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# ESTABLISHMENT AND DEVELOPMENT OF NON-CLASSICAL LINEARIZED APPROACH FOR STUDYING OF THE EARTH SCIENCES PROBLEMS (Review)

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ABSTRACT. The work was devoted to the review of publications dedicated to the new non-classical approach of studies of various problems of the Earth Sciences. The integrated interdisciplinary approach was based on the nonlinear theory of deformation of continuous solid media. Various specific tasks of mining mechanics, the internal structure and dynamics of the Earth, seismology, geophysics, seismic exploration were studied using the established approach.

The deformation process of three-dimensional bodies with fractures and cavities of non-circular cross-section was studied. The mathematical three-dimensional theory of stability of wells was established.

The theoretical bases of studies on the problem of geodynamic-tectonic and structural evolution of the Earth were developed. The basic principles of construction of the non-classical approach were given. The problems of different scale structure formations were studied from the standpoint of the new approach. The processes of structure formations in the sedimentary cover due to the prediction of oil and gas content were studied. Near-surface and near-fault structure formations were considered. The features of the deformation processes in the formation of internal structures and dynamics of the Earth were shown.

Geodynamic aspects of earthquakes and destruction mechanics of deformable solids were studied within the concept of instability.

Theoretical bases of seismogelogical model of the geological medium were developed on the base of propagation of elastic waves in the stress nonlinear anisotropic media.

The seismic anisotropy and influence of deformation on values of elastic parameters of the geological medium were studied on the basis of seismic and well data considering the current geodynamics.

Keywords: deformation, non-classical linearized, fault, geodynamic, earthquake, mechanism, seismic, magnitude, tomography

Geology made a turn from the broad speculative sentiments to practice of rigorous experiment at the turn of XIX – XX centuries. Descriptions of phenomena and natural philosophy, which became the cornerstone of abstract constructions based on centuries-old dogmas dominated in geology prior to that. If physics has already begun to release from Aristotle's views and to transform into an exact experimental science in the XVII – XVIII centuries, so, the breaking away from natural philosophical traditions were delayed until the beginning of XX, i.e., before the appearance and application of instrumental geophysical methods of studies. Geology and geophysics achieved great results in this way. Geologists firmly made clear that facts are the base of science development. The founder of the experimental direction in physiology of higher neural activity - I. P. Pavlov wrote: "Facts are – the air of the scientist". However, he noted further that the collection and accumulation of facts is not the real science yet. The naked empiricism without generalizing theories is blind. Experimental direction in geology, in contrast to the previous, purely descriptive direction implies not only the collection of facts, but also purposeful statement of questions. A geologist – experimenter plans an experiment. He judges on the internal structure of the Earth and features of its functioning on the basis of analysis conducting the accumulated geological and geophysical data. Therefore, the best representatives of the experimental direction were not limited by the collection of facts, but established theories on their basis. Jeffrey Gutenberg's theories, Parametric Earth Models (PEM), plate tectonics, plume tectonics,



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the tectonic layering of lithosphere, etc., established as a result of analysis of the vast factual material are the most prominent.

Along with it, there is a lack of generalizing theories that are able to unite and group disparate facts, indicate perspectives of further studies, establish preconditions for the integration of results, methods and approaches of various sciences and for the generalization of a number of observations in order to ultimately formulate new questions on nature and essence of phenomena.

In this sense, noteworthy is the decision of the Presidium of the AS of the USSR adopted in the early 80s of the twentieth century on support of effort of integration approaches in scientific studies of various field.

Based on these considerations and demands of geology, geophysics, seismology, seismic exploration, development of oil and gas deposits, well drilling, etc., departments of "Geodynamics and geomechanics" (headed by H.H. Guliyev) and "Geofluid dynamics" (headed by R.D. Javanshir) were created in the mid-80s of the last century in the Institute of Problems of Deep Oil-Gas Fields (IPDOGF) of Azerbaijan National Academy of Sciences. The development of scientific basis of geodynamic development of the lithosphere and its structures was determined as one of the main directions of scientific researches of these departments. These departments have been assigned the task to achieve the improvement of integration of methods to study mathematics, mechanics, geology, geophysics and the science on oil and gas in studying the various problems on the Earth Sciences.

A great number of studies were performed in the above mentioned direction for the past time by participation and under the leadership of this group. A new non-classical approach of studying fundamental and practical tasks related to different sections of the Earth Sciences was established on the basis of the integration of current results of mathematics, physics, mechanics and information technologies.

Evolution of the Earth within the non-classical-linearized approach (NLA) is studied in the form of the sequence of change of unstable equilibrium states manifested in the form of disturbances (anomalies) of the baseline continuous development. The disturbed states characterize the formation of structural elements of different scale and occur in certain critical correlations between geometric, different (of arbitrary nature) force and deformation parameters of the baseline state. Structural elements of the internal structure of the Earth correspond to fundamental characteristics of a deformable system; the presence of earlier found vertical and lateral structures of fault type following from NLA are theoretically justified by geological and geophysical methods and it's shown that they occur as necessary stages of natural development of the Earth. New mechanisms are proposed to form these and similar tectonic structures. Much attention was paid to methodological aspects of theoretical studies of deformation processes in tectonophysics. The development of scientific basis of deformation processes shows fundamental and practical interest in geodynamics.

Geological objects including the Globe are theoretically open non-linear systems. The study of such systems has serious theoretical (physical and mathematical) difficulties in many cases. On the other hand, problems of the current geodynamics, in principle, relate to interdisciplinary. In this regard, the current geodynamics of the Earth and its structures hasn't been studied sufficiently yet in a theoretical sense.

