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SEDIMENTARY TUNNEL-TYPE BASIN GEOMODEL FOR THE HYDROCARBONS OF THE VOLGA-URALS PROVINCE OR THE NEW STRONG SOLUTION OF NAVIER-STOKES EQUATION FOR DEFORMED POROUS MEDIA

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ABSTRACT: *Subsurface diagenesis is related with the phenomena of high pressure, deformation moments, temperatures and physical/chemical reactions. Geo-dynamical de-compaction of impulse character for the tunneling of the formations in relation with the resonant moments of deformation arranges local and global multi-scale stratified porous fractures lithological traps of diagenesis. Microscopic anisotropy of vertical permeability is related with micro-structure super-conductivity, plastic de-compaction and development of fractures as per Poisson and Young along with the structural phenomenological compaction of viscous-elastic matrix. Here we present the analytic overview and analysis of Navier-Stokes equation solutions for the development of porous media through the geological evolution of permeability and diffusive conductivity of matrix as per new Darcy – Fick's Law for orbital emission of subduction with Euro-Asian oceans and their triplex form of unloading through the examples of Zhiguli dislocation in Samara trans-Volga region and generalized saturation of middle part of the Urals.*

KEYWORDS: Zhigulevsk Break, Micro-Structure, Reservoir Contacts, Seismic Emission, Diffusion, Relaxation.

INTRODUCTION

The present-day ways to interpret the studies of oil and gas-saturated cross-sections are based upon the specific presentations on formation rock and reservoir structures intersected by wells as well as upon the hypothesis of their diagenesis. Initially there were no sediment on the Earth - there was only continuous media of magma and gaseous atmosphere. During the process of diagenesis (Krinari, 2013) with the formation and precipitation of sediments they were affected by the pressure of the overburden, by gravitational and geo-dynamical forces of the oceans, by physical/chemical potentials of rock leaching, by ionic streams and electro-magnetic forces. Continental sediments at the continents and in the ancient oceans have migrated, compacted and cracked and have transformed into formation rock with block-type structure. The driving force of these geo-dynamical phenomena in orbital evolution are presented by quantum-mechanical phenomenon of tunneling and tangential compacted saturation of dissipative structures in electro-magnetic, gravitational fields (Kazantseva, 2006; Koptev, 2010) while studying the Sun and the Universe (Barenbaum, 2014).

The problem relates to the difficulty in summing-up the waves with various phase angles and scales of averaging (Klimchouk, 2008; Samelson, 2009). For example, the mean velocity of the Atlantic stream *U* forms the vast off-shore coastal beach structural zone near Europe. The same time the reverse-type jets velocity and impulse streams of the Pacific Ocean (Frolov, 2011) form the numerous basalt ocean trenches including the Marianna trench, the world's deepest one. At the level of heliocentric orbit of the Earth and with cosmic velocities of the movement there appear very great deformation moments at the micro-scales of porous space. To make a systematic approach in evaluating the similar secondary and tertiary moments for the direct and reverse-compacted progressive waves $F(r,k,\omega,t)$ we may use the presented analytical solutions showing the development of parabolic solutions of thermal-conductivity type in view of hyperbolic part of the Earth's dissipative structure.

Here we consider the boundary requirement for the evolutionary system of Navier-Stokes differential solutions and continuity

$$\frac{\partial}{\partial t}u_i + \Sigma_{j=1}^{n} u_j \frac{\partial u_i}{\partial x_j} = \nu \Delta u_i - \frac{\partial p}{\partial x_i} + f_i(\mathrm{x}, t), \quad \mathrm{div}\, u = \Sigma_{i=1}^{n} \frac{\partial u_i}{\partial x_i} = 0\,, \tag{1}$$

With initial conditions $u(x,0)=u^0(x)$, $(x \in R^n,\ t \geq 0)$. (2)

Here $u^0(x)$ – the given vector field for R^n, p – pressure, $f_i(x,t)$ – gravity force, ν – kinematic viscosity, Δ - Laplace operator. These equations are resolved using velocity vectors $u(x,t)=(u_i(x,t))_{1\leq i \leq n} \in R^n$ and pressure $p(x,t) \in R$, defined by position $x \in R^n$ and time $t \geq 0$.The equations on the status have the form of $\sigma_{ij,j}+f_j=0$, where σ_{ij} – is the stress on porous media. The character of movement and evolution of multi-phase filtration are defined by the conditions of equilibrium status for the surface boundaries of non-miscible phases, facies layers and structures of formation. Anisotropy of porous media, fracturing, elasticity and plasticity of the skeleton.

THEORETICAL BACKGROUND

The evaluation of present-day theoretical and experimental approaches (Popkov, 2014) to the problems with condensed media enables disclosing the actual trends in method development for the studies of macroscopic properties of the systems the phenomena of which are determined by their physics and chemistry (see Table). There are no intensive development of conceptual approaches towards the application of physical chemistry and macroscopic dynamics for the continuous media. They develop the cosmic non-linear approaches of orbital geology for the small planets in view of impulses from the secondary and tertiary moments of ballistic structure. The disadvantages of these theories for tracing the geological bodies are presented by the large volume of memory required to store the information on ephemeris of planets. It is obvious that the now it's required to update evolutionary the differential equations (Anping Liu, 2007) directly at the boundaries of emissions and to consider the strong solutions in view of multi-scaled status of the geo-environment (Popkov, 2014). In respect to the scaled emission and theory of relativity the impulse moment have great values by pressures (millions of atmospheres at resonant-harmonic loadings), temperature, electro-magnetic induction – like the lightning. The presented properties for large-scaled evolutionary modeling of the porous structure development are illustrated by numerical and analytical solutions of impulse

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conservation equations, like Navier-Stokes equation for the locally balanced status of deformed porous media (Maximov, 1994; Popkov, 2014).

