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ABSTRACT

of the dissertation for the degree of Doctor of Science

DEVELOPMENT OF METHODS FOR DETERMINING THE INDICATORS OF THE DEVELOPMENT OF OIL AND GAS FIELDS, THE ROCKS WHICH ARE SUBJECTED TO COMPLEX DEFORMATIONS

Speciality: 2525.01 – "Development and exploitation of oil and gas fields"

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GENERAL DESCRIPTION OF THE WORK

The actuality and study degree of the topic. Deep-lying oil and gas fields are characterized by high formation pressure and temperature, and their oil and gas collectors undergo complex characteristic deformation in the process of development, different from linear-elastic deformation. Currently, many experiments and mining studies have been collected, the research data of which prove that oil-gas collectors with high thermobaric conditions are subject to inelastic deformation. At the same time, it is reported in the scientific literature that such inelastic deformations of rocks can usually carry rheological characteristics. Thus, since the rock-collectors of deep oil and gas fields are under high geostatic pressure, the saturated pore environment that forms them and retains fluid (oil, gas, water), as well as solid rock grains are in a state of high degree of tension. As a result of the reduction of the formation pressure in the process of development of these rocks in the mentioned tension state oil and gas fields, the effective pressure falling on the pores and the rock substance increases accordingly, which, in turn, allows the rock grains to undergo redistribution within the boundaries of the formation. These redistribution processes, which occur regularly in the layers, have an important quantitative and qualitative impact on the energy characteristics of the layer, first of all, on the change in the composition of the layer. The change characteristics of the formation pressure, in turn, affect other natural and technological indicators of development, which ultimately makes it necessary to take into account of the complex stress-deformation state of the rocks forming them when designing the process of mastering the reserves of deep-lying oil and gas fields.

In connection with this necessity, the study of the problems of development of deep-lying oil and gas fields taking into account the inelastic, complex deformation features of rock-collectors and the creation of appropriate calculation methods are considered to be one of the urgent issues of special scientific and practical importance for the current conditions in which the specific weight of such

A lot of research works have been devoted to the study of

research issues related to the development of deposits within the framework of rheological non-elastic deformations of rocks, especially in recent times, and a number of results have been obtained in these works in accordance with various circumstances. The need to conduct research in these areas in accordance with different technological conditions is still evident.

In connection with those mentioned, the dissertation work is devoted to obtaining solutions of various types of development issues set within the framework of different technological conditions on the determination of oil and gas fields development indicators taking into account the complex stress-deformation state of rocks with the mentioned characteristics, making necessary assessments based on these solutions and preparing relevant results. Relevant research results obtained by the author are reflected in the dissertation work.

Object and subject of research.

Object of study - oil and gas fields whose rocks are subject to complex characteristic deformations as a result of the influence of thermobaric conditions; subject of study-determination of indicators of development of oil and gas fields whose rocks are subject to complex characteristic deformation

The purpose and main objectives of the study.

The purpose of the study is to develop calculation methods that allow determining the indicators of development of oil, gas and gas oil deposits, the rocks of which are subject to non-elastic deformations of a relaxed and creeping nature under the conditions of depletion.

In accordance with the research issues intended to achieve the intended goal, the following research tasks have been identified:

1. Creation of methods for determining the indicators of development of oil and gas fields whose rocks are subject to relaxation and creep deformation on the basis of numerical modeling in accordance with isothermal and non-isothermal conditions.

2. Oil, gas and gas oil fields, whose rocks are subject to relaxation and creep deformation, are subject to various technological and geological-physical conditions (activity of the post-contour water zone, gas segregation, immobility and mobility of the oil and gas

border, et al.) creation of methods for approximate determination of appropriate development indicators taking into account.

3. Creation of methods for determining the parameters of filtration-capacity and rheological deformation of oil and gas fields whose rocks are subject to relaxation and creep deformations on the basis of development data and research data of wells.

4. Investigation of the possibilities of taking into account relaxation and creep deformations of rocks in the determination of reserves of oil and gas fields.

Methods of research.

The problems were solved by using numerical and analytical mathematical methods widely used in the solution of one- and two-dimensional problems of liquid and gas filtration processes in porous media, methods of variational and graphic-analytical interpretation of the research data of formations and wells.

The main provisions brought to the defense.

1. Determination of development indicators of oil and gas fields whose rocks are subject to relaxation and creep deformation on the basis of numerical modeling in accordance with isothermal and non-isothermal conditions.

2. Approximate determination of the development indicators of oil, gas and gas oil fields, whose rocks are subject to relaxation and creep deformation, in accordance with various technological and geological-physical conditions.

3. Data on the development of filtration-capacity and rheological deformation parameters of oil and gas fields whose rocks are subject to relaxation and creep deformations and research of wells.

Scientific novelty of the study.

1. Methods for determining the indicators of development of oil and gas fields whose rocks are subject to relaxation and creep deformation on the basis of numerical modeling corresponding to isothermal and non-isothermal conditions have been created;

2. Methods of approximate determination of the development indicators of oil, gas and gas oil deposits with relaxation and creeping deformation of rocks in accordance with various technological and geological-physical conditions have been created;

3. Methods have been established to determine the parameters of filtration-capacity and rheological deformation of oil and gas fields whose rocks are subject to relaxation and creep deformations on the basis of development data and research data of wells;

4. In order to ensure the efficient development of deep-lying oil and gas deposits, the procedure for assessing the balance reserve taking into account the rheological non-elastic deformation feature of rocks was developed and the practical possibilities of its use were substantiated by implementing it on the example of a specific deposit.

5. Based on the hypothetical computational experiments carried out on the developed methods of determination, the qualitative and quantitative impact features of rheology of rocks on the development indicators of oil, gas and gas oil deposits within the technological and geological-physical conditions were clarified, and on the basis of this, a number of theoretical and experimental significance calculation results were obtained, including:

- An increase in the price of the initial formation pressure increases the influence of the rheological properties of rocks on the indicators of the development of deposits.

- The effect of relaxation deformation of rocks on the development indicators of gas fields compared to the development indicators of oil fields is less due to the fact that the gas acquires a greater degree of compressive and elastic properties.

- In the conditions of relaxation deformation of rocks, compared with elastic deformation conditions, the decrease in formation pressure occurs at a high rate, and in the conditions of creep deformation-at a slow pace, which has had an adequate effect on the operational capabilities of deposits in quantitative and qualitative terms.

- As a result of the process of segregation in elastic deformed layers, the formation of a gas cap occurs faster than in creep deformable layers, and slower than in relaxed deformed layers. In conditions of gas segregation, the final oil recovery coefficient in drag-deformed layers is higher than in elastically deformed layers. The influence of gas segregation conditions on the price of the final

oil recovery coefficient in elastically deformed formations is a more significant level.

- In conditions of self-expression of elastic and rheological properties of rocks under the condition of non-isothermal of the flow of gaseous oil in the reservoir, the rate of reduction of well pressure slows down in comparison with the conditions of isothermal of the flow, and temperature values are less in relaxation rocks and more in drift rocks compared to elastic deformation of rocks.

- As a result of temperature changes in a layer with a creeping deformation, the values of permeability at the bottom of the well exceed the contour values. This is due to the fact that the decrease in temperature occurs to a greater extent at the bottom of the well in those layers whose rocks have a creeping deformation.

- Expansion (increase) of the volume of the oil part in a layer with elastic deformation of rocks occurs more rapidly than in a layer with relaxation deformation of rocks, both when taking into account the passage of gas from one part to another and when it is not taken. Taking into account the passage of gas from one part to another in both deformed layers, the rate of increase in the volume of the oil sector slows down. Excluding the latest stage of development, the increase in the volume of the oil part occurs at a greater interval in deposits, the rocks of which are elastically deformed if the gas passes from one part to another.

- Creep and relaxation deformation of rocks reduces the impact on development indicators of gas oil deposits in the exhaust mode in comparison with elastic deformation of rocks under the conditions of gas segregation. The creep of the rock accelerates the growth of the volume of the oil part towards the gaseous part.

Theoretical and practical significance of the study. The issue of taking into account the influence of the complex stress-deformation state of rocks exposed in the study of the process of development of oil and gas fields is one of the issues of essential importance of modern oil and gas production. Taking this effect into account, the improvement of methods for determining the technological indicators of oil and gas fields is of great practical importance from the point of view of the development of theory and

practice of deep-lying field development. Thus, the use of these methods can allow preliminary project calculations and current analysis estimates of the development of deep-lying oil and gas fields in depletion mode to be carried out taking into account the mentioned deformation conditions, thereby ensuring a high degree of reliability of the relevant decisions made in this regard from the point of view of practical use. From this point of view, the results obtained in the carried out research work can be characterized as results that have theoretical and practical significance due to their scientific and applied characteristics.

The obtained and applied results enable the assessment of the current reserve potential of deep-lying oil and gas deposits, the rocks of which have rheological non-elastic deformation properties, and the determination of adequate decisions in accordance with the formation conditions for the effective assimilation of this reserve potential. Some of the results of the work have passed the experimental approbation in the fields of "AZNEFT" PU.

Approbation and application.