Problems of the given direction received a powerful impetus of the further development with the development of technique and methods of seismic tomography, aerospace sensing, GPS technology and with the progress in the study of physico-mechanical, petrophysical properties of minerals and rocks at high thermobaric conditions. Many well-established scientific theories greatly refined, have undergone significant changes and additions. A number of scientific conceptions and theories were developed and accepted by specialists that playing their role in studying of these problems were reconsidered further. Their place is now occupied by other approaches, and the process continues. Many generalizing monographs, review articles and original works of reputable scientists, numerous specialized scientific journals on the given subject appeared in recent years also show that the scientific community makes serious efforts to solve these fundamental problems. It's



known for example that, the program "Deep structure of the Earth" is one of the main directions of the activity of Institutes of the department of the Earth Sciences of the Russian Academy of Sciences.

## 1. MINING MECHANICS

**1.1. The studying of deformation process of three-dimensional bodies with fractures and cavities of non-circular cross-section.** A unified approach was established to study the above mentioned classes of tasks within the non-classical linearized mechanics of deformable solids, the variational method was also developed to solve and an entire group of etalon tasks was also solved. The monograph was published on the basis of materials of these studies [6]. The review of the published scientific papers on the given subject was also given in it. The review was also given in the paper [8].

**1.2. The mathematical three-dimensional theory of the stability of wells.** Scientific bases of the mathematical theory of the stability of wells were developed in modeling the geological medium in the form of the compressible and non-compressible deformable materials within the three-dimensional NLA. Developments of the mathematical theory of the stability of wells based on general principles of stability theories were begun to conduct within the mechanics of a deformable solid body [3].

The obtained numerical results were included in generalizing monograph [5], which was awarded by silver medal of the All-Union Exhibition of Economic Achievements of the USSR in 1988. The review of the published scientific papers on the given subject was also given in it.

## 2. THE INTERNAL STRUCTURE AND DYNAMICS OF THE EARTH

The review of publications and the current state of problems of the internal structure and dynamics of the Earth were performed in papers [9, 10, 12, 14, 15, 16, 18].

The problem of the internal structure of the Earth is – super-complicated and multi-faceted (meaning unclear). A number of main directions were outlined in studies of this problem. Geological-geophysical tasks and models relating to the continental and oceanic crust (there is also the internal differentiation, i.e., structures of the sedimentary cover and consolidation core – the foundation), the continental and oceanic lithosphere, the upper, middle and lower mantle, the outer and inner core are considered separately. The most developed are the tasks related to the sedimentary cover, i.e. there is a possibility of direct observation by well drilling along by indirect geological and geophysical methods of studies. Geophysical methods to study deeper Earth's interior are also tested and sampled in studying the sedimentary cover.

Tomographic studies show that there is also heterogeneity and geosphere interfaces in the middle and lower mantle. It was found that the matter density isn't increased below the point of certain depths, on the contrary it (i.e. the matter) is in a deconsolidated state.

Based on the analysis of three-dimensional images of seismic tomography irregularities, their spatial displacement, shapes, sizes and intensity in mantle geospheres concluded that tectonosphere isn't limited by the lithosphere or the upper mantle as they think, and extends to the Earth's core covering the mantle in its entirety.

Structures of fracture type (spreading zones, rifts, transformation, demarcation, magistral, oblique faults, zones of subduction, collision, listric faults, suture zones, sutures, etc.) are one of the main objects of the study in geology and geophysics. Passive and active models of riftogenesis exist.

There are a large number of works devoted to experimental facts and scientific concepts that form the basis of model studies on the lithosphere structure.

Abnormal density changes on depth of the Earth are related with the chemical and phase transitions.



**2.1. Theoretical basis of studies on problem of geodynamic-tectonic and structural evolution of the Earth.** NLA is one of the integrated approaches. Assumptions on the evolution of the spherical Earth filled by continuous deformable composite medium (in mechanics and physics notion) were used as an initial position in the creation of NLA. It is considered that tectonic and structural evolution (consisting of continuous and discontinuous, including catastrophic changes) of this spherical deformed body occurs over 4, 6 – 4, 7 billion years.

**2.2. Basic principles of NLA construction.** Based on the results of analysis obtained in geology and geophysics, studies on geodynamics can conditionally be divided into two groups. The historical course of the formation and development of separate geological structures and the whole of the Earth is described within the first direction using methods of geological reconstructions over geological period. The other group consists of studies on the current geodynamics, i.e., the study of movements, structural formations, destructions, etc. which occur at present in the Earth's interior and in principle, are subjected to direct or indirect observation by the same or another instrumental way.

Classical linear approach was widely used in different fields of natural science. The initial non-linear tasks are exposed to too rigid simplicity.

Another widely used approach of simplification is the non-classical linearization. In this case, the linearization is conducted in a small vicinity of the actual state at any stage of deformation.

A new theoretical model of the lithosphere evolution was established within the NLA [10, 12, 13]. The given approach allows newly studying large classes of tasks of geology, geophysics and seismology on a unified theoretical base.

The instability concept was proposed within the NLA [10, 13] in the current geodynamics according to which all processes and phenomena are considered not in a traditional geological, but in a new geophysical medium.

Basic systems of equations and boundary conditions of three-dimensional NLA in a Lagrangian coordinate system $x_i$ for compressible models of medium were given [3]

$$\frac{\partial}{\partial x_i}\left(\omega_{ij\alpha\beta}\frac{\partial u_\alpha}{\partial x_\beta}\right)=\rho\frac{\partial^2 u_j}{\partial t^2}\qquad i,j,\alpha,\beta=\overline{1,3}. \tag{1}$$

The boundary conditions in stresses

$$N_i\omega_{ij\alpha\beta}\frac{\partial u_\alpha}{\partial x_\beta}\Big|_{S_i}=P_j. \tag{2}$$

The boundary conditions in displacements

$$u_j\big|_{S_2}=f_j. \tag{3}$$

Similar equations are also recorded in case of incompressible media with additional conditions of incompressibility.