The near-wellbore space of the productive reservoir is a specific high-active and energy dynamically unstable zone. The process of reservoir penetration by drilling or well completion or its operation breaks the natural stability of the reservoirs, thus making the de-compaction and compaction of the rock (see Fig. 1). The near-wellbore zone experiences the changes in properties and characteristics of the rock, fluids, physical/chemical and chemical/biological transformations as well as the drainage conditions (Garagash, 2014; Neprimerov, 1958). All this processes make the severe impact upon the porous permeability thus forming the skin-zone, and, consequently, giving the multiple reduction in well inflow.

Table 1. Physical and Chemical Phenomena of Deformed Porosity

Physical/ chemical phenomena	Equations for phenomena	Physical sense in phenomena	Geo-dynamics of phenomena
Seismic emission	Navier - Stokes, Hook’s Law	Deformation, dissipation of pressure pulse	Emission energy and deformation
Fluid dynamic viscosity	Navier (Stokes)	Internal friction of pulse transfer	Di-pole electric moment
Energy of viscosity activation	Arrhenius -Eyring	Velocity of molecule thermal movement	Energy of polarization
Porosity, capillary filtration	Poiseuille - Darcy	Shear stress for viscous flow	Electrical moment, Debye’s radius
Surface wetting	Laplace formulae	Surface free energy	Electrical moment
Stationary diffusion	Fick’s equation	Mass transfer of concentrations, chemical potentials	Difference in electrical moments
Equilibrium absorption	Langmuir - Freundlich	Free energy at interface boundary	Difference in electrical moments
Double electrical layer	Helmholtz, Guye, Chapman, Graham, Prandtl	Free energy at “metal – solution” boundary	Theorem of Ostrogradskiy - Gauss
Corrosion transfer	Mass and charge transfer	Thermo-dynamical potentials, Coulomb’ Law	Difference in electrical moments
Molar volume, Avogadro’s constant	Mendeleev - Clapeyron	Volume of one mole of substance	Work of electrical moment
Absorption of substance emission	Dispersions of di-electric permeability	Loss of pressure impulse, waves (photons)	Electrical moment in a system of charges

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Development of fractures in porous media is a well-known issue in geo-mechanics that was covered by the science at the stages of oil and gas field development description and simulation (An, 2009; Nikolayevskiy, 2010; Penrose, 2007; Petukhov, 2012). The item has become very acute recently when the traditional reservoirs were added by compacted/de-compacted deformed reservoirs with complicated pays of various diagenesis. Identification and presentation while selecting the specific mathematical model to range the fracturing is understood as a real challenge for the present-day science (Bayouk, 2012), physical chemistry, geology, field development, ecology, economics, social aspects and global mathematics in general.

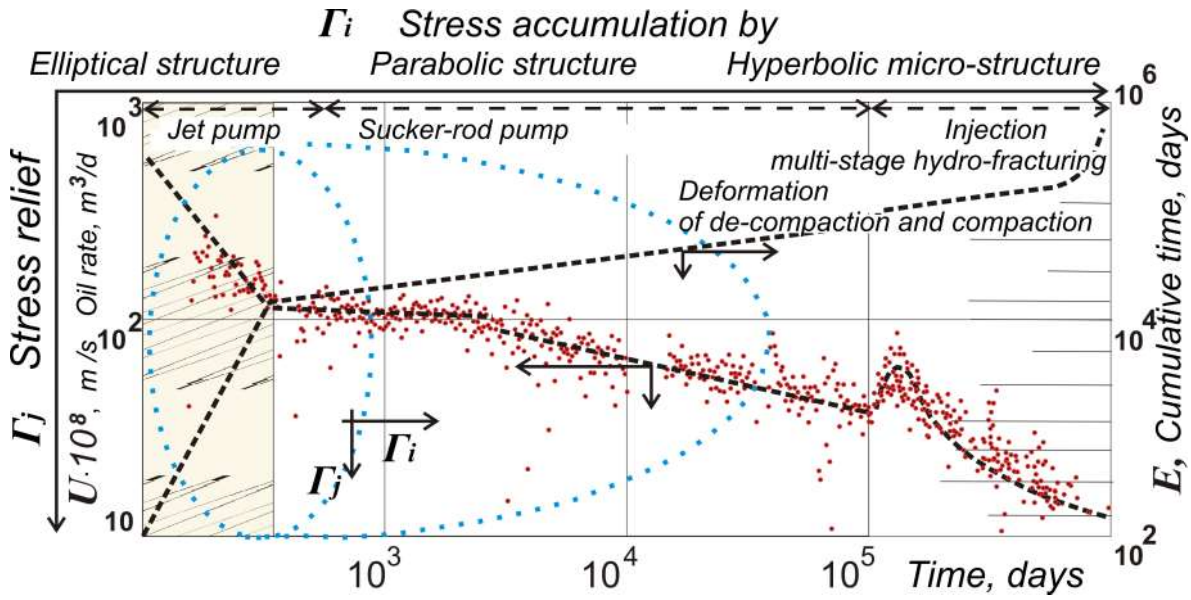

Figure 1. Scaled analogy for the Γ_i development energy accumulation stages for the oil and gas-saturated fields and rock-stress relief in physical and chemical phenomena of Γ_j drainage.

The paper, through the macroscopic methods of pressure, porosity and permeability diagnostics and the application of the latest results of statistical and dynamic analysis for the complexly organized reservoirs including the use of a new evolutionary solution as per Darcy – Fick's law that is based upon Navier-Stokes equation, presents the description and identification of physical/chemical and hydro-dynamic phenomena for various types of reservoirs (Litvin, 2015).

It presents the conceptual basin-type model showing the arrangement of local and global porous traps in the area of Zhiguli foothill dislocation through the examples of triplex interferenceof deep-water waves of Baltic, Mediterranean and Caspian diagenesis. Here we also present the models of two-in-one reservoir development dualism, compacted/de-compacted drainage by alternative methods (Christianovich, 2000; Popkov, 2014) and bottom-hole pressure drop in a complexly organized system (Fig. 2).

