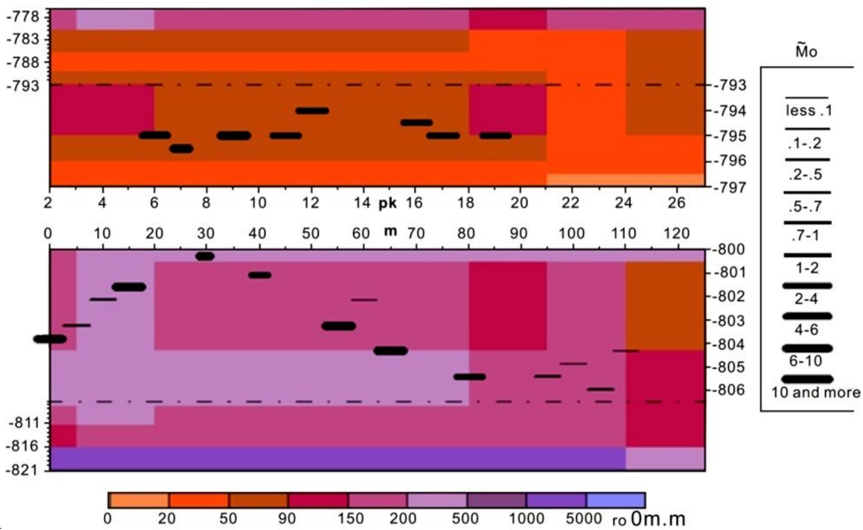
- The disintegration zones are located in the near hole space asymmetrically up and down from the hole and discrete: that is to say that there are intervals in the near hole space, where they are absent.
- The maximum change in the massif, which is under man caused occurs just in the morphology of the space location of that zones depending on time.
- Introduction of a new integral parameter of the subinterval distribution intensity of the disintegration zones allows achieving the detailed quantitative classification of massif by the degree of stability and arranging for those quantitative criterions.

In the paper (Hachay, 2004a), we described the natural results, which had been achieved by revealing the self-organization phenomenon in the rock massif by man-caused influence and the method of defining criterions of stability state on the base of our classification method. Those results had been received during some cycles of electromagnetic monitoring in the Tashtagol mine. The research had been provided on the depths 540-750m for revealing the morphology of the disintegration zones in around the hole area of the rock massif, which was influenced by intense natural and man-caused stress field.

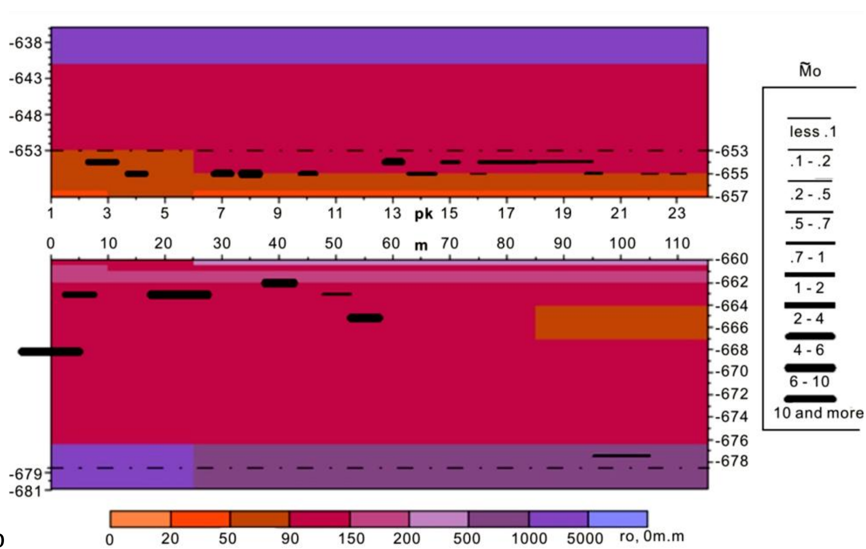
9.6 Phenomenon of Self-Organization in the Rock Massif by Man-Caused Action