The main provisions of the dissertation work were reported at the following conferences, forums, sessions, meetings and seminars, included in the relevant printed materials:

- Scientific-Practical Conference dedicated to the 70th anniversary of AOISRPI (Azerbaijan Oil Industry Scientific-Research Project Institute) (Baku, April 14-15, 1998);

- International Scientific Conference dedicated to the 90th anniversary of the birth of G.G. Tumashev "Boundary value problems of aerohydromechanics and their applications" (Russia, Kazan, November 21-24, 2000);

- Republican Scientific Conference "Mathematical modeling and computational experiment" (Uzbekstan, Tashkent, March 25-27, 2002);

- Republican scientific conference "Modern problems of informatization, cybernetics and information technologies" (Baku, April 28-30, 2003);

- II Republican Scientific Conference "Modern problems of informatization, cybernetics and information technologies" (Baku,

October 26-28, 2004);

- III international Scientific Conference (Russia, Makhachkala, September 24-27, 2007);

- All-Russian seminar dedicated to the centenary of Aminov Mongim Shakurovich (Russia, Kazan, February 4-5, 2008);

- All-Russian seminar dedicated to the centenary of P.A. Kuzmina (Russia, Kazan, November 11-12, 2008);

- International Conference "Current problems of applied mathematics and information technologies - Al Khorezmi 2009" (Uzbekistan, Tashkent, September 18-21, 2009);

- VI International Scientific Conference "Functional differential equations and their applications" (Russia, Makhachkala, September 21-24, 2009);

- VI Republican Scientific Conference of Young Scientists and Students "Modern Problems of Mathematics and Computer Science" (Belarus, Brest, November 26-28, 2009);

- III International Scientific and Practical Conference "Youth and Science: Reality and Future" (Russia, Nevinnomyssk, May 17-20, 2010);

- VII Azerbaijan International Geophysical Conference on" ways to improve the efficiency of Geophysical Research in active Geodynamic conditions on the example of the south Caspian Depression " (Baku, may 11-13, 2010);

- XI International Youth Scientific Conference "Severgeoecotech-2010" (Russia, Ukhta, March 17-19, 2010);

- 3rd International Conference on Control and Optimization with Industrial Applications (Turkey, Ankara, Bilkent University, 22-24 August 2011);

- II International Scientific-practical Conference on "New technologies in oil production" " (Baku, 6-7 September 2012);

- IV International Conference "Problems of cybernetics and informatics" 2012 (Baku, September 12-14, 2012);

- 34th International Geological Congress "The modern problems of geology and geophysics of the Eastern Caucasus and the South Caspian depression" (Australia, Brisbane, August 5-10, 2012);

- International Scientific Conference "Innovative development

of the oil and gas complex of Kazakhstan" (Kazakhstan, Aktau, April 25-26, 2013);

- 5th International Conference of young scientists and students on "Fundamental and Applied Geology: achievements, prospects, problems and ways of their solution" dedicated to the 90th anniversary of national leader of Azerbaijan Heydar Aliyev (Baku, November 14-15, 2013);

- International scientific conference "Non-Newtonian systems in the oil and gas industry", dedicated to the 85th anniversary of academician Azad Khalil oglu Mirzajanzadeh (Baku, November 21-22, 2013);

- 1st International Scientific Conference of Young Scientists and Specialists "The role of multidisciplinary approach in solution of actual problems of fundamental and applied sciences (Earth, Thechnical and Chemical). (Baku, 15-16 october 2014);

- International multidisciplinary forum of young scientists and specialists dedicated to the 70th anniversary of ANAS "Academic Science Week - 2015" (Baku, November 2-4, 2015);

- International Scientific and Practical Conference "Priority directions for the development of modern science" (Russia, Makhachkala, February 24, 2015);

- Scientific Session on "Fundamental and applied problems of oil and gas field development" dedicated to the 90th anniversary of Academician M.T.Abasov (Baku, October 14, 2016);

- Scientific-Practical Conference "Khazarneftgazyatag-2016" (Baku, December 22-23, 2016);

- International Scientific and Practical Conference "Modern mathematics and its applications" (Russia, Ufa, May 18-20, 2017);

- International Conference on "Innovative technologies in oil and gas production and modern problems of Applied Mathematics" dedicated to the 90th anniversary of Academician Azad Mirzajanzade (Baku, December 13-14, 2018);

- International Scientific and Practical Conference "State and prospects for the exploitation of mature fields" (Kazakhstan, Aktau, May 16-17, 2019);

- International Scientific and Practical Conference "Modern

methods of developing fields with hard-to-recover reserves and unconventional reservoirs" (Kazakhstan, Atyrau, September 5-6, 2019);

- III International Scientific and Practical Conference "Modern Programming" (Russia, Nizhnevartovsk, November 27-29, 2020);

- International Scientific and Practical Online Conference on the topic: "Modern technologies in science and education", dedicated to the 30th anniversary of Independence of the Republic of Kazakhstan (Kazakhstan, Aktau, April 28, 2021);

- IV International Scientific and Practical Conference on the topic "Modern Programming" (Russia, Nizhnevartovsk, December 08, 2021):

- IV Republican Scientific Conference on the topic "Applied issues of mathematics and new information technologies" (Sumgayit, December 9-10, 2021);

- II Republican scientific conference dedicated to the 60th anniversary of Sumgayit State University on "Fundamental problems of mathematics and application of intellectual technologies in education" (Sumgayit sh., December 15-16, 2022);

- International Scientific-Practical Conference "Heydar Aliyev and Azerbaijan Oil Strategy: progress in oil and gas geology and geotechnologies" dedicated to the 100th anniversary of the National Leader of the Azerbaijani people Heydar Aliyev (Baku, may 23-26, 2023).

- Section, nationwide seminar and scientific council meetings of the Institute of Problems of Deep Oil and Gas Fields of ANAS (1995-2003), Institute of Geology and Geophysics (2003-2016) and Institute of Oil and Gas (2016-2023).

The obtained results were approved by applying them in the implementation of the following economic accounting works:

- Economic contract work concluded between SOCAR "AZNEFT" PU and the Institute of Geology and Geophysics of ANAS (2010-2011) on the creation of a research product on "Development of recalculation methods of oil and gas reserves of deposits in the process of operation taking into account the relaxation and creep deformation of rocks"(relevant reference was attached to

the work);

- Economic contract work concluded between SOCAR "AZNEFT" PU and the Institute of Geology and Geophysics of ANAS (2011-2012) on the creation of a scientific-research product on the topic "Calculation of the initial and current reserves of the Lower Kirmaki suits formation of the "Northern fold"of the Pirallahi field on the basis of 3D geological modeling and preparation of geological - technological proposals on the involvement of the current reserve in active development" (relevant reference was attached to the work);

- Issues included in the areas of research on this topic were studied and obtained through development within the framework of an interdisciplinary research work covering a two-year period on the topic "A set of theoretical and experimental studies of interdisciplinary problems of geomechanics", which won the program competition announced by ANAS in 2015 year, which was performed directly by one of the applicant's performers. the results are included in the work report;

- The study of most of the issues covered by the dissertation topic was included in the plan of scientific-research works carried out within the framework of scientific-research programs at the Institute of Problems of Deep Oil and Gas Fields of ANAS (1995-2003), Institute of Geology and Geophysics (2003-2016) and the Institute of Oil and Gas;

- Some of the results obtained on the dissertation work were recognized as the most important results of ANAS on Earth Sciences in 2012 and 2021;

- In 2009, a short review in Russian was published in the publishing house "Elm" on the issues investigated in the dissertation, co-authored by the applicant, entitled "Deformation of rocks and its influence on their filtration-capacitive properties and on the processes of filtration and development of oil and gas fields";

- A methodical instruction on "Oil and gas well extraction technology: Determination of indicators of development of oil and gas fields taking into account deformation of rocks" was developed and published at Azerbaijan State Oil and Industry University under

the co-authorship of the applicant with reference to some results of the dissertation work;

- During 2019-2021, the methodological work on two topics intended for the use of students studying at The Bachelor's level 050606 “Oil and gas engineering” at the Department of “Oil and Gas Engineering” of the Faculty of “Gas-oil-mining” of the Azerbaijan State Oil and Industry University was approved in the Scientific Council and recommended for use in educational process.

108 scientific works on the materials of the dissertation work, including 63 articles or theses in scientific journals (22 abroad), 43 articles or theses in conference, forum, session materials (23 abroad), 1 book and 1 methodical instruction were published.

The name of the organization where the work was performed. İnstitute Geology and Geophysics and İnstitute Oil and Gas of the Ministry of Science and Education of the Republic of Azerbaijan.

The total volume of the thesis with a separate indication of the individual structural parts of the thesis.

The dissertation work consists of an introduction, 5 chapters, conclusions, a list of used literature in 395 issues and an appendix in 2 issues. The work consists of 406 pages, including 7 figures, 128 graphs and 8 tables. The volume of the dissertation with a signs on individual parts is Title-432, Table of contents - 7402 , Introduction - 19297, Chapter I - 86305, Chapter II - 93460, Chapter III - 125070, Chapter IV - 47749, Chapter V - 52283, Conclusion - 7582, excluding tables, graphs, figures, appendices and list of literature. The total volume is 439580 signs.

BRIEF CONTENT OF THE WORK

In the introductory part, the general characteristic of the dissertation work is commented.

In the first chapter, based on an extensive literature review, the selection of research issues of the dissertation with an analysis of the degree of development of the topic of the dissertation is substantiated, as well as theoretical models describing the complex

state of stress-deformation of rocks are interpreted.

It was noted that the porosity and permeability of oil and gas layers are subject to a certain degree of change in the process of development, which, in turn, has an impact on the change in the time and space coordinates of the indicators characterizing this process. Based on this factor, it has always been relevant to solve the problems of assessment of these collector properties with the help of mining-geophysical and mining-experimental research methods, which differ in different geological and physical properties, as well as depth of deposit and correspond to homogeneous and inhomogeneous formation conditions. Thus, an accurate assessment of oil and gas field development indicators in accordance with the real conditions of formation leads to the achievement of favorable decisions both in terms of designing and analyzing and forecasting the development. As can be seen, the achievement of favorable decisions on the development of oil and gas fields largely depends on the reliable assessment of the porosity and permeability of the reservoir in accordance with the conditions of the formation. In this regard, during the implementation of theoretical and experimental studies, it is necessary to determine the characteristics of the collector either on individual parts of the reservoir (for example, on layers, on the area around the well, et al.).), or the development of mathematical models that determine depending on the layer pressure on the layer in general.