Submicroscopic Phase Equilibrium

Following the analysis of test results in defining the pore size, their distribution and role in filtration process (Astafiev, 2013; Bayouk, 2012; Lalin, 2012; Popkov, 2012), obtained through numerous test modeling and field investigations with dynamic relative phase permeability, we have grounded the new more adequate energy stable model of reservoir structure and rheology (Popkov, 2013; Roschin, 2013) in view of their porous deformation. It provides the calculation of hydrocarbon recoverable reserves by a volumetric procedure with an accuracy that in principle, cannot be achieved through the application of the presently accepted model at the basis of Darcy Law and Euler-type equations for gas dynamics (Balandin, 2014).

The cyclic processes of wedge-type sedimentation and de-compaction of reservoir tops are taking place simultaneously, but in different ways. In reservoirs – due to mutual regrouping of mineral skeleton particle locations up to the molecular level, in shales – due to the increase/decrease in distance between structural layers of dissolution, diffusion and washing-out, i.e. absorption and sedimentation. The deformation moments and elasticity value of capillary adhesion to the skeleton of pores give the additional conditions for Cauchy problem and reverse-type objective for the historical parametrization of phase status and evolution of traditional parabolic equations (Anping Liu, 2007) of thermal conductivity type.

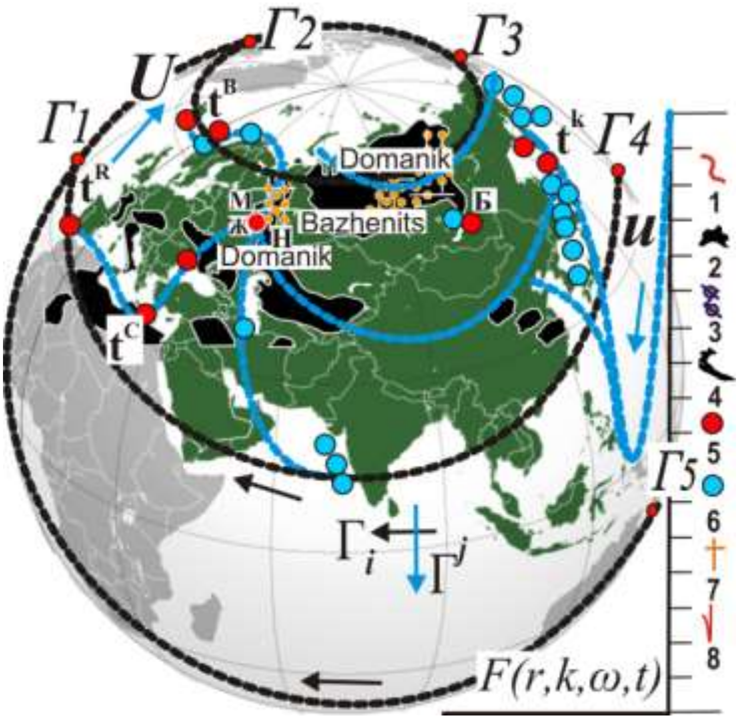

Figure 2. Evolution of internal vertical and horizontal deformations Γ_i^j for orbital emissions ***Г1-Г5*** in shaping local and global traps of sedimentary tunneling 1 and compacted reservoirs, allochthons 2 for Domanik & Bazhenits 3 at saturation 4 of the generalized middle part of the Ural Mountains **Н** b y the unloading of fluid contacts 5, gas hydrates 6 at off-shore, African $\mathbf{t}^{C}$, European $\mathbf{t}^{R}$ continents, Baltic $\mathbf{t}^{B}$, Moscow **М** & Baikal **Б** platforms, jet flows $\mathbf{t}^{k}$ in Euro-Asia, including Zhiguli **Ж** dislocation: uplifts (for oil), drops (for gas) at geo-physical conjugation of velocity **U** from Atlantic Ocean and reverse jet pulsation, Pacific Ocean and migration of Earth's geo-spheres.

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Spacing for Status, Processes and Cycles

Let's introduce the spacing for status that is the space the parameters of which are the parameters of its status μ^i (phase space). The plurality of media status that corresponds to some sequence in values of status parameters is called a process. The process a result of which the system returns back to the space of status in its initial position is called a cycle. The examples of these are the geological cycles in arranging the oil and gas-saturated field reservoirs. The internal status of the deformed media is characterized by deformation tensor and temperature as well as by physical constants – Young's modulus, Poisson ratio and thermal capacity. While introducing these models they consider that the stresses do depend not only on deformations and temperature in a given moment, but on the complete pre-history of mass deformation. This is equal to the statement that p^{ij} are dependent on ε_{ij}, T and all of their derivatives in time. An example of such complicated status of the system is presented by a flow of multi-phase fluid that includes plastic and solid substances to a well from heterogeneous oil and gas saturated reservoir (Fig. 3).

The determination of the status parameters for the complexly structured porous space is linked with the solution of non-linear equations inside the complicated mathematical theory on final amplitude wave distribution in heavy fluid. A specific type of equation solutions are presented by the solutions for the type of non-attenuated progressive wave, like $F(x,y,z,k,w,t)= Real\ g(y,z,k,\omega)e^{i(kx-\omega t)}$, where k and ω – are the constants (in general) complex numbers, like g – some complex function, $i=(-1)^{1/2}$, F – function under search. What concerns the flat sinusoidal-type progressive wave that is spread towards the direction of vector $\boldsymbol{k}$ and is valid by formula of $F=Real\ Ae^{\ i(\boldsymbol{kr}-\omega t)}$, where A – a constant, $\boldsymbol{r}$ – radius-vector. If $\boldsymbol{k}$ and ω – are the constants then the flat wave is distributed as a solid body; and if it's a function of particle status, the different statuses are distributed with different velocities and the shape of this wave will be deformed.