In the present time, there are sufficient data, which indicate the two significant features of the modern geological medium evolution: -the mechanical matter displacements of the Earth occur on any space and time scales; - the accessible for research matter of Earth's crust constitutes a block-hierarchic structure, which is a result of destruction and destroy processes (Goldin, 2002). A significant role for understanding and forming the hierarchic structural deformation levels in solid bodies play the theoretical and experimental results, which had been developed on specimens (Panin et al., 1985). Using it, an approach was developed basing on the conception about dissipative structures in non equilibrium systems (Nikolis and Prigozin, 1979), for which on each hierarchic level processes of self-organization exist. As it was shown in (Nikolis, 1989), self-organization occurs by hierarchic structure existing. That approach can be used for research of natural and man-caused systems as are massive, when they are in the process of outworking. The model of open dynamical systems is used for its describing the book (Nikolis and Prigozin, 1990). The analysis of the event of self-organization processes can give the representation about the system stability and promote to develop criterions of massif state stability as a whole relatively the dynamics events of given energetic class. That idea has something in common with the statement, written in the paper (Goldin, 2002), which claimed a hypothesis about the divisibility of the medium scales. For each area with the dimension l_0 the distraction act exists of a definite energetic classc (and higher), for which the preparation can be regarded from the positions, where the deterministic presentations play a significant role and therefore the forecasting of the events can be arranged (for the place and time. But the disintegration for smaller scales confine to the conception on no stationary random process, for which forecasting of individual events is not possible.

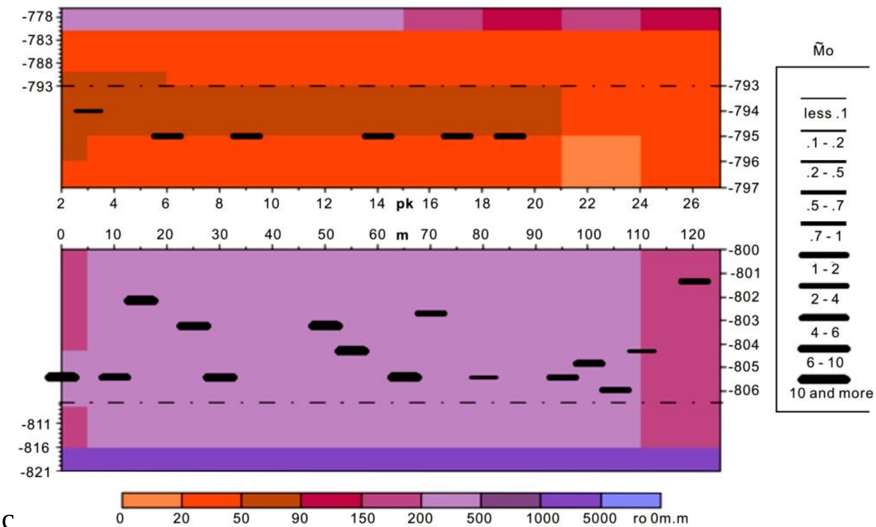
In the papers (Hachay et al., 2003a; Hachay, 2004b) are published the results of defining with use of 3D electromagnetic induction space-time monitoring (Hachay et al., 2001) the fact, that the structure of the rock massif of different matter content can be described by a model of hierarchic discrete medium. In the frame of concrete modification we could trace two hierarchic levels.


-778
-783
-788
-793
-811
-816
-821
pk
m
M̃o
less .1
.1-.2
.2-.5
.5-.7
.7-1
1-2
2-4
4-6
6-10
10 and more
0 20 50 90 150 200 500 1000 5000 ro 0m.m

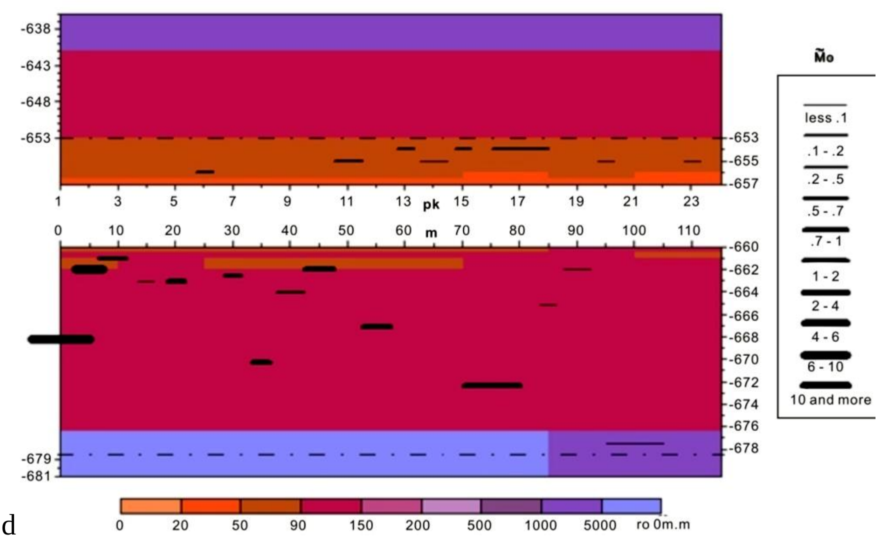
a


-638
-643
-648
-653
-679
-681
pk
m
M̃o
less .1
.1 - .2
.2 - .5
.5 - .7
.7 - 1
1 - 2
2 - 4
4 - 6
6 - 10
10 and more
0 20 50 90 150 200 500 1000 5000 ro, 0m.m