Analysis of the scientific-research works carried out so far in this direction shows that the deformation features of rocks have been determined based on geological knowledge and experimental results, at the same time, taking into account these features, theoretical-experimental flat and reverse laying issues of filtration and field development in oil and gas layers have been studied. Research in this direction is carried out in our country and abroad specifically by Abasov M.T., Mirzajanzadeh A.X., Jalilov G.N., Guliyev A.M., Jalalov G.I., Dunyamaliyev M.A., Karimov Z., Imanov A.A., Zheltov Y.P., Yentov V.M., Leibenzon L.S., Nikolayevsky V.N., Barenblatt G.I., Krylov A.P., Gorbunov A.T., Zakirov S.N., Basniev K.S., Ametov N.M., Shelkachev V.N., Dobrynin V.M., Yerzhanov J.S.,

Chernykh V.A., Telkov A.P., Grachev S.I., Molokovich Y.M., Karev V.I., Tercagi K., Reyner M. and others.

It is noted that as a result of these studies, the corresponding regularities for the description of deformations of rocks of linear and nonlinear elastic, as well as non-elastic rheological nature have been determined. In the dissertation research was carried out on the basis of these laws in accordance with different conditions of development and operation. In the case of creep deformation of rocks, basically, a model of deformation with a memory function of the Voltera type (creep core) was considered. The main focus of the work is on the creation of effective numerical and approximate calculation methods for determining the indicators of development of oil, gas and gas oil fields in accordance with various technological conditions [1].

In the second chapter, numerical and approximate methods of determination of the development indicators of gas deposits whose rocks are subject to relaxation and creep complex deformations have been developed in accordance with various technological conditions are interpreted. The developed numerical and approximate methods of determination of the indicators of the development of gas fields taking into account the relaxational and creep deformations of rocks, respectively numerical modeling of the flow of gas into the well system and into a separate well, and the method based on the use of material balance equations within the framework of the “average" well concept, it also covered the cases when the creep deformation of rocks with Abel type memory was taken into account.

The problem of determination of the indicators of the development of a gas field with a network of wells whose rocks are subject to relaxation and creep deformation within the framework of the relevant receptions was solved by mathematical formula in the following statement [2 3 4 5 6 7]:

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[1] Kuliev, A.M. Deformation of rocks and its influence on their filtration-capacitive properties and on the processes of filtration and development of oil and gas fields / A.M. Kuliev, B.Z. Kazymov. – Baku: Elm, 2009. – 88 p.

[2] Kazymov, B.Z. Numerical modeling of gas deposit development by a system of arbitrarily located wells taking into account creeping deformation of rocks // Abstracts of reports of the II international scientific-practical conference on “New technologies in oil production”, − Baku: − 6−7 September, − 2012, − p. 170.

- equation of two-dimensional undetermined flow of gas into the well system

$$\frac{\partial}{\partial x}\left(\frac{k_l p}{\mu_g(p)z(p)}\frac{\partial p}{\partial x}\right)+\frac{\partial}{\partial y}\left(\frac{k_l p}{\mu_g(p)z(p)}\frac{\partial p}{\partial y}\right)=$$

$$=\frac{\partial}{\partial t}\left(\frac{mp}{z(p)}\right)+\frac{p_{at}}{h\cdot\beta}\sum_{\nu=1}^{N_1}q_\nu(t)\delta(x-x_\nu)\delta(y-y_\nu) \qquad (1)$$

- case equation of porous medium
in the case of relaxation deformation

$$m+\tau_m\frac{\partial m}{\partial t}=m_0 e^{\beta_s(p-p_0)} \qquad (2)$$

in the case of creep deformation

$$m=m_0\left[1+\beta_s(p-p_0)+m_1\int_0^t e^{-\gamma_m(t-\tau)}(p-p_0)d\tau\right] \qquad (3)$$

- initial and boundary conditions

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[3] Kazymov, B.Z. Numerical modeling of gas reservoir development by a system of arbitrarily located wells taking into account creeping deformation of rocks // − Baku: SOCAR Proceedings, − 2012. №3, − p.42-46.

[4] Guliyev, A.M., Kazimov, B.Z. Study of rhealogical properties of reservoirs during relaxation and creep strain of rocks and usage of these properties for addressing of applied objectives of oil-gas fields development // Special İssue Papers of 34th İnternational Geological Congress "The modern problems of geology and geophysics of Eastern Caucasus and the South Caspian depression", – Brisbane: Nafta-Press (Baku), – 5 – 10 August, – 2012, – p.117-131.

[5] Kazimov, B.Z. Method of numerical determination of indicators of development of gas field with a system of wells with relaxational deformation of rocks // - Baku: News of ANAS. Series of Earth Sciences, - 2013. №2, - p. 63-68.

[6] Kazimov, B.Z. Assessment of the impact of creep deformation of rocks on gas production of gas field // − Baku: Western University. Journal "Scientific news", – 2015. №3, − p. 69-73.

[7] Oil and gas extraction technology: Determination of indicators of development of oil and gas fields taking into account deformation of rocks (methodical instruction) / A.M.Guliyev, T.Sh.Salavatov, T.A. Samadov [et al.]. – Baku: Printing house of ASOİU, − 2018. − 61 p.

$$p(x,y,0) = p_0, m(x,y,0) = m_0 \tag{4}$$

$$\left.\frac{\partial p}{\partial x}\right|_{x=0;L} = 0, \left.\frac{\partial p}{\partial y}\right|_{y=0;H} = 0, \tag{5}$$

where x,y and t - respectively, the length, width of the layer and time quantities: $\{(x,y): x \in [0,L], y \in [0,H]; 0 \le t < \infty\}$; k_l - permeability of the layer; $p = p(x,y,t)$ - current layer pressure; $\mu_g(p)$ - viscosity of the gas; $z(p)$ - coefficient of extreme compression of the gas; $m = m(x,y,t)$ - porosity of the layer; p_{at} - atmospheric pressure; h - thickness of the field; β - coefficient of the temperature correction for gas; N_1 - number of wells; q_ν - the debit of the ν -th well ($\nu = \overline{1..N_1}$); δ - Dirac function; τ_m - relaxation time of porosity; m_0 - initial porosity of the rock; p_0 - initial pressure of the layer; β_s - coefficient of elastic compression of rocks; m_1, γ_m - the parameters of creep that correspond to the characteristics of the change in porosity.

The permeability of the layer is calculated on the following nonlinear dependencies:

- in the case of relaxation deformation of rocks

$$k_l = k_0 e^{\alpha_k (p - p_0)}, \tag{6}$$

- in the case of creep deformation of rocks

$$k_l = k_0 \left[1 + \alpha_k (p - p_0) + k_1 \int_0^t e^{-\gamma_k (t-\tau)} (p - p_0) d\tau \right], \tag{7}$$

where k_0 - initial permeability; α_k - coefficient of change in permeability by pressure; k_1, γ_k - the parameters of creep corresponding to the characteristics of change of permeability.

In order to solve the problem using the method of finite differences, the layer area with a rectangular surface is replaced with the following network area:

$$\omega = \{(x_i, y_j, t_k) : x_i = i \cdot \Delta x \ (i = 0,1,..., N;\ N \cdot \Delta x = L);$$
$$y_j = j \cdot \Delta y \ (j = 0,1,..., M; M \cdot \Delta y = H); t_k = k \cdot \tau, \ k = 0,1,2,...\}$$

where x_i, y_j, t_k - respectively and the values of their quantities at the node point of the network (*i,j,k*); $\Delta x, \Delta y$ and τ - fixed network steps, respectively, by the length, width of the layer and time; *N* and *M* - the number of divisions by the length and width of the layer, respectively, by the *x* and *y* coordinates.

As a result, obvious, non-obvious (linear and nonlinear) finite-differences equations were obtained for calculating pressure. The calculation of porosity is carried out according to the iteration expressions obtained on the basis of approximation relations of Equations (2) and (3) respectively.

At the same time, depending on the physical parameters included in the filtering model, the obtained finite difference equations and the stability conditions of the iteration schemes were determined. Thus, based on the obtained difference equations, schemes of continuous numerical solution of the problem were proposed.

The modeling of wells was carried out based on the existing procedure within the framework of the adoption of the pseu-dostacioanar nature of the flow to the well with a fixed radius around the small nodes located in the wells.

The results of the calculations based on the numerical calculation model created taking into account the relaxation defor-mation of the rocks allowed the following to be noted:

1) during the field depletion process, after a certain initial stage, the pressure decrease occurs at a greater rate in the case of relaxation deformation than in the case of inelastic deformation of rocks;

2) during the field depletion process, the reduction of porosity occurs at a slower rate in the case of relaxation deformation than in the case of inelastic deformation of rocks;

3) at the same value of the average wellbore pressure in the wells, compared to the case of non-linear deformation, in the case of relaxation deformation of the rocks, the current gassing coefficient of

the field is less, and this manifests itself more prominently when the wellbore pressure decreases more (up to 3%).

The results of the calculations based on the numerical calculation model created taking into account creep deformation of rocks allowed the following to be noted:

1) the influence of the creeping deformation of rocks on the reduction of pressure and porosity during the process of field depletion is significantly greater than that of inelastic deformation;

- during the process of field depletion, the pressure decrease occurs at a lower rate in the case of creep deformation than in the case of inelastic deformation of rocks;

- during the process of field depletion, porosity reduction occurs at a greater rate in the case of creep deformation than in the case of inelastic deformation of rocks;

2) the compressibility of rocks has less effect on the decrease of the pressure values at the well bottom over time in the case of creeping deformation of the rocks than in the case of inelastic deformation;

3) the compressibility of rocks has a greater effect on the decrease in porosity well wall around values over time in the case of creep deformation of rocks than in the case of inelastic deformation.;

4) at the same value of the average wellbore pressure on the wells, compared to the case of non-linear deformation, in the case of creeping deformation of the rocks, the current gassing coefficient of the field is greater, and this manifests itself more prominently when the wellbore pressure decreases more (up to 17,7%).