In contrast to the classical approach, solutions of equations along with linear physico-mechanical properties are constructed depending on values and character of non-linear physico-mechanical properties, geometric and force parameters. The principal difference is that the eigenvalue tasks are considered instead of boundary tasks of mathematical physics.

**2.3. Some results on problems of different scale structure formations from the NLA standpoint.** Development of a mathematical model of the formation and development of folding through various forms of stability loss of equilibrium states allowed conducting a theoretical base under the geotectonic construction in part of structural formations [9, 10, 12, 13, 14, 15,].



Qualitative analysis of equations' system (1) shows that it has three mutually perpendicular families of characteristic surfaces. They correspond to meridional, equatorial and spherically concentric families of surfaces in a spherical coordinate system. Coaxial cylindrical surfaces are also
characteristic in axisymmetrical deformation. Two families of characteristic lines are in the two-dimensional case in the polar coordinate system: radial rays and concentric circles. The basic systems of equations are degenerated in these characteristic lines and surfaces in certain correlations between physico-mechanical and

force parameters [15]. It turns out that herewith, deformations endure discontinuity in these lines and surfaces. A good example experimentally confirming this theoretical result of NLA is a well known picture of destruction of car windshields in contact with stones.

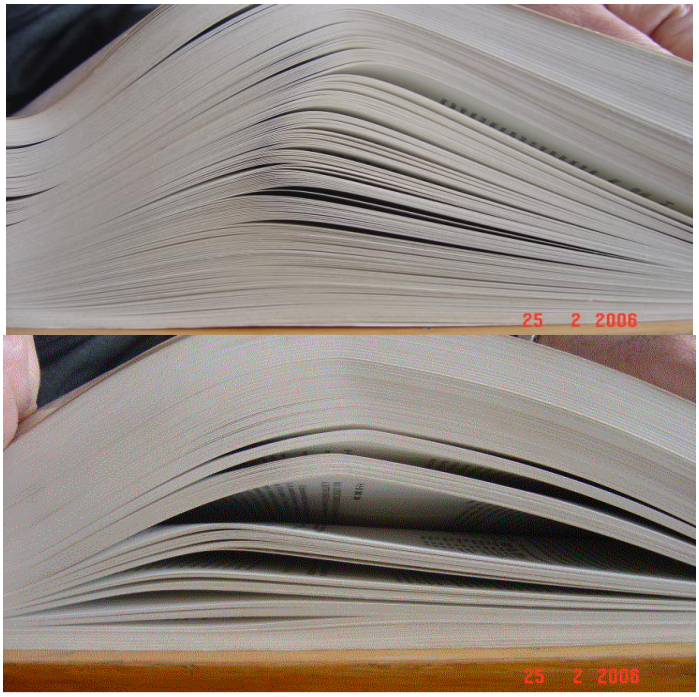



Figure 1. Destruction through delamination (brooming).

It was concluded [14, 15, 16] that lateral faults which occupy large areas should exist at various depths of the Earth (Fig.1). Naturally, we can assume that some shift, cover, thrust, deconsolidated zones and large mantle heterogeneities are lateral faults with waveguide properties.

Based on results of studies of the destruction mechanism of the layered composite materials, it was suggested that the destruction with the delamination (brooming) at various stressful conditions can be one of possible mechanisms of the formation of lateral faults in the Earth's interior [14, 15] (Fig.1.).

Acceptance of the fact on presence of newly formed plates with large degrees of freedom both vertically and laterally within different platforms and possibly, median masses allowed suggesting a new mechanism to implement vertical movements (including the raising of lumps).

The results of analysis [11, 16] show that, formations of certain types of structural elements and their paragenesis in the isolated state or in the baseline of larger movements and forming can be realized depending on the degree of development of geodynamic condition and geological conditions at different scales and levels.

**2.4. Structure formation in the sedimentary cover due to the prediction of oil and gas content.** An important issue of geotectonics is the basis of nature and mechanism of formation of horizontal stresses in sedimentary complexes and, as a sequence, roles of the latter in folding genesis [9, 10, 12, 13].



Two possible mechanisms to form horizontal compression forces due to "internal" factors of sedimentary complex were proposed, which allows approaching to the problem of folding in sedimentary basins from new standpoints [12, 13]. These mechanisms are the followings:

*a. The occurrence mechanism of inner basin horizontal compression stresses due to inversion of rocks' densities.*

*b. The occurrence mechanism of horizontal compression stresses in quickly sinking basin.*

The implementation of other mechanisms of formations of horizontal compression stresses that are sufficient to form the folding through the stability loss in the equilibrium state of the considered layer is possible in the sinking basin.

**2.5. Near-surface and near-fault structure formations.** Many tectonic and geodynamic problems are related with the formation and development of various geological structures near the free and loaded surfaces in varying degrees.

Geological problems of the near-surface and near-fault structure formations are reduced to mechanical and mathematical tasks that are put in semi-restricted fields, i.e., in the semi-plane and semi-space.

A special class of stability tasks is the tasks of the near-surface and near-fault loss of stability where disturbances extending along infinite sides and surfaces of semi-planes and semi-space are localized in their close vicinity and sites die out in the displacement from them to the internal zones.

**2.6. On the fundamental role of deformations in the internal dynamics of the Earth.** One of the main sections of the study in theoretical models of the Earth's evolution is related with the question on the distribution of the density of the geological medium.