b



c



d

Figure 5. *Event of the self-organization process in morphology of disintegration zones, revealed by data of electromagnetic induction monitoring. a) Geoelectrical section for the ort 19, horizon -350, 20 kHz, the year 2003. b) Geoelectrical section for the ort 8, horizon -210, 10 kHz, the year 2002. c) Geoelectrical section for the ort 19, horizon -350, 20 kHz, the year 2002. d) Geoelectrical section for the ort 8, horizon -210, 10 kHz, the year 2003.*

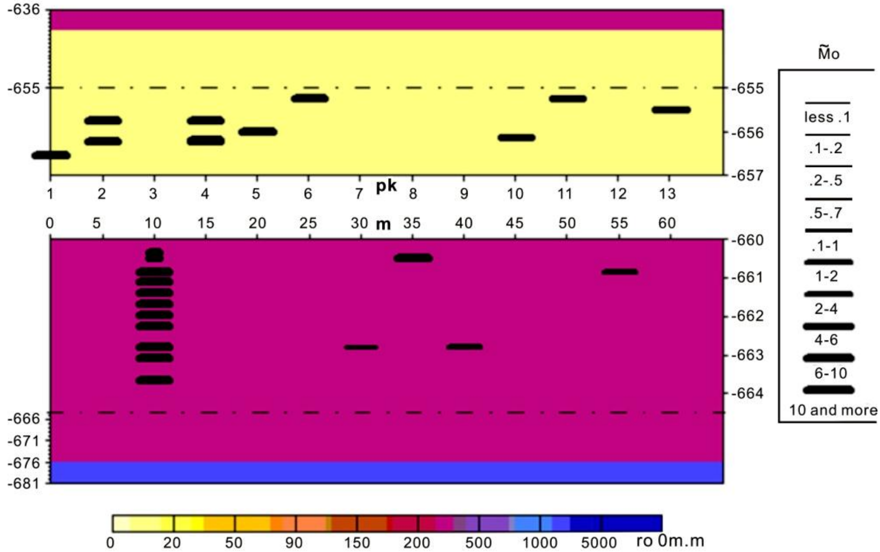


Figure 6. *Geoelectrical section for ort.3, N-W place, horizon -210, 5 kHz, the year 2007.*

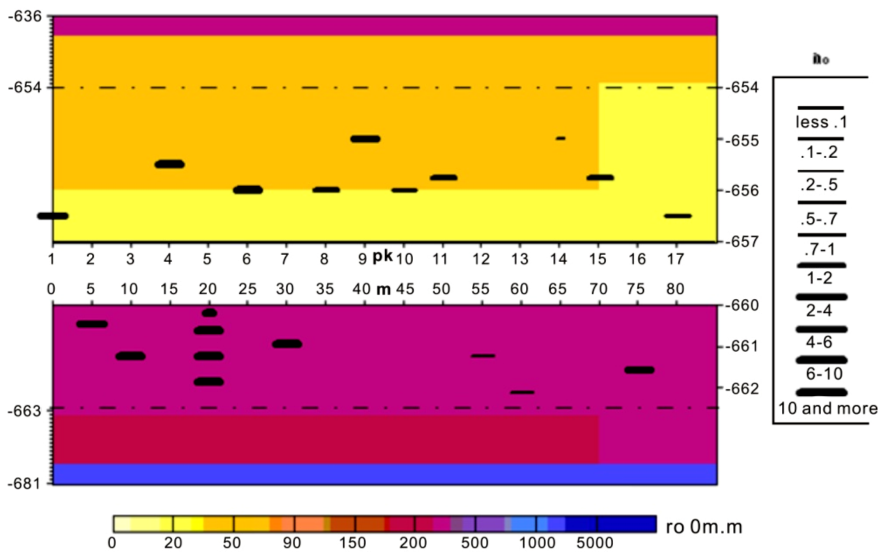


Figure 7. *Geoelectrical section ort.4, n-w place, horizon -210, 10 kHz, the year 2007.*

In the paper (Hachay, 2006) we had described the results of using a complex seismic and electromagnetic active and passive monitoring for forecasting destroying dynamical events before and after mass explosions. Additionally we shall analyze here the morphology of structure features of the disintegration zones before a powerful dynamical event with energy lg E=6.9 in the Tashtagol mine on the depth 683m. (figs.6, 7) Before 3 days till the rock burst in the holes 3,4 in the geoelectrical sections of the hole ground sub vertical discrete structures occur, which are the combining of the disintegration zones.