A similar problem was also solved for the case of axisymmetric plane-parallel radial flow of gas into a separate well in a reservoir with relaxed and creepally deformed rocks. In this case, the characteristics of the flow were taken into account as much as possible by switching to an appropriately selected intermediate transformation variable [8] [9] [10] [11] [12] [13].

[8] Kazymov, B.Z., Nasirova, K.K. Numerical calculation model for determining the main characteristics of the development of gas deposits with a creeping medium // Materials of the VI Republican Scientific Conference of Young Scientists and Students “Modern Problems of Mathematics and Computer Science”, − Brest: −

At the same time, the problem of determining the development indicators of gas fields with relaxational and creep deformation of rocks under real gas seepage conditions was formulated, and approximate solutions to these problems were obtained by applying the averaging method and using material balance equations. Using these solutions, the development indicators of the reservoir can be calculated [14] [15] [16] [17] [18].

November 26 − 28, − 2009 , – p.133-134.

[9] Efendiev, R.M., Kazymov, B.Z. Numerical solution of a boundary value problem associated with gas filtration to a well in a relaxation porous medium // Materials of the XI international youth scientific conference "Severgeoecotech-2010" (part IV), – Ukhta: – March 17 – 19, – 2010, – p. 259-262.

[10] Nasirova, K.K., Kazymov, B.Z. Method for calculating the influx of real gas to a well in a creeping formation // Abstracts of reports of the VII Azerbaijan International Geophysical Conference on "Ways to improve the efficiency of geophysical research in active geodynamic conditions on the example of the South Caspian Depression, – Baku: – 11 – 13 May, – 2010, – p. 106.

[11] Guliyev, A.M. The numerical and approached simulation gas inflow to a well with creeping medium / Arif Guliyev, Vahid Babanly, Bunyad Kazimov [et al.] // Book of Abstracts of 3rd International Conference on Control and Optimization with Industrial Applications, – Ankara: – 22 – 24 August 2011, – p.136-137.

[12] Kazimov, B.Z. Numerical definition of reservoir pressure and porosity of creeping gas layer on values of change of an well production // Scientific enquiry in the contemporary world: theoretical basics and innovative approach. Research articles. Natural sciences & technical sciences, – San Francisco: – 2015. v.3, – p. 22-25.

[13] Kazymov, B.Z. Procedure for Determining the Dynamic Characteristics of a Gas Reservoir with a Creeping Porous Medium // – New York: Fluid Dynamics, – 2018. v.53. s.2, – p. s34-s37.

[14] Kuliev, A.M. Modeling of gas field development taking into account the relaxation of rocks / A.M. Kuliev, M.A. Gadzhiev, B.Z. Kazymov [et al.] // Theses of the scientific-practical conference dedicated to the 70th anniversary of AOISRPI (Azerbaijan Oil Industry Scientific-Research Project Institute), – Baku : – April 14 – 15, – 1998, – s. 60-61.

[15] Babanli, V.Y., Kazimov, B.Z. Mathematical model of gas fields with sliding environment // − Baku: News of Baku University. Physics and Mathematics Series, - 2003. - №4, - s. 91-96.

[16] Kazymov, B.Z., Aslanov, M.S., Tagiyeva, S.E. Estimation of accuracy of approximate solutions in case of gas inflow to a well in a deposit with relaxation-compressible porous medium // − Baku: Scientific works of AzTU, series of Fundamental Sciences, − 2007. v. VI (23). №3, − p. 62-65.

It is accepted that if the field is operated with a n number of wells and the debit of each well is q_{q1}, then the current production on the field will be

$$q = nq_{q1} \tag{8}$$

In accordance with each case under consideration, using this expression, appropriate solution schemes were proposed in accordance with the technological situation when the number of wells on the network is given and not given, as well as when the depression (ΔP) on the field is given. The problems of determining the number of wells providing the given production dynamics on the field in case the number of wells is not given have been investigated [19] [20] [21] [22] [23] [24]

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[17] Kazimov, B.Z., Nasirova, K.K. Method of approximate determination of the development indicators of a gas field with a relaxing environment // – Baku: Works of young scientists, − 2009. №2, − p. 81-92.

[18] Kuliev, A.M., Efendiev, R.M., Kazymov, B.Z. The influence of rock creep on the development indicators of a gas field under gas conditions // Materials of the international scientific conference "Non-Newtonian systems in the oil and gas industry", dedicated to the 85th anniversary of academician Azad Khalil ogly Mirzajanzade. Baku: – November 21 – 22, – 2013, – p.145-147.

[19] Kuliev, A.M. The influence of well pattern density on gas recovery from deposits with relaxing reservoirs / A.M. Kuliev, R.M. Efendiev, B.Z. Kazymov [et al.] // Oilfield Engineering, – Moscow: – 2005. No. 11, – p. 31-34.

[20] Kuliev A.M. The influence of rock relaxation on the required number of wells for the development of gas fields / A.M. Kuliev, R.M. Efendiev, M.A. Gadzhiev [et al.] // Scientific works of the research institute "Geotechno-logical problems of oil, gas and chemistry", – Baku: – 2007. v. VIII, – p. 282-291.

[21] Aslanov, M.S., Kazymov, B.Z. Determination of the dynamics of the annual input of wells to ensure a given rate of production in the development of gas deposits with creeping medium // Proceedings of the Third International Scientific Conference "Functional-differential equations and their applications", − Ma¬khachkala: − September 24 − 27, − 2007, − p.44-50.

[22] Kazimov, B.Z., Aslanov, M.S., Nasirova, K.K. The method of determining the dynamics of input into operation of wells in sliding medium gas fields that pay for the given production // – Baku: Works of young scientists, − 2008. №1, – p. 75-83.

[23] Kuliev, A.M., Babanly, V.Yu. Efendiev, R.M., Kazymov, B.Z. The influence of the rheological properties of rocks on the development indicators of a gas field in gas mode // Proceedings of the international conference "Current problems of applied mathematics and information technologies − Al Khorezmi 2009", − Tashkent: − September 18 − 21, − 2009, − p. 238-241.

[25] [26].

On the basis of the received solutions, for the purpose of evaluating the effect of the density of the well network on the development indicators, a strip bed with a length of 1500 m, a width of 1000 m and a thickness of 50 m was taken as a hypothetical field. For a square network of wells, the distance between the wells was $R=2l=1000$; 750 and 500 m, and three variants were considered, in which the number of wells was 12, 20 and 35, respectively.

The analysis of the results of the calculations made using the solutions obtained for the gas fields, the rocks of which are deformed by relaxation, made it possible to come to the following conclusions:

- In the development process, the reduction of formation pressure in the formations with a relaxed medium occurs at a greater rate than in the formations with a non-linear elastic medium in the densities of all well networks.

- In the initial period of development, the difference between the formation pressure value in the layers with relaxed and non-linear elastic media is insignificant, and then, as the gas is removed from the field, this difference becomes more significant, and towards the end of development, this difference again decreases to an insignificant degree. This situation is also reflected in the nature of the change in permeability. This change character is preserved in different densities of the well network.

- In fields with a dense network of wells, formation pressure decreases faster than in fields with a sparse network of wells.

- A sharp change in porosity during processing is most noticeable in beds with a non-linear elastic medium.

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[24] Kuliev, A.M. The influence of rock creep on the required number of wells for a given gas extraction / A.M. Kuliev, M.S. Aslanov, R.M. Efendiev [et al.] // Mechanics, Mechanical Engineering, – Baku: – 2009. No. 1, – p.26-30.

[25] Kuliev, A.M., Efendiev, R.M., Kazymov, B.Z. Determination of gas field development indicators taking into account rock creep // − Baku: News of ANAS, Series of Earth Sciences, – 2014. No. 1-2, – p.65-71.

[26] Kazymov, B.Z. Influence of changes in permeability of formations on the determination of the predicted value of the required number of wells in the development of gas deposits / B.Z.Kazymov, S.G.Novruzova, E.V.Gadasheva [et al.] // Oilfield Engineering, − Moscow: − 2022. №6, − p. 31-34.

- Regardless of the density of the well network, the gassing coefficient in fields with a relaxed environment is always lower than in fields with a non-linear elastic environment. In dense networks, the coefficient of current gassing in deposits with both relaxation and nonlinear elastic medium is greater than in sparse networks.

The analysis of the results of the calculations made using the solutions obtained for the gas fields, whose rocks undergo creep deformation, allowed us to come to the following conclusions:

- In the development process, the reduction of reservoir pressure in layers with a creeping environment occurs at a slower rate than in layers with a non-linear elastic environment in the densities of all well networks.

- In the initial period of development, the difference between the formation pressure value in layers with creeping and non-linear elastic media is relatively small, and then, as the gas is removed from the field, this difference increases significantly and reaches a maximum at the end of development, and this difference decreases again to an insignificant level near the end of development. This situation is also reflected in the nature of the change in permeability. This change character is preserved in different densities of the well network.

- In fields with a dense network of wells, formation pressure decreases faster than in fields with a sparse network of wells.

- A sharp change in porosity during processing is most noticeable in beds with a creep deformation environment.

- Regardless of the density of the well network, the coefficient of gasification in fields with creeping medium is always lower than in fields with non-linear elastic medium. The final gassing coefficient is greater in beds with a creeping environment than in beds with a non-linear elastic environment. The creep deformation of rocks has a greater effect on obtaining the same value of the gasification coefficient when operating with a sparse well network.

The analysis of the obtained numerical results shows the need to take into account the influence of the rheological properties of the rocks when determining the development indicators, including the influence of the formations on the seepage-capacity parameters and

the oil yield coefficient at different well densities.

Taking into account the relaxation and creep deformations of the rocks, the issues of determining the number of necessary wells that ensure the given level of production have been solved, and the corresponding solution expressions have been obtained. Numerical calculation experiments were performed on the basis of hypothetical data based on the obtained calculation expressions.