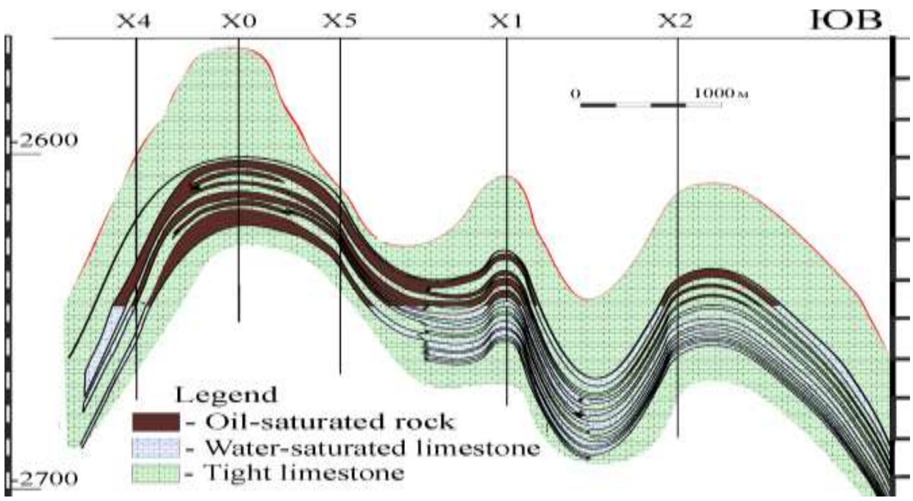

Figure 3. Scaled organization and range hierarchy of porous media for Upper Devonian formations at Zhiguli dislocation in Cis-Urals

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Surface of Breaks and Fracturing

At the surface of breaks that separate the areas of process discontinuity between the characteristics of movement and status at various sides of the surface the following universal energy correlations should be completed (Landau, 2002). In order to get the continuous solutions it is requited to consider a more complicated model, e.g. using Navier-Stokes equations and to introduce additional rated correlations at the boundary of dissipative effects that arise due steep gradients for the distribution of velocities, temperatures, density, pressure, etc. One of the examples for such heterogeneous surfaces for the breaks in continuous media is presented by the structural surfaces of fracturing in facies and phase boundaries of porous media. As a representative model of such complexly organized structure one may take the cylindrical geo-mechanical model of production well bottom-hole or subduction of ocean bottom that may be also presented by the inclined fracture in a continuous media of porous space (Fig. 4). The objective is to develop the stable evolutionary solution for the reservoir and the porosity and fracturing development both in time and in space.

The flow of migration and diffusion in a boundary layer of the micro-structure is characterized by the obvious non-linear interaction processes for various physical/chemical and hydro-dynamic fluctuations, defined by the processes of origin, diffusion, conective transfer, adsorption, desorption, electromagnetic phenomena and energy dissipation with further sedimentation, compaction and mass transfer for the crushed particles particles downstream. In the close proximity to the capillary surface of the viscous sub-layer it is possible to make the verified description and simulate the pulsing and mean characteristics using off-stationary Navier-Stokes equations (Popkov: 2014, 2015). In conditions that preserve the viscous sub-layer in time the linearized solutions are in good coordination with experimental data for these areas up to $\eta \approx 5 \div 7$, that defines the thickness of viscous sub-layer in porous micro-structure.

For example, in the area of Samara trans-Volga and Cis-Ural region they have registered the verical shifts of the surface with the velocity of 2 mm per annum (Yakovlev, 2014). For million years the abcient Urals were evolutionary formed as well as the Zhiguli mountains, being their triplex reflection. The area between these reflecting mountains had accululated significant reserves in deposited high-structured types of oil, from the light de-compacted oil to the hard-to-recover high-viscous oil and bitumen as wellas by clastic/abraded compacted reservoir of Domanik allochtones (Stoupakova, 2015).

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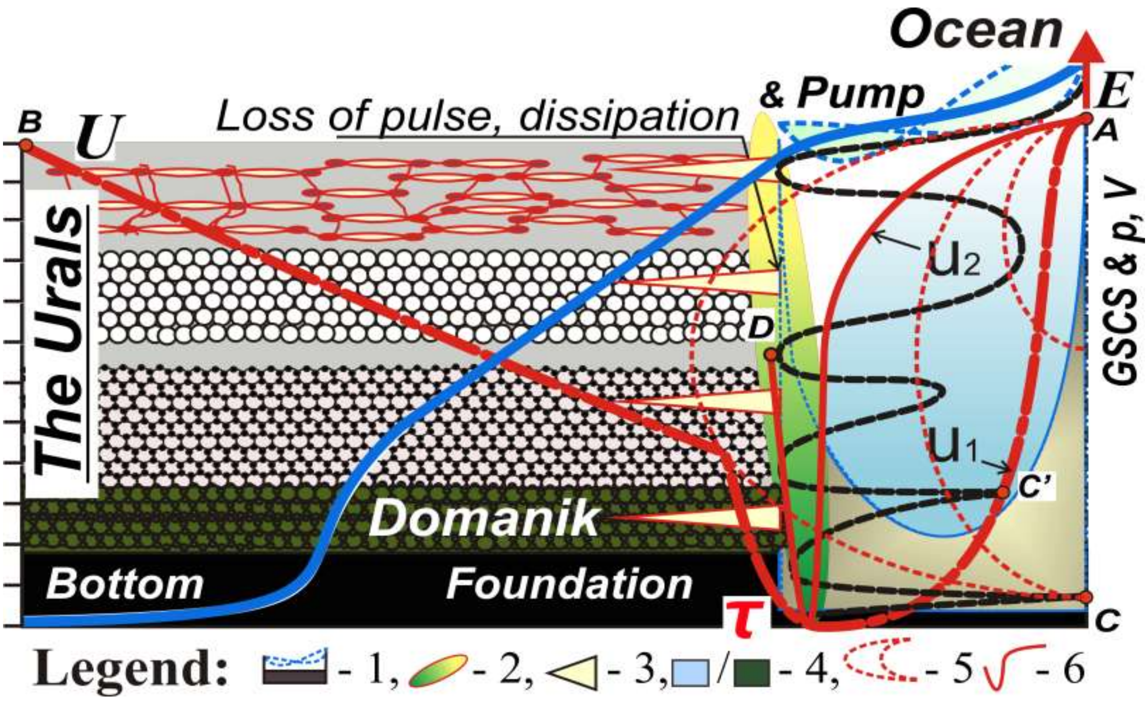

Figure 4. Geological and statistical cross section (GSC) of multi-scaled complexly organized reservoir outflow from well 1 or ocean spreading, deformations 2, perforations 3, de-compactions and compactions 4, sedimentary tunneling 5: A - D – critical point to upscale the porous models of filtration by S.A. Chistianovich and V.I. Popkov.