It's assumed in structural geology that the distribution of matter density of the Earth's interior has the form shown in Fig. 3a.

Based on fundamental properties of the main systems of equations of the mechanics of deformable solids, it's shown that there are some general geomechanical bases of these phenomena [16, 18]. It's shown that there is a general mechanism of consolidation of compressive medium, which moves to deconsolidation in certain stages of process. In the further evolution some of these deconsolidation zones can turn into the focus of the diluted mass and give rise to a mass flow in different directions.

In particular, the results reflected in Fig.2 show that the non-uniformity of deformations has a significant impact on the growth of density [16, 18].

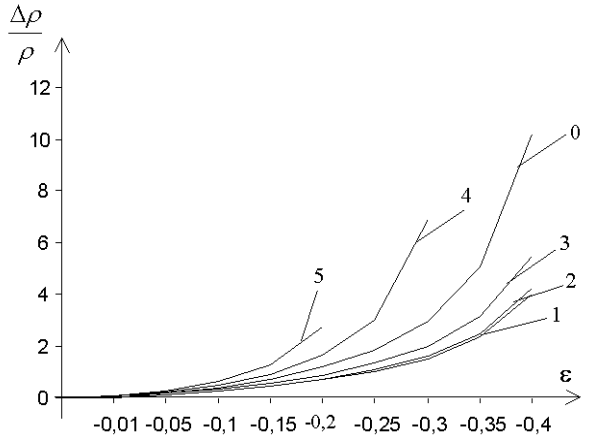



Figure 2. Graphs of the density accretion in the case of 3D non-uniform deformation (Guliyev, 2010): line 0 - $\alpha=\beta=\gamma=1$; line 1 - $\alpha=\beta=1,\ \gamma=0{,}01$; line 2 - $\alpha=\beta=1,\ \gamma=0{,}1$; line 3 - $\alpha=\beta=1,\ \gamma=0{,}5$; line 4 - $\alpha=\beta=1,\ \gamma=1{,}5$; line 5 - $\alpha=\beta=1,\ \gamma=2$; $\varepsilon_1=\alpha\varepsilon_0,\ \varepsilon_2=\beta\varepsilon_0,\ \varepsilon_3=\gamma\varepsilon_0$.

Seismoprogn. Observ. Territ. Azerb., V.11, N.1, 2014

Various non-uniform overall deformation states were considered. It was shown within the NLA that these solutions are unstable for a variety of media. It means that consolidation process of substances moves to deconsolidation process with the growth of values of deformations. Based on these theoretical results a new idea on the distribution of matter density of the Earth on depth was proposed (Fig. 3b).

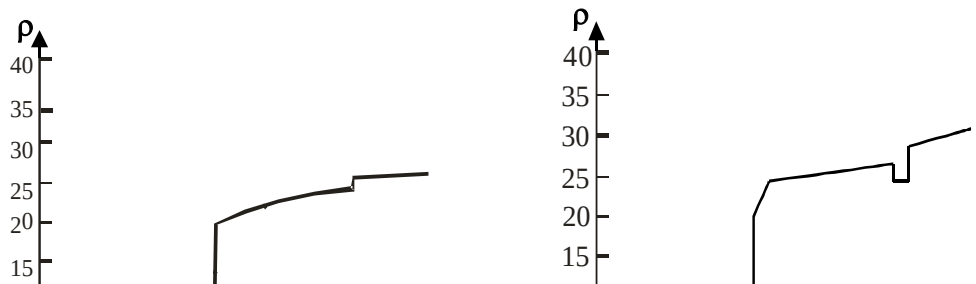


Figure 3. The chart of the distribution of matter density of the Earth on depth.

It was shown that [17, 18], as a result of a specific deformation, consolidation processes move to deconsolidation processes at various depths and zones of phase transitions, cavities, zones of low shear stiffness (waveguides), foci of the diluted mass and generation of autonomous mass flow, not related with the external liquid of the Earth's core are formed.

## 3. SEISMOLOGY

**3.1. Geodynamic aspects of earthquakes.** The Globe is located in ongoing geodynamic evolution. The earthquake is one of recent manifestations of this evolution. Slow continuous baseline geodynamic changes (during which accumulation of deformation energy and its transfer to other forms of energy occurs in parallel) move to quick (intermittent) geodynamic changes (in course of which a partial or complete release of the accumulated energy of deformation occurs by much quicker movements) in certain local zones of lithosphere. The results of such changes in the form of elastic vibrations appear on the surface of the Earth. Sometimes, fractures are formed on the surface of the Earth.

The above mentioned approach also allows offering one of the possible theoretical bases of the phenomenon "Induced earthquakes". There is a scientific assumption on the earthquake as the "induced" phenomenon for more than 70 years, i.e. it is considered that the earthquake isn't purely internal property of the geodynamic system, and may also be caused by extraneous action.

**3.2. The mechanism of destruction of deformable solids within the instability concept.** The following statement is important in the suggested concept: the value of a monotonically increasing external load corresponding to the loss of ellipticity was accepted for theoretical tensile strength (TTS) of model of homogeneous isotropic unlimited material, and dependences determining this value, serve as local criteria of destruction within the linearized theory. However, these criteria are integral as a whole. At the same time, regardless of the types of external efforts (dead, followed), structures of the linearized boundary conditions and geometry body, equations (1) have a non-trivial and non-unique solutions. Such situation is possible when lines (surfaces) of destruction are formed or developed in the body. Characteristic lines (surfaces) of system of hyperbolic equations (to which the system of equations (1) moves in achieving values of external loads equal to TPP) are lines (surfaces) of a weak



fracturing, i.e. the fracturing of deformations. The equations (1) are linear. Therefore, their grid of characteristics doesn't depend on their solutions, i.e. the direction of destruction is determined by purely mechanical properties of the material and character of initial stressed state.