These structures occur in a resonance regime on different frequencies and only on one frequency for each hole. That phenomenon is observed in different mines. The occurrence of such structures are precursors of powerful dynamical events. For defining the place and the magnitude of the event we must have an information about the place in the classification table of the stability of the massif volume.

9.7 Seism Acoustic Active Borehole Monitoring in Oil Saturated Massif

In the Institute of geophysics UB RAS, the method of active seism acoustic monitoring of the oil layer is developed and improved (Drjagin et al., 2009). That method is used for the estimation of oil saturation and its possibility to oil recovery.

For crack-porous collectors, which are in the process of operation by the method of high liquid head water displacement of oil, the possibility of intensification of ultra sound oscillations can be of a large technique importance. Even a very weak ultra sound can be destroyed during a long time action viscous oil films, which occur in cracks among the blocks, which can be a reason of layers permeability lowering and increasing extraction of oil (Alekseev et al., 2001). For describing of these effects it is needed to consider the wave process in a hierarchic block medium and theoretically research the mechanism of self-oscillations origin by action of relaxation shear stresses (Hachay and Khachay, 2008). In the papers (Hachay and Drjagin, 2010a, b) the algorithm of phase portrait or diagram construction using data of seismic- acoustic monitoring is considered. As a result of borehole monitoring we have three sets of intensity of seismic-acoustic radiation: phone $I(t,x)_f$, after the first excitation $I(t,x)_{V1}$ and after the second excitation $I(t,x)_{V2}$ .These three functions for fixed z are observed on a time interval 14 seconds and with a frequency of discretization 44100Hz with a step along the borehole 0.5m. The whole time interval we divide on 14 subintervals with a length 1 second. In our paper using the earlier developed algorithm we added a new algorithm of changing space, but integral in time for equal periods of observation. Thus we obtain a new parameter Is (conventional units), which is calculated as an average in time value for the whole interval of observation along the borehole for all cycles of observation (two for phone data, and two for each observations after first and second excitations) (fig 8).

Let us think that to the end of corresponding cycles of observation for all points of the oil layer a massif state mainly no equilibrium is formed. It is known that after the Darcy law the filtration velocity is proportional to the pressure gradient. By analogy let us research the distribution of space derivative of is along the borehole (fig.9.). Let us divide for three cycles of observation intervals along the borehole, for which the module of is is larger than 20000 conventional units.

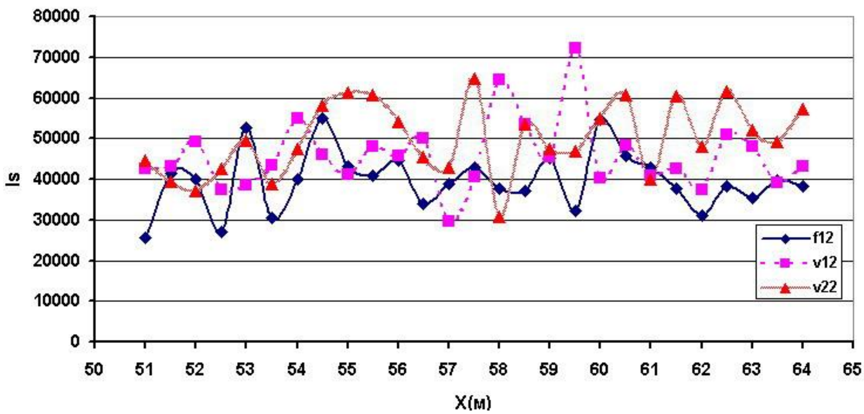


Figure 8. *Distribution of the integral in time intensity of seism acoustic response along the borehole.*

Symbols: f12-average in time intensity of the massif response of the oil layer before excitation, v12- average in time intensity of the massif response of the oil layer after the first cycle of excitation, v22- average in time intensity of the massif response of the oil layer after the second cycle of excitation. Is- average intensity (conventional unit), coordinate along the borehole: X=X(m)+2600m.