The process of dynamic interaction between the flow and the by-passed surface micro-structure of porous surface in traditional Teerigenous or cavernous compacted Carbonate reservoirs becames more complicated in presence of a deformed (in small scale) surface. The Reynolds' numbers in case with changes in scale of interaction may increase up to the critical points with flow break-down. The flow regime in this case is changed from convergent to divergent thus forming extended shady tails of compacted fluid and fine-dispersed shale fraction. The amenability in small is defined by the surface amplitude characteristics, that should be significantly thinner that thickness of viscouls filtration sub-layer. In view of the resonant interaction frequencies and dissipative parameters of the layer the deformation amplitudes increase till the critical values of rock destruction with the formation of micro-fracturing that in geological amd technogenic time will be extended additively. The amenability of the surface at amplitudes $\xi_2 \ll \delta$ forms the conditions when additional perturbations created by the surface will change Reynolds' stresses both as normal and tangential stresses. Within the limits of geological age for the evolutionary additiveness of thickness and stratified lamination this solution will come out far beyond the boundaries of the viscous layer. In this case the front of wave solution movement will form completely crushed porous space of this or that formation.

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RESEARCH METHODOLOGY

Structural Model

While simulating the rheology of petro-physical properties they have widely used the structural mathematical models with which it is possible to describe many non-linear effects on non-elastic deformation and viscous-elastic destruction (Litvin, 2015). The polycrystalline material of the skeleton and viscous-elastic properties of fluids are simulated by a system of inclined-deviated layers that work with strain/compression and viscous flow where each local element of the system is having the simplest deformation properties: linear elasticity, ideal plasticity and non-linear viscosity. The deformation is presented in a form of $\varepsilon = e + e^p + e^в$, where e – are elastic, e^p – plastic, $e^в$ – non-linear viscosity (Radchenko, 2004). The equilibrium is described by the equations on movements and generalized Hook's Law. The status - by shear and elasticity modulus, function of relaxation (Astafiev, 2013; Popkov, 2015). The solution of non-stationary Navier-Stokes equation

$$\partial \mathbf{u}/\partial t + 1/\rho \cdot \partial p/\partial x = v\partial^2 \mathbf{u}/\partial y \quad (3)$$

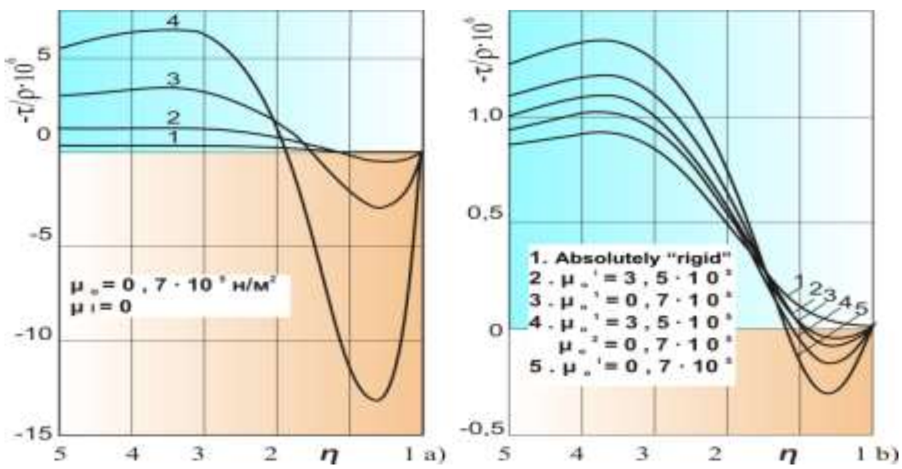

Figure 5. Reynolds' stresses vs frequency at elastic (a) and viscous-elastic surfaces with frequency 2000 Hz (b)

Is presented in a form of the wave $u = g(y) exp\ i[\mathbf{kx} - \omega t]$. Reynolds's induction stresses are defined analytically, (Fig. 5):

$$\tau = k_x C^2 (1+tg^2\theta)/(8\omega/v)^{1/2} \{K_1+K_2-2S sin\ \varphi_2 - [(K_1+K_2) cos\ \eta + (K_1-K_2) sin\ \eta +$$
$$+(K_1^2+K_2^2)(cos\ \eta - sin\ \eta) - 2S(K_1 \cdot sin(\eta+\varphi_2) + K_2 cos(\eta+\varphi_2)) + 2\eta(K_1 \cdot sin\ \eta +$$
$$+K_2 \cdot cos\ \eta)] exp(-\eta) + (K_1^2+K_2^2) exp(-2\eta)\}, \quad (4)$$

where, $S = -U_o/C \cdot |\xi_2|(\omega/2v)^{1/2}/(1+tg^2\theta)$, $K_1 = 1 + (|\xi_2|U' \cdot cos\ \varphi_2 + |\xi_1|\omega \cdot cos\ \theta \cdot sin\ \varphi_1)/C$,

$K_2 = (|\xi_1|\omega \cdot cos\ \theta \cdot cos\ \varphi_1 - |\xi_2|U' \cdot sin\ \varphi_2)/C$, $U_o = \omega/k_x$, $C = p_o/\rho U_o$, $\eta = y(\omega/2v)^{1/2}$, $u_z = u_x tg\ \theta$,

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ξ_α - displacement, φ_α – phase shear. The external flow U_o defines phase velocity $C=0,8U_o$ and energy sector of pressure pulsing (Brekhovskikh, 1989)

$$p(\omega)=0,75\cdot 10^{-5}\alpha^2\rho^2U_o^3\delta^*[3/2(m-1/m)],\ \omega<\omega_o, \quad (5)$$

$$p(\omega)=1,5\cdot 10^{-5}\ (\alpha^2\rho^2U_o^6/\omega^3\delta^{*2})\ [3/2(m-1/m)](2\pi U_o/5\omega\delta^*)^{m-3}, \quad (6)$$

where $\omega_o=2\pi U_o/\delta,\ \delta=5\delta^*$, δ^* - effective thickness of boundary layer, parameters $m=1/C$ – breaking and α - Kraichnan – are considered as given. The value of pulsing pressure was given by a constant one $(\omega)/\rho u_*^2=1$, where u_* - minimum velocity of impregnation, that correspond to a mean value of pressure pulsing at energy-carrying frequency ω_o.