The analysis of calculation results obtained taking into account the relaxation deformation of rocks shows that:

- the numerical results indicating the required number of wells in accordance with the conditions of relaxation and nonlinear elastic deformation of rocks at all stages of development are slightly different from each other (the possibility of their significant difference in one or another technological conditions is not excluded);

- the difference in the required number of wells is significant (especially in the final development stage) if the permeability change depending on the pressure is taken into account for both cases of rock deformation;

- the influence of the depression in the formation and the distance between the wells on the prices of the required number of wells is as follows: 1 - in all the considered cases, the number of wells is required to ensure the production dynamics with the increase of the distance between the wells (this difference manifests itself especially during the period of stabilization and monotonous decrease of the dynamics of gas production appears in a large interval); 2 - with an increase in depression, the required number of wells decreases in proportion to the increase in depression values;

- in cases of non-linear elastic or relaxational deformation of rocks, if the change of permeability depending on the pressure is not taken into account, the required number of wells, compared to the case where the permeability and porosity of the formations are assumed to be unchanged (especially during the period of relative stabilization and monotonous decrease of the dynamics of gas production), led to big wrong results (in this case, even if rounded off, a difference of 2 wells may appear).

These results can be successfully used in the development

projects of gas fields whose rocks are deformed by relaxation and in the analysis of the development process.

Similarly, the analysis of calculation results obtained taking into account creep deformation of rocks shows that:

- with the exception of the initial stage of development (the stage when the total gas production has not yet reached the maximum value), the numerical results expressing the required number of wells corresponding to the conditions of creeping deformation and nonlinear elastic deformation of rocks in the later stages differ significantly from each other;

- as the value of the parameter m_1, which characterizes the rheological properties of rocks, increases, the numerical results expressing the required number of wells corresponding to the conditions of creep deformation and nonlinear elastic deformation of rocks differ more significantly from each other (in this case, a decrease in the number of wells is observed);

- with an increase in depression, the required number of wells decreases in proportion to the increase in depression values;

- as the distance between the wells increases, there is a tendency of the number of wells to increase at both values of depression (which may be due to a decrease in the specific flow rate of a well under the same depression conditions for each time period as the distance between the wells increases, and in this case, more wells are needed to cover the given production rate number is required).

Taking into account creep deformation of rocks, the problem is investigated in a different way. Thus, the number of wells determined as a result of the calculation is directly expressed in positive integers. In other cases, these well numbers are specified as fractional numbers and expressed as whole numbers only after rounding. In this approach, these numbers are determined directly. The calculation results made in accordance with this situation allowed us to note the following:

1. In the case of creep of the medium, the rate of decrease of the wellbore pressure (including the contour pressure) is slower than in the case of elastic and non-deformation conditions of the medium,

and the decrease of porosity is faster.

2. While the current and total production of a well until the maximum value of the given production rate is reached, as well as in creeping, elastic and non-deformable environments, these values differ considerably in the mentioned environments.

3. Fewer wells are required in fields with a creeping environment to achieve the same production rate. For example, to obtain gas from the field in the amount of $88{,}617 \cdot 10^9$ m^3 , compared to deposits with nonlinear elastic deformable medium, fields with a creep medium require 20% less wells, and fields with a non-deformable medium-20% more wells.

Experience shows that during the development period, the intensive reduction of formation pressure during operation in the depletion mode increases the activity of the water zone surrounding the field, which enables the expression and development of the natural subduction regime in the field. This situation has a significant impact on all development characteristics characterizing the development process of fields.

In connection with the mentioned, in this chapter, the issue of improvement of the prediction methods used in the design of the development process of gas fields with complex stress-deformation conditions, taking into account the activity of the water zone behind the contour, and the creation of a new prediction method on this basis was studied.

According to the obtained calculation scheme, during the processing process, the water-gas contact is continuously displaced, which is determined by the value of the corresponding quantity that expresses the state of its displacement. At this time, the values of the current production volume of gas from the field and the volume of water entering the gaseous part are taken into account, taking into account the initial volume of water at the current time.

In this chapter, an approximate solution to the problem of development of gas fields, taking into account creeping deformation of rocks with Abel type memory, has been obtained [27]. The obtained

[27] Kazymov, B.Z., Efendiev, R.M., Nasirova, K.K. Iterative scheme for determining the development indicators of a gas field in depletion mode, the rocks of

solution allows to take into account the variation characteristics of creep parameters in a fairly wide range. By performing calculations on the obtained solution, the possibility of determining the indicators characterizing the process of working gas fields, taking into account the Abel creep core, was shown.

In the case of taking into account the creep deformation of rocks with Abel type memory, the law of change in porosity was adopted in the form of the following dependence when obtaining the appropriate solution scheme[28]:

$$m = m_0\left(1+\beta_s(p-p_0)+\delta\int_0^t \frac{p-p_0}{(t-\tau)^{\alpha}}d\tau\right), \qquad (9)$$

where δ and α - the parameters of creep deformation: $0<\alpha<1$.

It should be noted that within the framework of the work, numerical and approximate numerical solutions were obtained for the problems of gas flow from homogeneous and heterogeneous formations to the well, taking into account the deformation of rocks, as well as issues related to the displacement of gas from the formation with water and the selection of the optimal operating mode of the gas well, which are reflected in the work [29] [30] [31] [32] [33] [34] .

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which are subject to creeping deformation with an Abel core // Materials of the international scientific and practical conference "Modern methods of developing fields with hard-to-recover reserves and unconventional reservoirs", – Atyrau: – September 5 – 6, – 2019, – p.231-233.

[28] Kuliev, A.M. Deformation of rocks and its influence on their filtration-capacitive properties and on the processes of filtration and development of oil and gas fields / A.M. Kuliev, B.Z. Kazymov. – Baku: Elm, 2009. – 88 p.

[29] Efendiev, R.M., Kazymov, B.Z. Displacement of gas by water in a fractured-porous medium taking into account formation deformation // − Baku: Proceedings of IPDOGD "Issues of development and physical chemistry of oil and gas bearing formations", – 1999, – p. 36-44.

[30] Kazymov, B.Z., Efendiev, R.M. Displacement of gas by water in circular deposits taking into account formation deformation // Materials of the international scientific conference dedicated to the 90th anniversary of the birth of G.G. Tumashev "Boundary value problems of aerohydromechanics and their applications", – Kazan: – November 21 – 24, – 2000, – p. 313-314.

[31] Kazymov, B.Z., Kerimova, I.M. Methodology for choosing the optimal operating mode for a gas well, taking into account rock deformation // − Moscow:

In the third chapter, numerical and approximate methods of determination of oil fields development indicators in dissolved gas mode, whose rocks are subject to relaxational and creep complex character deformations, developed in accordance with various technological conditions are interpreted. The developed numerical and approximate methods for determining the indicators of the development of gas fields taking into account the relational and creep deformations of rocks, respectively numerical modeling of the flow of oil into the well system and into a separate well (isothermal and non-isothermal) and the method based on the use of material balance equations within the "average" well concept, it also covered the cases when the creep deformation of rocks with Abel type memory was taken into account.

The problem of determination of the indicators of the development of the oil field with a network of wells whose rocks are subject to relaxation and creep deformation within the framework of the relevant receptions was solved by mathematical formula in the following statement [35] [36] [37] [38] [39]:

"Automation, telemechanization and communication in the oil industry", – 2020. No. 10, – p. 30-33.

[32] Kazymov, B.Z. Study of the process of gas filtration to the well in relaxation-deformed heterogeneous gas reservoir // Proceedings of the International Scientific and Practical Online Conference, timed to the 30th anniversary of Independence of the Republic of Kazakhstan "Modern technologies in science and education" (Kazakhstan, April 28, 2021), − Aktau: − April 28, − 2021, − p. 172-175.

[33] Kazymov, B.Z., Nasirova, K.K. An approximate method for calculating pressure changes in a nonequilibrium-deformable formation in the case of real gas flow to a well // − Moscow: Oil and Gas Technologies, − 2021. No. 4, − p. 36-39.

[34] Kazymov, B.Z., Zeynalov, R.M. Selection of the optimal mode of operation of the gas well taking into account creeping deformation of rocks // Proceedings of the III International Scientific and Practical Conference on the topic "Modern Programming", − Nizhnevartovsk: − November 27 − 29, − 2020, − 2021, − p. 159-162.

[35] Guliyev, A., Kazimov, B. Numerical Modeling of Development of Oil Deposit with System of Wells Taking into Account the Relaxation of Deformation of Rocks // Materials of the IV International conference "Problems of cybernetics and informatics" (PCİ′2012, vol. III), – Baku: –12 – 14 September, – 2012, p.135-138

[36] Guliyev, A.M., Kazimov, B.Z. Study of rhealogical properties of reservoirs during relaxation and creep strain of rocks and usage of these properties for

- equation of two-dimensional undetermined flow of oil into the well system

$$\frac{\partial}{\partial x}\left(\frac{k_l \bar{k}_n(\sigma)}{\mu_o(p)a(p)}\frac{\partial p}{\partial x}\right)+\frac{\partial}{\partial y}\left(\frac{k_l \bar{k}_n(\sigma)}{\mu_o(p)a(p)}\frac{\partial p}{\partial y}\right)=\frac{\partial}{\partial t}\left(\frac{m}{a(p)}\sigma\right)+$$
$$+\frac{1}{h}\sum_{\nu=1}^{N_1} q_{\nu o}(t)\cdot\delta(x-x_\nu)\delta(y-y_\nu) \qquad (10)$$

- equation of two-dimensional undetermined flow of gas into the well system

$$\frac{\partial}{\partial x}\left\{\left(\frac{k_l(p)\bar{k}_o(\sigma)S(p)}{\mu_o(p)a(p)}+\frac{\beta}{p_{at}}\frac{k_l(p)\bar{k}_g(\sigma)p}{\mu_g(p)}\right)\frac{\partial p}{\partial x}\right\}+$$
$$+\frac{\partial}{\partial y}\left\{\left(\frac{k_l(p)\bar{k}_o(\sigma)S(p)}{\mu_o(p)a(p)}+\frac{\beta}{p_{at}}\frac{k_l(p)\bar{k}_g(\sigma)p}{\mu_g(p)}\right)\frac{\partial p}{\partial y}\right\}=$$
$$=\frac{\partial}{\partial t}\left\{m\left(\frac{S(p)}{a(p)}\sigma+\frac{\beta}{p_{at}}p(1-\sigma)\right)\right\}+\frac{1}{\cdot}\sum_{}^{N_1} q_{\nu o}(t)\cdot G\cdot\delta(x-x_\nu)\delta(y-y_\nu) \qquad (11)$$

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addressing of applied objectives of oil-gas fields development // Special İssue Papers of 34th İnternational Geological Congress "The modern problems of geology and geophysics of Eastern Caucasus and the South Caspian depression", – Brisbane: Nafta-Press (Baku), – 5 – 10 August, – 2012, – p.117-131.