The process of brittle destruction is considered the main mechanism of energy release of deformation in "focal" earthquakes. General physical principles of geodynamic development in particular the Earth and its lithosphere were formulated which allow more reasonably creating theoretical models of the formation of earthquakes' "focus" and their further evolution.

According to the instability concept of mechanics of brittle destruction of the deformed solids with fractures [1, 2, 6], the destruction process doesn't begin by straight-line shape of fracture which is in the body of undeformed and initially-deformed states, but with its other curved configuration.

In the case of "internal instability", the equilibrium state of homogenously-deformed body is lost completely, i.e. unlike other local and general forms of the stability loss, the body exhausts the possibility of transmission to the other equilibrium states.

Criteria of brittle destruction of materials in non-uniform stress states considering the theoretical tensile strength of material in the form of a critical force of "internal instability" have been proposed [4, 6].

A local form of stability loss of equilibrium state of three-dimensional space in the vicinity of a flat fracture in a uniform force field, with the involvement of variational method was studied for the first time [6].

The cases of uneasily compression of homogeneous and composite bodies along the existing fractures in them were considered in all of the above mentioned papers. The values of the critical forces of local forms of instability can be taken for values destructing the loads for certain classes of tasks.

It was shown within the linearized mechanics that [4, 6] it's not possible to create fractures with zero thickness in the model of ideal elastic medium. There are restrictions for any form of the section, to which dependences between geometric parameters of section and force parameters are subjected. These restrictions were formulated in the form of destruction criterion under non-uniform stress states.

Various forms (bending, symmetric and mixed) of general stability loss of the band were studied [16, 18] in statement of external impacts of various nature in its side surfaces within the three-dimensional linearized theory.

## 4. THE DEVELOPMENT OF NLA IN PROBLEMS OF GEOPHYSICS

**4.1. On the propagation of elastic waves in the stressed non-linear anisotropic media.** In a large quantity of works [11, 13, 18], theoretical bases of three-dimensional non-classical linearized baseline are developed within the NLA based on three-dimensional non-linear elastodynamics with the purposes of more complete, reliable, accurate and reasonable studying of influences of various linear and non-linear physico-mechanical properties of compressible media, three-dimensionality of deformation process, stress states and geometry of geological structures on the formation process of kinematic and dynamic characteristics of elastic waves.

The kinematic and dynamic characteristics of pressure and shear waves have been studied in non-linear elastic isotropic media at various homogeneous stress states involving a three-dimensional linearized theory.

An approach to determine the true values of Poisson's coefficient was suggested on the basis of laboratory and field seismic data.

The basic principles of construction of strict 3D multi-component seismicity were developed on the basis of nonlinear elastodynamics.

The velocities of the propagation of elastic waves are defined by formulae in the most general form [11]



$$2\rho V_\alpha^2 = \omega_{3333} + \omega_{3113} + (\omega_{1111} + \omega_{1331} - \omega_{3333} - \omega_{3113})\sin^2\theta_\alpha \pm Q_\alpha; \tag{4}$$

$$Q_\alpha = \left\{\left[(\omega_{1111} - \omega_{1331})\sin^2\theta_\alpha - (\omega_{3333} - \omega_{3113})\cos^2\theta_\alpha\right]^2 + 4(\omega_{1133} + \omega_{3131})^2 \sin^2\theta_\alpha \cos^2\theta_\alpha\right\}^{\frac{1}{2}}$$

In the expression (4) the sign "+" before the additive $Q$ corresponds to quasi-pressure $P$ wave and wherein $V_\alpha = V_p$; but the sign "_" to – quasi-shear SV wave and wherein $V_\alpha = V_{SV}$.

The value of velocity $V_{SH}$ is determined from the characteristic equation

$$\rho V_{SH}^2 - \omega_{1221}\sin^2\theta - \omega_{3223}\cos^2\theta = 0. \tag{5}$$

The effective values of parameters characterizing the linear and non-linear physico-mechanical properties of rocks can be calculated theoretically for all three components of the elastic wave velocity in the presence of seismic data.

**4.2. On the kinematic corrections in the stressed media.**

The values of average velocities of elastic waves are one of the main kinematic characteristics which are used in seismicity. In contrast to the isotropic case, the necessity to determine the values of average velocities of waves arises in anisotropic media even in a single layered medium.

An effective method for synthesizing the true values of the physico-mechanical properties of rocks from the database of field measurements (for example, the registration of parameters of seismic waves) was developed.

The wave used in seismic exploration is propagated in stress medium. It was received in this case [7]

$$\nu \approx \nu_0 + \frac{p}{2\rho\left(V_{p_0}^2 - V_{s_0}^2\right)}\left[\left(1-2\nu_0\right)A - 2B\left(1-\nu_0\right)\right] + \ldots \qquad (6)$$