Therefore, viscous-elastic porous streucture generates negative tangential stresses (Fig. 5), that at $\tau_\omega \geq \rho u_*^2$ make the draft. The strengthening of deformation is seen at the boundaries of breaking where second deformation moments at micro-scales and resonant frequencies (Dinariev, 2005; Ayachi, 2010; Lalin, 2012) become very high. At point D the stress is changing the sign from positive to negative. This change in sign of stresses point-out to the possible plastic breading-down and fracturing development, as well as the third derivative for pressure impulses. The extreme values of diffusive moments with fluid filtration and rheology of porous space are taken into account in view of their sign for deformation moment as per second Darcy-Fick's Law (Popkov, 2015; Maximov, 1994)

$$u = G\cdot\Delta\ (p - p_c - \rho gh) - D\ \partial^2u/\partial^2y, \quad (7)$$

where p_c – capillary pressure, G - conductivity, D - diffusion factor.

With transition to its own frequency ω_s at $C > a_\mu$ phase angles of pulsing velocities are changing by 180^o, that gives the change in sign K_1. The elastic bulk layers with phase velocities of $C/a_\mu > 1$ at $\omega > \omega_s$ are capable to induce only negative Reynolds' stresses in whole viscous sublayer and this reduces the friction resistance. The amplitudes that arise at the surfaces of similar type are significantly larger than the viscous sublayer and in the area of its proper frequency ω_k ~1 – in several dozens of time, and the surface does not satisfy the conditions of hydraulic smoothness.

As for the multi-layered phase surfaces in heterogeneous reservoirs and their viscous layer near the boundaries where they have high gradient of second moments, the amplitudes of Reynolds negative stresses have the highest value. It should be added here that the boundary of the porous space in heterogeneous reservoirs is always located in close vicinity to porous fluid. If to consider the process in geological age or in anthropogenic one then the evolutionary processes of deformation are evidenced in all scope of geological blocks with saturation and drainage during their development.

Geo-physical Conjugation of Viscous Flow Geo-Dynamics Having dissipative compaction and sedimentation of porous media

Following the geo-physical studies the potential outflow of genesis and well inflow do not have the perfect symmetry by permeability and pressure and this is a consequence of dynamic distribution with extreme gradients for velocities and relaxation time, capillary and gravitational forces. Let's consider filtration velocity U in the double-layered area (fluid + skeleton) of permeable layer (Fig. 4) and diffusive pulsing velocity u for the shear zone with capillary impregnation u_* with minimum velocity of micro-scale $l_*=\nu/u_*$. Let's make conjugation of multi-scaled deformation of micro-world droplets-stats and micro-world conductivity that is asymmetric to de-compacted porous reservoirs and to diffusive impregnation of compacted matrix.

The movement of non-compressible fluid with dynamic viscosity ν is described by a system of Navier-Stokes equations in Reynolds format (Popkov: 2012, 2014, 2015) for mean values of U, pulsing velocities u and continuity

$$\partial u_i/\partial t+u_ju_{i,j}-\langle u_ju_{i,j}\rangle+u_jU_{i,j}+U_ju_{i,j}=-1/\rho\partial p/\partial x_i+\nu\Delta u_i,\ u_{i,i}=0,\ \nu U'=u_*^2+\langle u_iu_j\rangle. \tag{8}$$

Here $\langle u_ju_{i,j}\rangle=(u_iu^*_{i,j}+u_i^*u_{i,j})/4$, *- is a complex conjugation, i, $j=x,y,z$. Initial conditions are $U(x,0)=U_0(x)$. The equilibrium of porous skeleton is described by the equations on movement of the viscous-elastic media of differential type and generalized Hook's Law

$$\sigma_{ij}=\mu(\xi_{i,j}+\xi_{j,i})+\lambda\delta_{ij}\,\xi_{i,i}\,,\quad \sigma_{ij,j}=\rho\partial^2\xi_i/\partial t^2, \tag{9}$$

where λ, μ - are the generalized parameters of viscous-elasticity. At the boundaries of intermediate layers q

$$\sigma_{ij}^{q-1}n_j|_{y=hq}=\sigma_{ij}^{q}n_j|_{y=hq},\ \xi_i^{q-1}|_{y=hq}=\xi_i^{q}|_{y=hq}, \tag{10}$$

where, n – is normal. The external layer is either fixed as $\xi_i|_{y=0}=0$ or free as $\sigma_{ij}n_j|_{y=0}=0$. In the point of contacta $\Sigma|_{y=Y_o}$ the conjugation of macro- and micro-worlds determines the additional boundary conditions at contact Y_o at $\eta=(y-Y_0)/l^*=0$:

$$u_x=\partial\xi_x/\partial t,\ u_y=\partial\xi_y/\partial t-\xi_y\partial U/\partial\eta,\ -p+\partial u_y/\partial\eta=\sigma_{yy}/\rho u^{*2},\quad \partial u_x/\partial\eta+\partial u_y/\partial x=\sigma_{xy}/\rho u^{*2}. \tag{11}$$

In this case the variable values are dimensionless both in micro-scale and impregnation velocity. The generalized model of viscous-elasticity in the harmonic law of loading is determined by the dependencies of shear modulus μ and elasticity modulus λ versus frequency ω

$$\mu(\omega)=\mu_o+\Sigma^n{}_{j=1}\mu_j(\omega\tau_j)^2/(1+(\omega\tau_j)^2)\ -\ i\Sigma^n{}_{j=1}\mu_j\omega\tau_j/(1+(\omega\tau_j)^2), \tag{12}$$

$\lambda(\omega)=\lambda_o-2/3(\mu(\omega)+\mu_o)$ and relaxation function $\mu(t)=\mu_o+\Sigma^n{}_{j=1}\mu_je^{-t/\tau j}$, where μ_o, λ_o – are static modulus and τ_j – relaxation spectrum.