[37] Kazimov, B.Z. Numerical solution of the problem of development of oil field by Wells system taking into account the creeping deformation of rocks // Theses of the 5th International Conference of young scientists and students on the theme "Fundamental and Applied Geology science: achievements, prospects, problems and ways of their solution" dedicated to the 90th anniversary of the National Leader of Azerbaijan Heydar Aliyev,−Baku: −14 −15 November, – 2013, − p. 158.

[38] Guliyev, A.M. Assessment of the effect of creep deformation of rocks on oil recovery coefficient of the field developed in dissolved gas mode / A.M.Guliyev, B.Z.Kazimov, R.M. Efendiyev [et al.] // – Baku: Scientific Works of the Scientific-Research Institute "Geotexnological problems of oil and gas and chemistry", −2014. v. XV, − p.81-87.

[39] Oil and gas extraction technology: Determination of indicators of development of oil and gas fields taking into account deformation of rocks (methodical instruction) / A.M.Guliyev, T.Sh.Salavatov, T.A. Samadov [et al.]. – Baku: Printing house of ASOİU, − 2018. − 61 p.

- initial and boundary conditions

$$p(x, y,0) = p_0, m(x, y,0) = m_0 \ , \ \sigma(x, y,0) = 1 \tag{12}$$

$$\left.\frac{\partial p}{\partial x}\right|_{x=0;L} = 0, \left.\frac{\partial p}{\partial y}\right|_{y=0;H} = 0, \tag{13}$$

where σ - oil saturation coefficient; G - gas factor; $q_{\nu o}$ - debit of oil from the ν-th well; $\bar{k}_o$ and $\bar{k}_g$ - relative phase permeability for oil and gas respectively; $a(p)$ and $S(p)$ - the volume coefficient of oil and the solubility coefficient of gas in oil, respectively; μ_o and $\mu_g(p)$ - is the viscosity of oil and gas, respectively.

The case equations of porous medium are given by Equations (2) and (3), respectively, in the case of relational and creep deformations, and the change in the permeability of the layer is given by the relations (6) and (7), respectively.

In order to solve the problem using the method of finite differences, the layer area with a rectangular surface was adopted as analogous to the corresponding network area adopted in the first chapter. The solution schemes were obtained in accordance with the idea of the "non-obvious scheme for pressure and obvious scheme for saturation".

At the same time, depending on the physical parameters included in the filtering model, the obtained finite difference equations and the stability conditions of the iteration schemes were determined. Thus, based on the obtained difference equations, schemes of continuous numerical solution of the problem were proposed.

The modeling of wells was carried out based on the existing procedure within the framework of the adoption of the pseudostacionar nature of the flow to the well with a fixed radius around the small nodes located in the wells.

The results of the calculations based on the numerical calculation model created taking into account the relaxation deformation of the rocks allowed the following to be noted:

- the decrease of the bottom pressure in the central well occurs

at a greater rate in the case of relaxation deformation of rocks than in the case of nonlinear elastic deformation;

- the reduction of the values of porosity at the bottom of the well occurs at a slower rate in the case of relaxation deformation of rocks than in the case of non-linear elastic deformation;

- the nature of the effect of the relaxation deformation of rocks on the reduction of the bottom hole pressure and oil saturation well wall around values in the central well is the same as in the case of nonlinear elastic deformation;

- values of the gas factor at each value of time are greater than in the case of nonlinear deformation in the case of relaxation deformation of rocks;

- in case of elastic deformation of the rocks at all values of the wellbore pressure, the values of the oil yield coefficient are higher than in the case of relaxation deformation of the rocks (up to 18,7% in the considered case).

The results of the calculations based on the numerical calculation model created taking into account creep deformation of rocks allowed the following to be noted:

- the reduction of the bottom pressure in the central well occurs at a greater rate in the case of elastic deformation of rocks than in the case of creep deformation;

- in contrast to the case of relaxation deformation, in the case of creep deformation of rocks, the porosity varies in a larger interval than in the case of non-linear elastic deformation of rocks;

- the nature of the effect of the creepeng deformation of rocks on the reduction of the bottom hole pressure and oil saturation well wall around values in the central well is the same as in the case of nonlinear elastic deformation;

- values of the gas factor at each value of time are greater in the case of non-linear deformation of rocks than in the case of creep deformation;

- at all values of the pressure in the well, in the case of creep deformation of the rocks, the values of the oil yield coefficient are higher than in the case of non-linear deformation of the rocks (up to 75,2% in the considered case).

A similar problem was also solved for the case of axisymmetric plane-parallel radial flow of oil into a separate well in a reservoir with relaxed and creepally deformed rocks. In this case, the characteristics of the flow were taken into account as much as possible by switching to the appropriately selected intermediate conversion variable [40] [41].

At the same time, the problem of determining the development indicators of oil fields with relaxational and creep deformations under the conditions of oil seepage in the formation was formulated, and approximate solutions to these problems were obtained by applying the averaging method and using material balance equations. Using these solutions, the development indicators of the formation can be calculated [42] [43] [44] [45] [46] [47] [48]

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[40] Kazimov, B.Z. Numerical calculation algorithm of radial flow of gaseous oil into the well in the oil field taking into account drift deformation of rocks // – Baku: Scientific Works of the Scientific-Research Institute "Geotechnological problems of oil, gas and chemistry", − 2013. v. XIV, – p. 55-64.

[41] Kazymov, B.Z. Numerical Definition of Indicators of the Development of Creeping Oil Layer on values of Change of an Well Production // – New York: International Journal of Theoretical and Applied Mathematics, – 2017. v. 3. is. 5, – p. 167-173.

[42] Kuliev, A.M., Efendiev, R.M., Kazymov, B.Z., Tagieva, S.E. Modeling the development of oil fields taking into account the relaxation of rocks // Theses of the scientific-practical conference dedicated to the 70th anniversary of AOISRPI (Azerbaijan Oil Industry Scientific-Research Project Institute), – Baku: –14 – 15 April, – 1998, – p. 54-55.

[43] Kuliev, A.M. Modeling the process of developing oil fields in the dissolved gas regime, taking into account the relaxation of rocks / A.M. Kuliev, R.M. Efendiev, B.Z. Kazymov [et al.] // News of the AAS, Series of Earth Sciences, – Baku: – 1998. No. 2, – p. 21-25.

[44] Kuliev, A.M. Modeling the process of developing oil fields taking into account the relaxation of rocks and pressure / A.M. Kuliev, I.A. Nasrullaev, R.M. Efendiev [et al.] // News of the ANAS, Series of Earth Sciences, – Baku: – 2000. No. 2, – p. 12-17.

[45] Kuliev, A.M. Modeling the development of deep-lying deposits taking into account the creep of rocks / A.M. Kuliev, M.A. Dunyamalyev, R.M. Efendiev [et al.] // News of the ASA, Series of Earth Sciences, – Baku: – 2000. No. 2, – p. 18-24.

[46] Guliyev, A.M. Solution of the problem of the flow of gaseous liquid into the well in oil fields with a relaxing environment // A.M.Guliyev, R.M.Efendiyev,

Appropriate solution schemes were proposed in accordance with the technological situation when the number of wells is given and not given, as well as when the depression (ΔP) on the field is given [49] [50] [51] [52] [53] [54] [55] [56] [57] [58] [59] [60] [61].

B.Z.Kazimov [et al.] // Scientific works of AzTU. Series of Fundamental Sciences, − Baku: − 2006. v. V (18). №2, − p.56-60.

[47] Kazymov, B.Z., Aslanov, M.S., Taghiyeva, S.E. On estimation of accuracy of approxlized solutions of one problem at relaxation deformation of porous medium // − Baku: Mechanics, Mechanical Engineering, − 2008. №1, − p. 35-37.

[48] Kuliev, A.M., Kazymov, B.Z., Efendiev, R.M. An approximate method for solving the problem of oil inflow to a well in deposits with a creeping medium // Materials of the All-Russian seminar dedicated to the centenary of P.A. Kuzmina, – Kazan: – November 11 – 12, 2008, – p. 75-76.

[49] Kuliev, A.M. Assessing the influence of rock relaxation on the required number of wells in oil deposits / A.M. Kuliev, B.Z. Kazymov, M.A. Gadzhiev [et al.] // Reports of ANAS, – Baku, – 2007. v. LXIII. No. 5, – p. 81-89.

[50] Kuliev, A.M., Efendiev, R.M., Gadzhiev, M.A., Kazymov, B.Z., Tagieva, S.E. The influence of rock relaxation on the required number of wells of oil deposits when developing them in the dissolved gas mode // Materials of the All-Russian seminar dedicated to the centenary of Aminov Mongim Shakurovich, − Kazan: − February 4 − 5, − 2008, − p. 42-43.