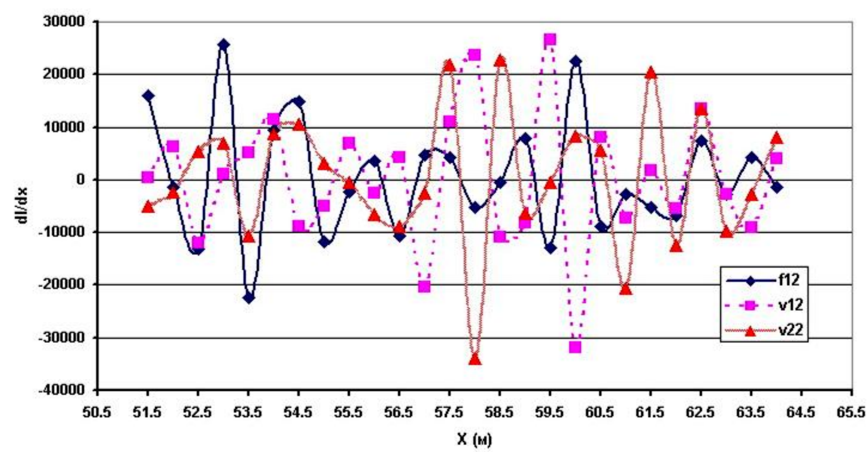


Figure 9. *Changing along the borehole of distribution of integral in time intensity of seism acoustic response. Here dI/dx=dIs/dx Symbols are the same as on the fig.8.*

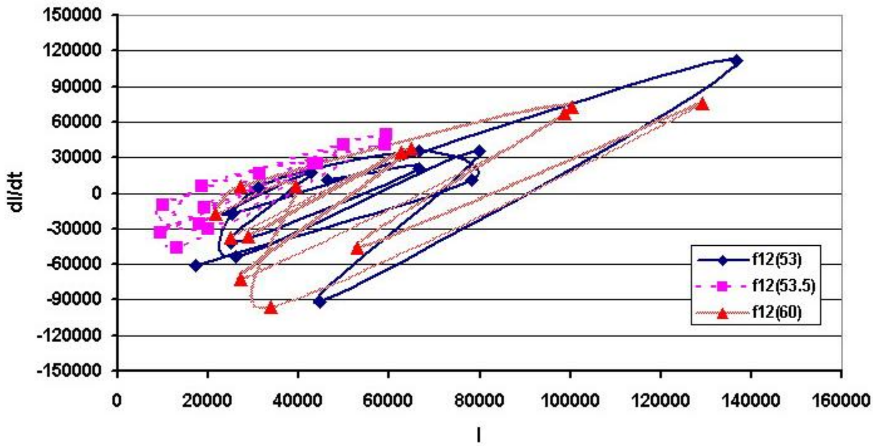


Figure 10. *Phase diagrams of oil layer massif state for the assigned intervals (table 2.) of the borehole area before the excitation.*

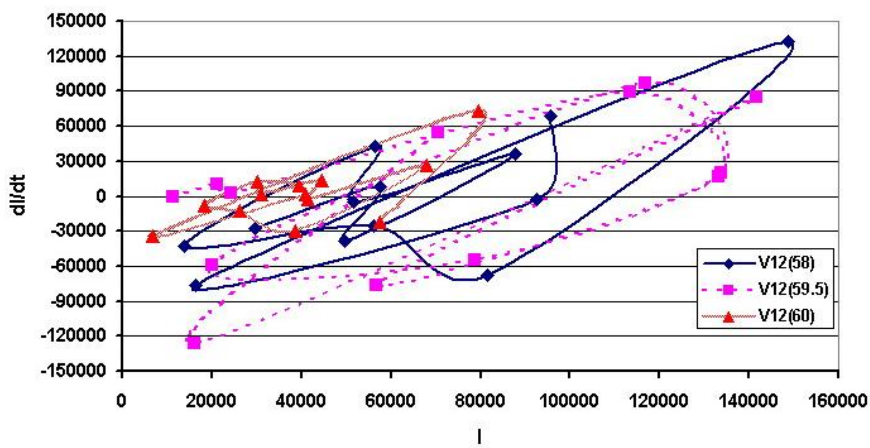


Figure 11. *Phase diagrams of oil layer massif state for the assigned intervals (table 2.) of the borehole area after the first excitation. Symbols are the same, as for the fig.10.*

Symbols: I-intensity of seism acoustic response as function of time for the period 14 sec. of observation (conventional unit), dI/dt-time derivative, by f12 in brackets are coordinates of the intervals along the borehole X+2600 (m).