The system of equations in case with neglecting the squared members of velocity pulsing allows us to have the solution in a form of waves $u_i=u_i(y)exp\ i(k_xx+k_zz-\omega t)$, $p=p(y)exp\ i(k_xx+k_zz-\omega t)$. While considering only the waves attenuating by η *the* solutions for the velocities and pressures are recorded in squarings

$$u_j(\eta)=1/k\int G_j(t)sh[k(\eta-t)]dt+C_je^{-k\eta},\ \ p(\eta)=1/ik\int G(t)sh[ik(\eta-t)]dt+C_4e^{-ik\eta}. \tag{13}$$

Here $G_x=\Theta_x+u_yU_x'+ik_xp$, $G_y=\Theta_y+p'$, $G_z=\Theta_z+ik_xp$, $\Theta_i=-i(kU_i-\omega)u_i$, $G=-ik_xU_x'u_y$. The shear stresses that coincide in their direction with wave velocity, i.e. if the torque coincides with the direction of the flow, increase the diffusion velocity.

$$\langle uv\rangle=Re\{1/k^2\iint G_1(t_1)sh(k(\eta-t_1))G_2(t_2)sh(k(\eta-t_2))dt_1dt_2+C_1C_2e^{-2k\eta}+$$
$$+C_2/k\int G_1(t_1)sh(k(\eta-t_1))e^{-k\eta}dt_1+C_1/k\int G_2(t_2)sh(k(\eta-t_2))e^{-k\eta}dt_2\}. \tag{14}$$

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Following the conjugation of diffusion velocities and velocities by Darcy $U=1/æ \ln \eta + C_æ$ we find parameters æ, $C_æ$ for the out-flow, $æ=1/R_oU'(R_o)$, $C_æ=U(R_o)-\ln R_o/æ$. Thus we get the geo-physically conjugated stress-deformed status of diffusive conductivity and dissipation of seismic emission dissipative layer with mean out-flow velocity and well production rate.

Proper Frequencies of Resonant Porous Impulses with Vertical Permeability While determining the diffusive and dissipative properties of sheared layers by pulsing filtration we have also considered the study of proper structural fluctuations and behavior in the area of proper frequencies (Ayachi, 2010; Popkov: 2012, 2014, 2015). At the basis of dispersion equation root analysis let's consider the character of wave distribution that depends on function of losses and type of fixing. Let's record the dispersion correlations for the proper forms of fluctuations on viscous-elastic cylindrical layer at non-symmetrical boundary conditions. The equations (9) presented in a form of Helmholtz have the solution in a form of longitudinal and transverse waves $F=F(r)\exp(i\gamma z-i\omega t)$, where $F=\varphi,\psi$, $\gamma=\alpha+i\beta$ – are complex wave number. In a cylindrical system of coordinates we get the system of differential equation of Bessel type and solution

$$\varphi(z_\varphi)=c_1J_0(z_\varphi)+c_2Y_0(z_\varphi);\quad \psi(z_\psi)=c_3J_1(z_\psi)+c_4Y_1(z_\psi). \qquad (15)$$

In this case $z_f=k_f\cdot r$, $k_f=(\omega^2/a_f^2-k^2)^{1/2}$, $f=\lambda,\mu$, $a_\lambda=((\lambda+2\mu)/\rho)^{1/2}$, $a_\mu=(\mu/\rho)^{1/2}$.

Satisfying the boundary conditions we get the transcendent set of equations of the fourth order. The condition to resolve the existence of a non-trivial solution for the system is the equality to zero for its determinant. This gives the characteristic equation for the proper wave numbers γ and resonant frequencies for viscous-elastic geo-physical emission of filtration attenuation and transformation of longitudinal filtration into transversal ones, $\det\{A\}=0$.

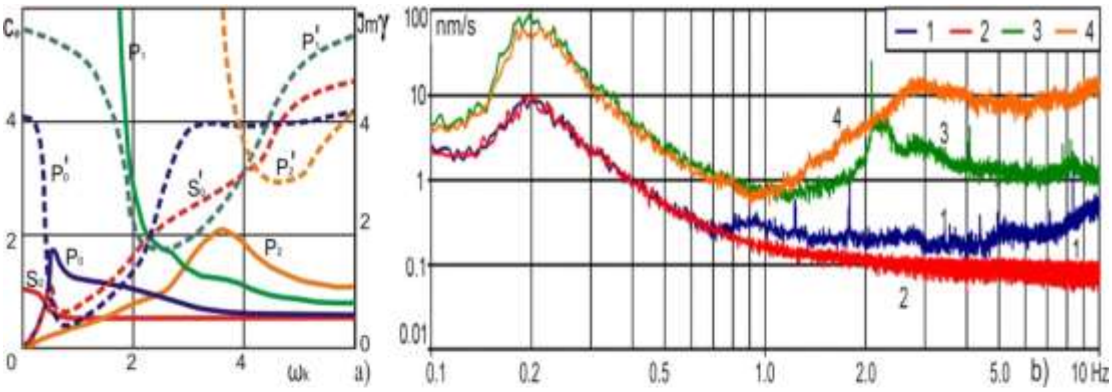

Figure 6(a). Phase velocity and attenuation factor of bended S and transversal P waves in viscoelastic free layers; (b) Seismic amplitude-frequency spectrum

Figure 6a presents the values of dimensionless phase velocity $c_\phi=c/c_o$ (solid line), where $c_o=[\mu(3\lambda+2\mu)/(\lambda+\mu)]^{1/2}$ and attenuation factor γ (dotted line) of free layer depending upon the frequency $\omega_\kappa=\omega h/c_o$. Starting practically from zero frequency there appears the bended line spreading at velocity defined by Young's modulus. With low frequencies there appears the bended wave of basic frequency ω_o. With frequency growth its phase velocity dashes to velocities on transversal waves. At $\omega_\kappa>1$ the porous media generates transversal lines with geoinformative structure, used with seismic studies of lithosphere and hydrocarbon traps. With basic frequencies there is the sharp reduction in attenuation factors.