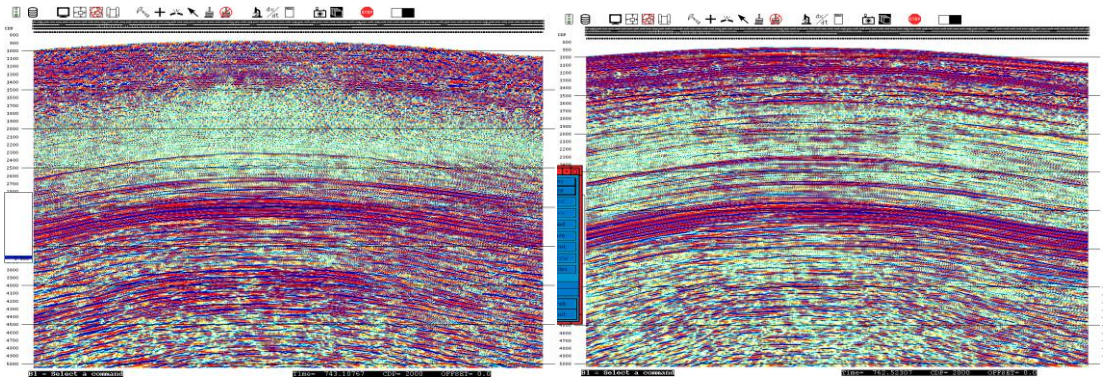
We see from (6) that only the first additive determines the value of Poisson's coefficient but the following additives reflect the influence of non-linear properties of material, three-dimensionality of phenomena of wave propagation, stress state, etc. on the value of velocity of pressure and shear waves.

## 5. SEISMIC EXPLORATION

**5.1. Seismic anisotropy.** Specific non-linear questions of seismic exploration arise in the case of considering non-hyperbolic part of hodograph in the processing and interpretation of seismic data. Studies of the given problems allow using seismic data from more distant CDP seismogram. The integration of these results with the results of studies of the kinematic and dynamic characteristics of elastic waves in the stressed non-linear anisotropic media allowed developing a modern approach to study the seismic anisotropy and appropriate interpretive software [11, 19].

The results of distribution the effective value of the anisotropy parameter were obtained on seven various CDP profiles. Some typical comparative results of the kinematic correction considering anisotropy and without it for specific CDP are shown in Fig.4.





**b)**

Figure 4. The summed seismic section without considering the anisotropy (a) and with the consideration of the anisotropy (b).

Various two-dimensional models of the combined elasticity moduli of the third order n1 and n2 were calculated in various values of the fracturing (Fig.5).

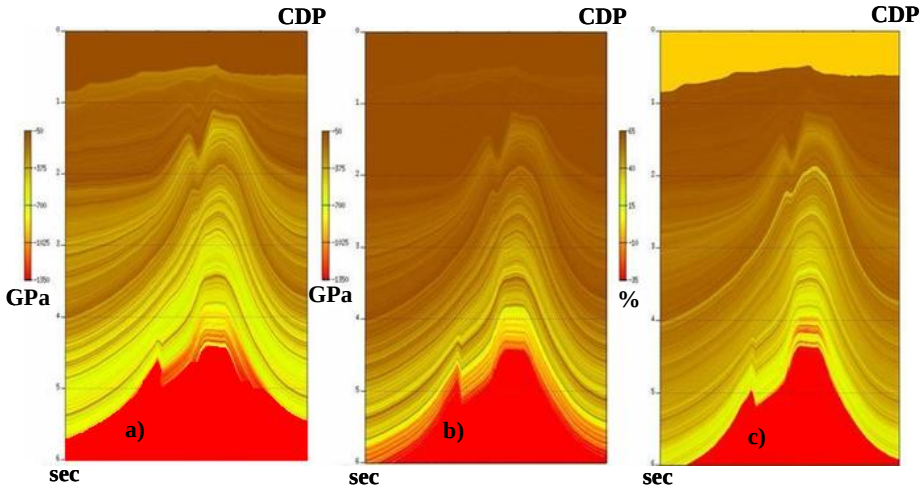



Figure 5. Time sections of the combined elasticity modulus n2 in the fracturing 0.02 (a), 0.08 (b) and their difference (c).

**5.2. The studying of pressure influence on values of elastic parameters of the geological medium on the basis of seismic and well data.** Based on the non-classical linearized theory, an approach to determine the second order of elasticity moduli as well as Poisson's coefficient was developed for the stressed non-linear media. There are numerous studies to determine elastic parameters that are partially reflected in papers [7, 11, 18, 21].

($E$): Calculation formulae to determine basic physico-mechanical parameters of the geological medium – Poisson's coefficient ($\nu$) and Young's elasticity modulus ($E$) were suggested:

$$\nu = \frac{V_{pzp}^2 - 2V_{sxp}^2 - F(\rho, V_{pz0}, V_{sx0}, P)}{2[V_{pzp}^2 - V_{sxp}^2 - F_1(\rho, V_{pz0}, V_{sx0}, P)]}; \qquad E = 2(1+\nu)[\rho V_{sxp}^2 - F_S^R(\rho, V_{pz0}, V_{sx0}, P)].$$

Calculation formulae $F$, $F_1$ and $F_S^R$ are differentiated for various stressed states of medium (prior to the excitation of seismic waves in it) and alternatives to simulate forms of elastic vibrations.

Acoustic and geodynamic models of the studied medium of the SCB were prepared on data of geophysical studies.



Depth sections of Poisson's coefficients were calculated using classical and non-classical theories: on the first variant of the theory of small and large initial deformations. The difference of two sections of Poisson's ratio is shown in Fig. 6a, b.

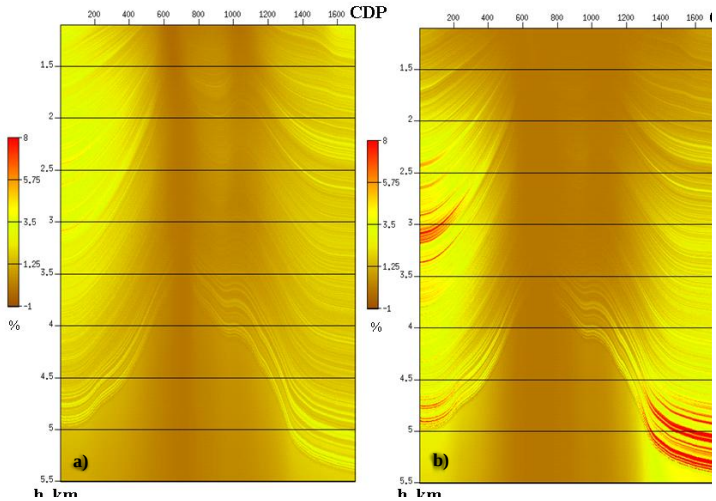



Figure 6. The difference of sections of Poisson's ratio calculated on classical and non-classical theories: the theory of large initial deformations (a), the second variant of the theory of small initial deformations (b).