[51] Kuliev, A.M., Efendiev, R.M., Kazymov, B.Z. The influence of well pattern density on oil recovery from reservoirs with a relaxing environment // Materials of the All-Russian seminar dedicated to the centenary of P.A. Kuzmina, – Kazan: – November 11 – 12, – 2008, – p. 77-78.

[52] Kuliev, A.M. Mathematical modeling of the process of developing oil fields with a creeping medium and its influence on the required number of wells / A.M. Kuliev, V.Yu. Babanly, R.M. Efendiyev [et al.] // News of Baku University. Series of Physical and Mathematical Sciences. – Baku: –2009, No. 3, – p. 67-77.

[53] Kuliev, A.M. Mathematical modeling of oil deposit development taking into account the rheological properties of rocks / A.M. Kuliev, V.Yu. Babanly, R.M. Efendiyev [et al.] // Jurnal of Qafqaz University, Mathematics and Computer Science, – Baku: – 2011. No. 31, – p. 85-92.

[54] Kuliev, A.M., Efendiev, R.M., Kazymov, B.Z. The influence of rock creep on the oil recovery of deposits developed in a natural mode // Abstracts of reports of the II international scientific-practical conference on “New technologies in oil production”, – Baku: – 6 – 7 September, – 2012, – p.169.

[55] Kuliev, A.M., Efendiev, R.M., Kazymov, B.Z. The influence of rock creep on oil recovery from deposits developed in natural mode // – Baku: SOCAR Proceeding, – 2012. No. 3, – p. 32-37.

[56] Kuliev, A.M., Kazymov, B.Z., Efendiev, R.M. Modeling the process of developing oil fields with a relaxation-deformable porous medium under depletion

Based on the obtained solutions, in order to estimate the effect of the density of the well network on the development indicators, a rectangular strip-shaped bed with a length of 1500 m, a width of 1000 m and a thickness of 50 m was taken as a hypothetical field. For a square network of wells, three options were considered, where the distance between the wells was $R=2l=400$; 300 and 200 m, and the number of wells was 12, 20 and 35, respectively.

The analysis of the results of the calculations made using the solutions obtained for the oil fields, the rocks of which are deformed by relaxation, made it possible to come to the following conclusions:

- In the development process, the reduction of formation pressure in the layers with a relaxed environment occurs faster than in the layers with a non-linear [illegible] regularity is preserved in the densities of all well networks.

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mode // – Baku: News of ANAS, Series of Earth Sciences, – 2016. No. 3-4, – p. 48-56.

[57] Kuliev, A.M., Efendiev, R.M., Kazymov, B.Z. Inelastic deformation of rocks and their impact on the development indicators of oil and gas fields // Materials of the Scientific Session "Fundamental and applied problems of oil and gas field development" dedicated to the 90th anniversary of Academician M.T.Abasov – Baku: – October 14, – 2016, – p. 209-231.

[58] Guliyev, A. Inelastic deformations of rocks and their influence on development of the oil and gas fields / Arif Guliyev, Ramiz Hasanov, Bunyad Kazimov [et al.] // Petroleum & Petrochemical Engineering Journal, Michigan – 2018. v.2, is.5, – 7 p.

[59] Kuliev, A.M. Study of the influence of well pattern density on the natural and technological indicators of oil field development taking into account creeping deformation of rocks / A.M. Kuliev, R.M. Efendiev, B.Z. Kazymov [et al.] // "Automation, telemechanization and communications in the oil industry", – Moscow: – 2019. No. 2, – p. 38-45.

[60] Kazymov, B.Z., Nasirova, K.K., Bunyatov, A.A. Determination of the dynamics of the required number of wells when developing oil deposits in the dissolved gas mode // − Yoshkar-ola: Scientific journal "Scientist of the XXI Century", – 2021. No. 6, – p. 3-8.

[61] Kazymov, B.Z., Zeynalov, R.M. Determination of the dynamics of the required number of wells when developing deep oil deposits in the dissolved gas mode // Materials of the IV International Scientific and Practical Conference on the topic "Modern Programming", – Nizhnevartovsk: – December 8, – 2021, – 2022, – p. 133-137.

- In the initial period of development, the difference between the formation pressure value in the layers with relaxed and non-linear elastic media is insignificant, and then, as the oil is removed from the field, this difference becomes more significant. This seems to be related to the fact that due to the small oil production in the initial period of development, the pressure in the layers with a relaxed environment in the reservoir is slightly reduced, and the rocks are not so strongly deformed and behave as an elastic medium in the initial period. As the formation pressure decreases, as oil is produced, the loading on the rock skeleton increases and the rock undergoes deformation, and these deformations differ from non-linear elastic deformation.

- In fields with a dense network of wells, formation pressure decreases faster than in fields with a sparse network of wells.

- A sharp change in porosity during processing is most noticeable in beds with a non-linear elastic medium. So, if the porosity of the layer decreases by 8% during processing in the beds with a non-linear elastic environment, it is about 2,1% in the fields with a relaxed environment. This shows that this circumstance must be taken into account when carrying out work on recalculating oil reserves.

- In reservoirs with a non-linear elastic medium, porosity decreases in the same way regardless of the density of the well network, the only difference is that it is achieved at different times at different densities. So, if with dense networks, this is achieved in less than a year, then with sparse networks (12 ha / well) it is achieved in about 3,5 years. Unlike deposits with a nonlinear elastic medium, deposits with a relaxation medium have a different nature of changing porosity at different densities.

- The nature of permeability changes in fields with relaxed and non-linear-elastic media is almost the same, and in fields with relaxed media the permeability of the bed decreases faster than in beds with non-linear elastic media. Moreover, this regularity is preserved in the densities of all well networks.

- As the formation is worked, the oil saturation in the relaxation environment in the formation decreases much more than in the

formations with nonlinear elastic environment, and this situation is observed in all well network densities.

- At all densities of the well network, the values of the gas factor in the layers with a relaxed environment are greater than in the layers with a non-linear elastic environment. This is due to the fact that in beds with a relaxed environment, during the entire period of processing, the formation pressure decreases faster than in beds with a non-linear elastic environment.

- Regardless of the density of the well network, the oil yield coefficient in fields with a relaxed environment is always lower than in fields with a non-linear elastic environment. Moreover, in dense networks, the current oil yield coefficient in fields with both relaxation and nonlinear elastic media is greater than in sparse networks.

- In fields with a relaxed and non-linear elastic environment, the final oil yield coefficient is almost independent of the density of the well network. The time to achieve the same final oil production volume is different in different well densities, whether in relaxed or non-linear elastic medium fields.

In fields with a relaxed environment, the oil yield coefficient is lower than in fields with a non-linear elastic environment. For the hypothetical bed sample under consideration, this difference can be 15-20%.

The analysis of the results of the calculations made using the solutions obtained for the oil fields, whose rocks undergo creep deformation, allowed us to come to the following conclusions:

- In the development process, the reduction of formation pressure in layers with a creeping medium occurs at a slower rate than in layers with a nonlinear elastic medium, and this regularity is maintained in the densities of all well networks.

- As the initial period of development continues, the difference between the value of the formation pressure in the layers with creeping and non-linear elastic media continues to increase. - In fields with a dense network of wells, formation pressure decreases faster than in fields with a sparse network of wells.

- A sharp change in porosity during development is most noticeable in fields with a creeping deformable environment, and this

regularity is maintained in the densities of all well networks. So, in all cases, if the porosity of the layer decreases by 8% during processing in deposits with a non-linear elastic medium, it is about 37% in the deposits with a creep deformable medium. This shows that this large decrease in porosity should be taken into account when calculating and recalculating oil reserves.

- The nature of the change of permeability in fields with a creeping and non-linear-elastic environment is the same as the nature of the change of porosity, but in this case the values of permeability decrease in a larger interval and this regularity is maintained in the densities of all well networks. Thus, in all cases, if the permeability of the layer decreases by 18% during processing in the fields with a non-linear elastic medium, it is about 54% in the fields with a creep deformable medium.

- As the formation is worked, the oil saturation in the creeping environment in the formation decreases much more than in the formations with non-linear elastic environment and shows a tendency of stability at a certain value. This regularity is observed in the densities of all well networks. Such a feature of reduction may be related to the nature of pressure reduction.

- At all densities of the well network, the values of the gas factor in the layers with a creeping medium are lower than in the layers with a non-linear elastic medium. This is due to the fact that during the entire period of working in fields with a creeping medium, the reduction of formation pressure occurs at a slower rate than in fields with a non-linear elastic medium.

- Regardless of the density of the well network, the coefficient of oil production in fields with a creeping medium is always greater than that of fields with a non-linear elastic medium (up to 95%).

The analysis of the obtained numerical results shows the need to take into account the influence of the rheological properties of the rocks when determining the development indicators, including the influence of the formations on the filtration-capacity parameters and the oil yield coefficient at different well densities.

The analysis of the calculation results obtained based on the solution of the problem of determining the necessary number of

wells in the absence of a network of wells, taking into account the relaxation deformation of the rocks, shows that:

- The required number of wells in relaxed deformation conditions is higher than in a non-linear elastic layer (up to 20% in some cases);

- The number of wells increases sharply near the end of development, and this is due to the fact that at the end of development, the flow rate of wells decreases sharply, and it is necessary to enter a large number of wells to ensure the speed of the given production volume;

- From the beginning of development at a constant production rate, the number of wells in layers with a relaxed environment, the required number of wells in layers with a non-linear elastically deformable environment does not increase significantly (in our case, up to 12% of the initial reserve), and then a sharp increase is observed;

- As the pressure difference (depression) increases, regardless of the distance between the wells, the number of wells in the fields with both relaxation and non-linear elastic media decreases sharply (this is due to the fact that the flow rate of the wells increases with the increase of the pressure difference, and this, in turn, , leading to a sharp reduction in the number of required wells).

The distance between the wells also affects the number of wells under the same technological conditions of well operation. Thus, with the increase in the distance between the wells, the number of wells in fields with different environments increases. However, if this difference is significant in minor depressions, this difference is insignificant in major depressions.