Table 2. *Intervals of anomaly values of space derivatives of integral in time intensity of the massif response for three cycles of observation along the borehole.*

X	1	2	3	4
f12	53	53.5	60	
v12	58	59.5	60	
v22	57.5	58	58.5	61

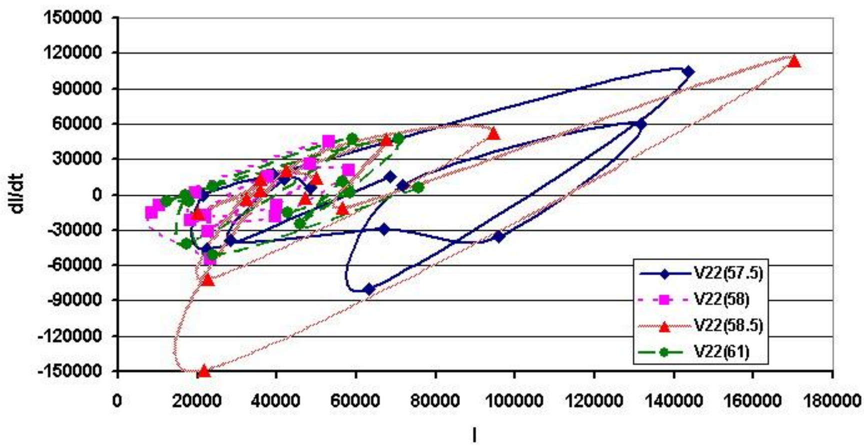


Figure 12. *Phase diagrams of oil layer massif state for the assigned intervals (table 2.) of the borehole area after the second excitation. Symbols are the same, as for the fig.10.*

From the analysis of the results fig. 8, we can notice that the increase of massif activization on a concrete divided interval by the value of the parameter dI/dx occurs if dI/dx >0, when dI/dx<0 the energy acivization decreases. That effect can be linked in the first case with an increase of oil mobility and in the second case with the increase with water mobility. The same considered effect that can be seen on phase diagrams (fig.10), but on other intervals after the first and second cycles of excitation (fig.11-12). As regards the method of phase diagrams, it will be developed in the next chapter.

Thus, the developed methods allow (on the quality and quantity levels) to make a classification of the many phases medium, which is an oil layer, using data for a multiple excitation. For a quantitative solution of earlier listed events of no equilibrium and hysteretic interaction of water and oil by out working of the oil layer, it is urgently to add and to further develop the system of seism acoustic and electromagnetic observations.

9.8 Conclusions

In this study, we carrid out a comparison of no equilibrium effects due to independent hydro dynamical and electromagnetic induction influence on an oil layer and its surrounding medium. It is known, that by drainage and steeps, the hysteresis effect on curves of the relative phase permeability in dependence on porous medium water saturation by some cycles of influence: drainage-steep-drainage, is observed. In earlier papers, the analysis of the seismic-acoustic monitoring data in regimes of phone radiation, response on the first influence of a given frequency and on the second influence is developed. For the analysis of seismic-acoustic response in time on fixed intervals along the borehole, an algorithm of phase diagrams of the state of many phase medium is suggested. On the base of a developed algorithm a new algorithm of analyze of space, but integral in time for equal observation periods changing by the method of a phase diagram state of many phase medium in the oil layer is developed. The developed method allows on quality level to classify the state of the polyphase medium, which is the oil layer, using data of many cycles influence. In that paper we suggest the algorithm of modeling for 2-d seismic field distribution in the heterogeneous medium with hierarchic inclusions. Using the developed earlier 3-d method of induction electromagnetic frequency geometric monitoring we showed the opportunity of defining of physical and structural features of hierarchic oil layer structure and estimating of water saturating by crack inclusions. That allows managing the process of drainage and steeping by water displacement the oil out of the layer.

References

[1] Alekseev, A. S., Tsetsocho, V. A., Belonosov, A. V. and Skazka, V. V., 2001. Physical-Technical Problems of Mining, 6, 3-12 (in Russian).w IPhE RAS, 2010. pp. 380-385 (in Russian).