Figure 6b presents amplitude-frequency spectra obtained at seismic stations 1-СНК, 2-VOS, 3-VRS, and 4-VRH, located within the boundaries of Voronezh crystalline massif at ancient Eastern-European platform. The studies (Nadezhka, 2010) show that with frequency range between 0.1 and 0.3 Hz the micro-seismic noises are formed mainly by microseism of de-compacted migration channel incoming from the Atlantic Ocean. Analysis of daily variations in micro-seismic noises within 1-8 Hz frequency range have shown that correlation of micro-seismic noises there may be motivated by the fact that geological structure and anthropogenic load produce the prevailing effect upon the formation of high-frequency constituent.

Here, in the paper we used also the data for deep-wave channel survey at Lofoten basin obtained in course of XVII Int'l Oceanic Expedition conducted by "Prof. Logachev" research vessel as per UNESCO/MOC program "Floating University Training through Survey", published in (Yurchenko, 2009). Subsea Lafoten basin is located in the northern part of the Norwegian Sea, stretching for more than 200 km from the mouth of Andoya canyon to the deep-water part of Lofoten basin and is in good correlation with presented model of structural-phenomenological stress release at Middle Oceanic Rift.

DISCUSSION OF RESULTS

The structural phenomenological forms of capillary/molecular movement in deformed porous micro-structure of the Earth correspond to all presently discovered phenomena of physical and chemical forms for the interaction between the matters. For the individual case with stress-deformed status of porous filtration hydro-dynamics in continuous media – this correspond to multi-phase trajectories for viscous, plastic and elastic phase movement.

Following the viscous-elastic properties of compacted reservoirs and models for duplicated porous space one may come to a conclusion that deformations are carried out at different velocities and phase angles of viscous dissipation. This defines the optimum conditions for the application of new procedures in search, exploration and development of the fields, the number of stages and level for hydro-fracturing in dense formations, development of high-viscous or bitumen reservoirs, water shut-off and water inflow divergence, application of various "smart" micro-elements, by enhanced oil recovery in view of energy potentials based upon the generalized Darcy's Law and deformation of phase diffusion (second Fick's Law). This solution gives the possibility to drop the risks and costs through all the life stages of the field.

Here we present the energy-substantiated geo-physical and physical/chemical global processes of Lithosphere, that take place in reservoirs and in adjacent geological media. In order to produce oil and gas using the well-known and the new-designed methods and technical means it's required to develop the scientific grounding for the effective and ecologically-safe system of de-fluidization and commercial development of the fields.

Analysis of complex equations of dispersion for the bulk saturated rock in elastic shell of bended membrane type have shown that with low frequencies it is possible to form the volumetric longitudinal mono-chrome auto-waves (Lalin, 2012) with minimum dissipation factor (Mironova, 2014; Popkov, 2012).

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This method enables us to create a new type of multi-phase computer software for numerical calculations over the pressure zones and well production rates (Manyrin, 2005). Three-phase 3D hydro-dynamic simulator with dynamic equilibrium for phase relative phase permeability in view of deformation rheology was tested both in Carbonate and Terrigenous reservoirs, in low-viscous and high water-cut fields, at high-viscous and bitumen reservoirs of Russian and Caspian regions.

For the solution of the designated targets we have applied the system-type approach (Popkov, 2009) that included the merge of theoretical methods with the performance of filtration, computational field experiments and the use of standard and specially designed methods. The procedures can be used both for express evaluation of oil recovery factors and for 3D hydro-dynamic modeling, at the stage of exploration and productive reservoir commissioning, while shaping the effective system of field development and for the stage of additional reservoir development, with the objective to locate the residual reserves, to increase the reservoir sweep by draining. The method to define the fracturing was considered using the representative materials for the Volga-Urals oil-gas bearing province and this enables us to apply its recommendations for the other oil-gas bearing regions.

THEORETICAL IMPLICATIONS

Through theory we have defined the connection between geo-mechanics and fluid flow and propose the simulation methods to change the reservoir permeability and other possible geo-mechanical effects. We have also considered the methods of optimum and safe conditions of reservoir operation and development in view of reservoir and cover compaction, expansion and integrity.

The mean viscous flow come to diffusion-dissipative impregnation at velocities $U=35u_{min}\sim 35\cdot 10^{-7}$ m/sec irrespective the type of geological boundary. The global structurally polarized energy basin-type modeling of the Earth's status is possible through the application of evolutionary conjugation of various types of equations or through the application of Navier-Stokes equations.

CONCLUSION

The unstable surface of viscous-elastic layer generates tangential stresses at the surface $\tau_{\omega}= -1/2\cdot\rho\omega^2|\xi_2||\xi_1| \cos\theta \cos(\varphi_2-\varphi_1)$. Taking into account the shifts along the horizontal axis this unstable surface generates additional stresses that are proportional to square of frequency and sum of surface motion amplitudes, as well as difference in phases for vertical and lateral shifting of the surface.

The authors have shaped the law on quadratic compaction of geological layers by porous-fractured orbital evolution and tunnel-type de-compaction of viscous-bulk and quadratic de-compaction by frequency, velocity and density – tangential compaction with significant period for relaxation. The solution generalizes the Newtonian Darcy's Law towards the second capillary inertial conjugation for the deformation of the porous fluid in continuous media, being valid both for fractured-porous and for compacted low-permeable reservoirs with high-viscous oil and natural bitumen being in the challenging geological and physical conditions.

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