Time sections of pressure waves without consideration (Fig. 7) and with consideration (Fig. 8) of differences of geostatic pressure in model point and in the current point of the profile on all of the given layers of the geological medium were calculated on the basis of acoustic model.

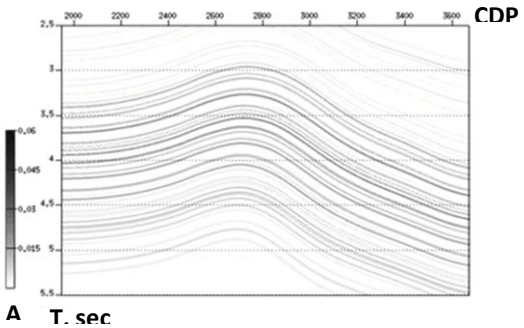



Figure 7. Synthetic time section of seismic profile without consideration of pressure change

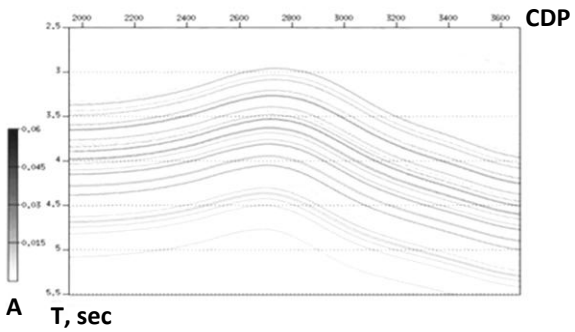



Figure 8. Synthetic time section of seismic profile considering pressure change after correction of layer velocities

The fracturing in the rock is modeled in the form of arbitrarily oriented disc-shaped micro-fractures of infinitesimal thickness. Such fracturing is used in practice as a model of rock porosity. To assess the influence of changes of parameters of porosity, pressure, velocities of pressure and shear waves on values of moduli $n_1$ and $n_2$, their values were calculated at various changes of one-dimensional thin-layered models.

**5.3. Studies of physico-mechanical properties of rocks of the geological section considering the effects of the current geodynamics.** Tectonophysical parameters (TP) of the geological medium, such as physico-mechanical properties of rocks, deformations, velocities of the propagation of elastic



waves, density etc. are usually determined experimentally in laboratory conditions or at atmospheric pressure and room temperature. It's assumed that the TP are formed through fundamental elastic coefficients (Lame and Poisson's coefficients). Hence, these parameters describe the geological medium (and rocks) in the case of which they are not exposed to external impact. Many problems and tasks are studied under natural conditions in geology and geophysics. Contributions are also brought in quantitative values of TP by the

current geodynamics (CG). The values of these contributions become significant for larger depths. The contribution related with the CG is transformed through the stress-deformation state. The dimension of stresses and fundamental elastic coefficients are the same. It is necessary to separate the main baseline part (undeformed state) and the contribution, related with the CG in the TP (further CG corrections in TP) under the interpretation of results.

Appropriate sections to solve the tasks of seismic profile inversion were directly used (observing carefully) to increase the accuracy and reliability of results in modeling of the geological section instead of extrapolation of well data to other sites of the section.

Seismogeodynamic corrections to various tectonophysical parameters were obtained using standard procedures of processing and interpretation of seismic data and NLA.

The described method was applied to predict the two-dimensional model of the medium on the basis of velocities of shear waves, GEW (Geophysical exploration of wells) data and 2D marine seismicity on pressure waves related to one of the structures of the SCB (Fig.9).

The sections of the elasticity moduli of the third order $n_1$ and $n_2$ were calculated on models (Fig.5).

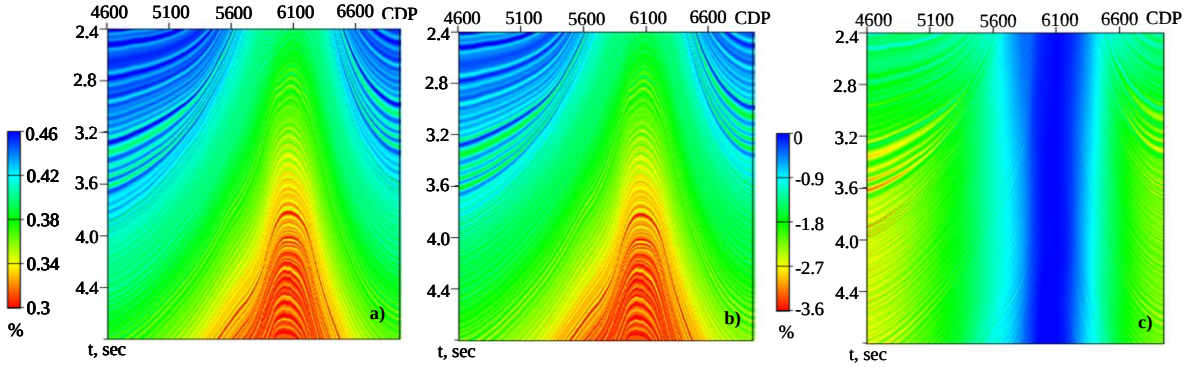



Figure 9. Time sections of Poisson's ratio on the classical (a), non-classical (b) (theory of large initial deformations in the case of simulation waveforms according to the "true" velocities) theory of deformations and difference of sections (c)