[2] Drjagin, V. V., Igolkina, G. V. and Ivanov, D.B., 2009. Experience of informative characteristics research of acoustic emission in oil saturated layers of terrigenous type. Geodynamics. Deep Structure. Thermal Earth's Field. Interpretation of Geophysical Fields. The Fifth Readings of Yu. P. Bulashevitch. Materials of the Conference. Yekaterinburg, IGF UB RAS, pp. 168-174 (in Russian).

[3] Frenkel, Ya. I., 1944. To the theory of seismic and seismoelectric effects in a humide soil Izvestija AN USSR, 8(4), 133-150 (in Russian).

[4] Goldin, S. V., 2002. Destruction of lithosphere and physical mesomechanics. Physical Mesomechanics, 5(5), 5-22 (in Russian).

[5] Hachay, O. A., 1994. Mathematical modelling and interpretation of alternating electromagnetic field of heterogeneous crust and mantle of the Earth. Dissertation of Doctor of Physical and Mathematical Sciences. Ekaterinburg, p. 314 (in Russian).

[6] Hachay, O. A. and Novgorodova E. N., 1997. The experience of area induction research of highly heterogenic media. Physics of the Earth, 5, 60-64 (in Russian).

[7] Hachay, O. A. and Novgorodova, E. N., 1999. Use the new 3D method of electromagnetic research of rock massive structures. Physics of the Earth, 5, 7-12 (in Russian).

[8] Hachay, O. A., Bodin, V. V., Hinkina, T. A., 1999a. A common approach for interpretation 3D Seismic and electromagnetic fields in frequency-geometrical variant by use local source of excitation. Questions of Theory, Interpretation Practice of Gravi, Magnetic and Electric Fields. Yekaterinburg, pp. 68-69 (in Russian).

[9] Hachay, O. A., Novgorodova E. N., Vloch N. P. and Khudjakov, S. V., 1999b. Electromagnetic monitoring of migration zones of overfracturings rock massif by man-caused influence. Geodynamics and Stress State of the Earth. Novosibirsk SB RAS, pp. 363-367 (in Russian).

[10] Hachay, O. A., Novgorodova E. N., 2000. Mapping and Identification Disintegration Zones of Rock Massive, which Differ by Matter Content, with use of Electromagnetic Method. UB RAS, Yekaterinburg, pp. 114-123 (in Russian).

[11] Hachay, O. A. et al., 2001. Three-dimensional electromagnetic monitoring of rock massive states. Phyzika Zemli, 2, 85-92 (in Russian).

[12] Hachay, O. A., Novgorodova, E.N. and Khachay, O.Yu, 2003a. A new method of revealing disintegration zones in near hole space of the rock massif of different matter content. Mining Information and Analytical Bulletin. MMSU, 11, 26-29 (in Russian).

[13] Hachay, O. A., 2003b, To the Problem of Structure a State Research of Geological Heterogenic Medium in the Frame of Discrete and Hierarchic Model. Geomechanics in Mining. Yekaterinburg IM UD RAS, pp. 30-38 (in Russian).

[14] Hachay, O. A., 2004a. The phenomenon of self organization in rock massif by man-caused influence. Physical Mesomechanics, 7, special issue, 2, 292-295 (in Russian).

[15] Hachay, O. A., 2004b. To the question about research of structure and state of geological heterogenic no stationary medium in a frame of discrete hierarchic model. Russian Geophysical Journal, 33-34, 32-37 (in Russian).

[16] Hachay, O. A., 2006. The problem of the transient process of redistribution of stress and phase rock states between powerful man-caused influences. Mining Information Analytic Bulletin, 5, 109-115 (in Russian).

[17] Hachay, O. A., 2007. Geophysical monitoring of state of the rock massive with use of the idea of physical mesomechanics. Physika Zemli, 4, 58-64 (in Russian).

[18] Hachay, O. A., and Khachay, O. Yu, 2008. Modeling of seismic and electromagnetic fields in hierarchic heterogenic media. Geophysical Research of the Ural and Adjacent Regions. Materials of International Conference. Yekaterinburg: IGF UB RAS, pp. 295-299 (in Russian).

[19] Hachay, O. A. and Drjagin, V. V., 2010a. Analysis of seism acoustic active space-time monitoring data of geological medium from the position of open dynamical system. Collection of Papers of Scientific Conference, Devoted to Anniversary of A. V. Rimskiy-Korsakov. Moscow AKIN, RAS, pp.143-146 (in Russian).

[20] Hachay, O. A. and Drjagin, V. V., 2010b. Method of phase diagrams for analyze of seism acoustic space-time monitoring data of oil boreholes. The questions of theory and practice of geological interpretation of gravitational, magnetic and electric fields. Materials of 37-th Session of International Seminar, D.G. Uspensky. Moscou.

[21] Hachay, O. A. and Khachay, A. Yu, 2011. About common methods of seismic and electromagnetic fields for mapping and state monitoring 2-D heterogeneities in the N- layered medium. Bulletin of YUSU. Series: Software Technologies, Management and Radio Electronics, 13(2) (219), 49-56 (in Russian).

[22] Hachay, O. A. and Khachay A. Yu, 2013. Modelling of seismic and electromagnetic field in hierarchic heterogeneous media. Bulletin of YUSU. Series: “Calculation Mathematics and Informatics”, 2(2), 48-56 (in Russian).

[23] Hasanov, M. M. and Bulgakova, G.T., 2003. Nonlinear and No Equilibrium Effects in Reological Complicated Media. Moscow, Ijevsk, Institute of Computer Research, p. 288 (in Russian).

[24] Khachay, A. Yu, 2006a. Algorithm for Direct Dynamical Seismic by Excitation of Horizontal Local Force, Located in an Arbitrary Layer of an n-Layered Elastic Isotropic Media Problem Solution. Informatics and Mathematical Modeling. Ural State University, Yekaterinburg, pp. 170-278 (in Russian).

[25] Khachay, A. Yu, 2006b. Algorithm for Direct Dynamical Seismic Problem Solution in a Frame a Model: Excitation of a Local Source of Vertical Force, Located in an Arbitrary Layer of an n-Layered Elastic Isotropic Media Solution. Informatics and Mathematical Modeling. Ural State University, Yekaterinburg, pp. 279-310 (in Russian).

[26] Klimontovitch, Yu. L., 2002. Approach to a Physics of Open Systems. Moscow, “Yanus-K”, p. 282 (in Russian).

[27] Kupradze, V. D, 1950. Boundary Problems of Oscillations Theory and Integral Equations. Moscow-Leningrad, State Publication of Theoretical Literature, p. 280 (in Russian).

[28] Kurlenja, M. V. and Oparin V. N., 1999. Modern Problems of Nonlinear Geomechanics. Geodynamics and Stress State of the Earth. Novosibirsk SD RAS, pp. 5-20 (in Russian).

[29] Nikolis, G., amd Prigozin, I., 1979. Self Organization in Noequilibrium Systems. M.: Mir, p. 300 (in Russian).

[30] Nokolis, G., 1989. Dynamics of Hierarchic Systems. M.: Mir, p. 486. (in Russian).

[31] Nikolis, G. and Prigogin, I., 1990. Knowing the Complicatedness. M.: Mir, p. 344 (in Russian).

[32] Olemskoy, A. I. and Kaznelson, A. A., 2003. Synergetics of Condensed Medium. Moscow, URSS, p. 335 (in Russian).

[33] Panin, V. E., Lichatchev, V. A., and Grinjaev, Yu. V., 1985. Structural Lebels of Deformation of Solid Bodies. Novosibirsk. SB AN USSR Nauka, p. 226 (in Russian).

[34] Panin et al., 1995. Physical mesomechanics, Novosibirsk Nauka, SB RAS, P.297 (in Russian).

[35] Rodionov, V. N., Sizov, I. A. and Kocharjan, G. G.., 1989. About modeling natural objects in geomechanics. The Book, 24, 14-18 (in Russian).

[36] Sadovskiy, M. A., Bolchovitinov, L. G. and Pisarenko, V. F., 1987. Deformation of Geophysical Medium and Seismically Process. M.: Nauka, p. 98 (in Russian).

[37] Shemjakin, E. I., Fisenko, G. L., Kurlenja, M. V., Oparin, V. N. et al., 1986. Effect of zone disintegration of rocks around the underground holes. DAN USSR, 289(5) (in Russian).

[38] Shemjakin, E. I., Kurlenja, M. V., Oparin, V. N.. et al., 1992. Discovery No 400. Effect of disintegration zones in rocks around the underground holes. Bulletin of Discoveries, 1 (in Russian).

[39] Strachov, V. N., 1993, 1994. Scentifical ideology I, II. Geophysics, 1(1), 9-21 (in Russian).

[40] Yegorov, P. V. and Redkin, A. V., 2001. Monitoring Rock Bursts by Outworking of Rock Deposits with Block Structure. Geodynamics and stress state of the Earth. Novosibirsk SD RAS, pp. 309-314 (in Russian).