## 6. CONCLUSIONS

A new non-classical approach was established to study various problems of geology, geophysics, seismology and other sections of the Earth sciences. The theoretical bases of the given approach were developed, the corresponding geological and geophysical models were generated within the framework of which the statements of the corresponding mathematical tasks were formulated, their solution methods were suggested and many specific tasks were solved (in many cases bringing to the numerical results). The approach in contrast to classical, allows studying various geological and geophysical processes, events and facts considering their geodynamic development. The specific application of the given approach to study fundamental and practical problems of geology, geophysics, seismology and science on oil and gas allowed obtaining a number of new scientific results, clarifying the origin nature of various processes and suggesting their implementation mechanisms.



## REFERENCES

[1] A.N. Guz, G.G. Kuliev, I.A. Tsurpal, *On fracture of brittle materials from loss of stability near a crack, J. Engineering fracture mechanics*, v. **10**, no. 2, Pergamon Press, Great Britain 1978.

[2] A.N. Guz, G.G. Kuliev, M.Sh. Dyshel, O.B. Milovanova, *Destruction and stability of thin bodies with fractures* (in Russian), Ed. "Naukova dumka", Kiev, 1981, p. 184.

[3] A.N. Guz, G.G. Kuliev, *The stability problem of the drilled wells* (in Russian), *J. Appl. mech.*, v. **19**, no. 2, 1983, p. 3-13.
[4] G.G. Kuliev, *A new approach to the calculation of theoretical tensile strength of materials* (in Russian), *J. Strength Problems*, no. 5, 1988 b, p. 83-92.
[5] G.G. Kuliev, *Basis of mathematical theory of stability of wells* (in Russian). Ed."Elm", Baku 1988a.
[6] G.G. Kuliev, *Destruction and stability of three-dimensional bodies with fractures and some related problems of mining and oil mechanics* (in Russian), Ed. "Elm", Baku 1983.
[7] G.G. Kuliev, *Determination of Poisson's ratio in stress media* (In Russian), Reports of the Russian Academy of Sciences, v. **370**, no. 4, 2000, p. 534-537.
[8] G.G. Kuliev, I.A. Tsurpal, *Problems of stress concentration considering physical nonlinearity of the material* (review) (in Russian). *J. Appl. mech*., v. **XI**, edition 7, 1974.
[9] G.G. Kuliev, L.A. Buryakovsky, R.D. Jevanshir, *Folding with many harmonics within the instability model of the deformed system* (in Russian). Reports of the AS of the USSR, v. **319**, no. 4, 1991, p. 939-942.
[10] G.G. Kuliev, L.A. Buryakovsky, R.D. Jevanshir, M.T. Abasov, *One of a general mechanism of the folding formation* (in Russian), Reports [of the AS of the USSR, v. **305**, no. 4, 1989, p. 926-929.
[11] G.G. Kuliev, M.D. Dzhabbarov, *Amplitude characteristics of elastic waves in stress media* (in Russian), Reports of the Russian Academy of Sciences, v. **370**, no. 4, 2000, p. 672-674.
[12] G.G. Kuliev, M.T. Abasov, R.D. Jevanshir, L.A. Buryakovsky, E.A. Aliev, Theoretical basis of a mathematical model of the mechanism of the folding formation through the stability loss (in Russian), J. Geotectonics, no. 3, 1992, p. 90-101.
[13] G.G. Kuliev, M.T. Abasov, R.D. Jevanshir, *The development model of the lithosphere* (in Russian), *Bulletin of the Russian Academy of Sciences*, v. **70**, no. 2, 2000, p. 129-135.
[14] G.G. Kuliev, R.D. Jevanshir, M.T. Abasov, *The destruction mechanism through delamination in the layered structures of the Earth* (in Russian), Reports of the RAS, v. **340**, no. 2, 1995 b, p. 222-224.
[15] G.G. Kuliev, R.D. Jevanshir, M.T. Abasov, *The faults on the lateral (horizontal) surfaces of the Earth's interior* (in Russian), Reports of the RAS, v. **340**, no.1, 1995 a, p.78-79.
[16] H.H. Guliyev, *A new theoretical conception concerning the tectonic processes of the Earth*, *New Concepts in Global Tectonics Newsletter*, no. 56, 2010, p. 50-74.
[17] H.H. Guliyev, *Deformations corresponding to processes of consolidation, deconsolidation and phase transitions in the internal structures of the Earth* (in Russian), *J. Geophysics*, no. 3, 2013.
[18] H.H. Guliyev, *Fundamental role of deformations in internal dynamics of the Earth*, *New Concepts in Global Tectonics Newsletter*, no. 61, 2011, p. 33-50.
[19] H.H. Guliyev, Kh.B. Aghayev, *Determination of physico-mechanical properties of rocks of sedimentary cover on the basis of seismic, well data and the theory of elastic waves of stress media* (in Russian), *J. Geophysics*, v. **33**, no. 6, p. 126-135 (2011).
[20] H.H. Guliyev, Kh.B. Aghayev, *Modeling of seismic sections considering the stress state of medium* (in Russian). *J. Geodynamics*, no. 1(9), 2010, p. 81-86, Lviv.
[21] H.H. Guliyev, Kh.B. Aghayev, N.M. Shirinov, *The research of the pressure influence on the values of elastic parameters of the geological medium on the basis of seismic and well data*, Bulletin of Kyiv National University named after Taras Shevchenko, *J. Geology*, no. 50, 2010, p. 10-16.