These results can be successfully used in the development projects of oil fields whose rocks are deformed by relaxation and in the analysis of the development process.

Similarly, the analysis of calculation results obtained taking into account creep deformation of rocks shows that:

- in all considered cases, the creeping deformation of the rocks starts to affect the required number of wells only after the maximum production volume is obtained from the field (up to the maximum

number of 2 wells);

- in the case of creeping deformation of rocks, the number of wells is less compared to the case of inelastic deformation of rocks;

- in the case of creeping deformation of rocks, the number of wells has less influence on the number of wells determined in the case of high depression than in the case of inelastic deformation of rocks;

- at large values of the inter-layer distance, the value of the number of wells determined by the creep of the rocks is high;

- as the value of the parameter m_1 increases, the number of wells in the case of creep deformation of rocks differs more than in the case of inelastic deformation of rocks;

- when considering the effect of rock creep on formation permeability, the number of necessary wells is greater than in the case of non-linear elastic deformation of rocks, compared to the case when the effect of rock creep on formation permeability is not taken into account;

- if the effect of creep of rocks on formation permeability is taken into account, the number of wells in low depression conditions has a maximum effect of up to 10 wells compared to the case of non-linear elastic deformation of rocks, while this effect is 6 wells in high depression conditions;

- taking into account the effect of rock creep on formation permeability, the fact that the number of necessary wells is greater than in the case of non-linear elastic deformation of rocks may be related to the relative stabilization of oil saturation in the formation due to a sharper decrease in permeability and, as a result, to a decrease in well production.

As mentioned, in this chapter, the methods of determining the development indicators of oil fields, taking into account the gas segregation, have been developed [62] [63].

[62] Kuliev, A.M., Efendiev, R.M., Kazymov, B.Z. Modeling of the process of the development of oil fields taking into account the relaxation of rocks and gas segregation // Proceedings of the II Republican Scientific Conference "Modern problems of informatization, cybernetics and information technologies", – Baku: – October 26 – 28, – 2004, – p. 11-13.

It is noted that it is known from the development experience of oil fields operated in depletion mode that as a result of formation pressure falling below the saturation pressure during the development process, the dissolved gas bubbles inside the oil separate from the liquid as a result of segregation and collect on the ceiling part of the formation, forming a gas cap, so that the dissolved gas regime is more effective. can lead to the replacement of the gas pressure regime and, as a result, an increase in the oil yield coefficient, and this factor determined the involvement of the relevant issue in the research.

The analysis of the results obtained from the calculations performed on the received solutions showed the need to take into account the effect of gas segregation in the conditions of relaxation and creep deformations of rocks when determining the development indicators of closed oil fields operated in the dissolved gas regime.

Also, taking into account the activity of the water zone behind the contour, the issue of oil fields, whose rocks are subjected to relaxation and creep deformation, in the sub-suspended mode, has been investigated. According to the continuous displacement of water-oil contact in the development process, a system of differential equations was obtained that allows determination of development indicators such as formation pressure, porosity, oil saturation, gas factor, and the volume of the oily part in the field.

In addition to the mentioned research issues, in this chapter, the methods of numerical determination of the development indicators of oil fields, whose rocks are subjected to relaxation and creep deformation, according to the conditions of non-isothermal filtration, have been developed [64] [65] [66].

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[63] Kuliev, A.M. Modeling the process of developing oil fields taking into account gas segregation and rock creep / A.M. Kuliev, R.M. Efendiev, B.Z. Kazymov [et al.] // Scientific works of AzTU. Fundamental sciences series, – Baku: – 2006. v. V (19). No. 3, – p. 39-44.

[64] Kazimov, B.Z. New calculation algorithms for the development of oil fields taking into account rheological models of rock deformations // Collection of articles of the scientific-practical conference “Xezerneftqazyataq-2016”, – Baku: – 22–23 December, − 2016, − p. 418-423.

[65] Kuliev, A.M. Mathematical modeling of non-isothermal filtration of carbonated

So that as the depth of oil and gas deposits increases, the effect of thermodynamic factors on the development indicators of the deposits is felt more. Thus, the change in the energy potential of the bed during the operation process also causes a change in its heat balance. This, in turn, affects the non-isothermal oil seepage in the porous medium on the one hand, and the mode of field development and the phase state of the formation system on the other hand. During the development process of this type of deposits, the temperature of the fluids in the formations differs from the natural temperature of the formation, even if the formation is not affected by heat.

The quantitative and qualitative analysis of the calculation results shows the importance of taking into account the non-isothermal processes occurring in the formation in accordance with the conditions characterized by the relaxation and creep deformation of the rocks when solving the design and evaluation issues of the development of oil fields.

For example, in the case of creep deformation of rocks, calculations have shown that:

- It is observed that the rate of decrease of the pressure values in the well is considerably slowed down due to the effect of the temperature change in the formation compared to the case of non-linear deformation (up to 50%);

- In the case of creep deformation, in the isothermal case, the permeability well wall around values are smaller than the contour values, while in the case of non-isothermal flow, the permeability well wall around values are greater than the contour values. In this case, the rocks of the temperature field mainly affect the character of the collector properties of the well bottom zone in the layer subjected to creep deformation;

- Temperature in creep-deformable layers reduces the rate of

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oil taking into account nonequilibrium deformation of rocks / A.M. Kuliev, R.M. Efendiev, B.Z. Kazymov [et al.] // "Automation, telemechanization and communication in the oil industry", – Moscow: – 2017. No. 9, – p. 17-22.

[66] Kazymov, B.Z. Influence of the relaxation deformation of rocks on the characteristics of nonisothermal filtration of live crude in the stratum // – New York: Journal of Engineering Physics and Thermophysics, – 2018. v. 91. No. 6, – p. 1539-1542

decrease by up to 18% compared to non-linear elastically deformable layers in the process of processing the layer. This can be explained by the low occurrence of temperature losses in layer conditions during the creeping deformation of rocks;

- Taking into account the temperature change in the layer during the creep deformation of rocks, the gas factor is high in both the creep and elastically deformed layers, which manifests itself in a wider interval in the layers undergoing creep deformation.

In this chapter, the issue of working oil fields in the depletion mode was also studied, taking into account the Abel creep core, and a corresponding approximate solution method was developed [67]. It is noted that thanks to the implementation of the obtained approximate solution scheme, it is possible to monitor the changes of the average formation pressure, porosity and oil saturation coefficients during the working period of the considered field.

It should be noted that within the framework of the work, the issues of flow of single-phase fluid and non-Newtonian oil into the well, taking into account the deformation of rocks, as well as the issues of development of oil fields exploited by inclined wells and the selection of optimal technological regime in gas condensate wells were also studied, the results of which are reflected in the work [68] [69] [70] [71] [72] [73] [74] [75] [76] [77].

[67] Kazimov, B.Z. Determination of oil field development indicators whose rocks are subject to Abel core creep deformation / B.Z.Kazimov, A.A. Damirov, R.M. Efendiyev [et al.] // Scientific and Pedagogical News of Odlar Yurdu University, – Baku: – 2020. № 56, – p. 30-34.

[68] Kuliev, A.M., Kazymov, B.Z. Exact solution to the problem of filtration of an elastic fluid in a creeping porous medium // – Baku: Proceedings of the IPDOGD ASA "Issues of development and physical chemistry of oil and gas bearing formations", – 1999. – p. 45-51.

[69] Guliyev, A.M., Kazimov, B.Z., Efendiyev, R.M. Determination of indicators of development of oil fields with inclined wells whose rocks are subject to relaxation and creep deformation // – Baku: "Oil and gas problems",−2019. №1, − p. 37-46.

[70] Kazymov, B.Z. Study of the process of oil filtration to the well in relaxation-deformed heterogeneous oil reservoir in the dissolved gas mode // Proceedings of the International Scientific and Practical Conference "State and prospects of exploitation of mature fields", − Aktau: − 16 −17 May, − 2019, − p.232-237.

[71] Mammadov, E.V., Kazimov, B.Z. Methodology for determining the optimal

In the fourth chapter, the methods of determination of the development indicators of gas oil deposits, the rocks of which are subject to relaxation and creep deformation, in accordance with various geological and technological conditions (immobility and mobility of oil-gas contact, gas segregation) are described [78] [79] [80] [81] [82]

operating mode of a gas condensate well taking into account the deformation of reservoir rocks // International Scientific Journal "Scientist of the XXI century", – 2020. № 6-3(65), – p. 3-7.

[72] Samedov, T.A., Kazymov, B.Z., Novruzova, S.G. Selection of the optimal operating mode of a gas-condensate well, taking into account the relaxation deformation of rocks // − Moscow: Oil and Gas Technologies, − 2021. No. 3, − p. 50-54.

[73] Kazymov, B.Z. Methodology of calculation of pressure changes in the non-equilibrium-deformed reservoir in the case of single-phase fluid flow to the well // − Moscow: "Automation, telemechanization and communication in oil industry", − 2021. №10, − p.37-41.

[74] Kazymov, B.Z., Zeynalov, R.M. A method for approximate determination of the indicators of development of a reservoir with rocks subjected to relaxation deformation in single-phase fluid flow // – Baku: Transactions of ANAS, Series of Physical-Technical and Mathematical Sciences. Informatics and Control Problems, – 2022. №2, – p. 73-79.

[75] Kazimov, B.Z., Zeynalov, R.M. Determination of oil reservoir development indicators on the first phase of filtration with relaxation of rocks // Materials of the II Republican scientific conference dedicated to the 60th anniversary of Sumgayit State University on the topic "Fundamental problems of mathematics and application of intellectual technologies in education", – Sumgayit: – December 15 – 16, 2022, – p.94-97.

[76] Kazymov, B.Z. Scheme for determining the filtration characteristics of filtration on the first phase of single-phase liquid in the formations, rocks which are subjected to deformation with creeping character // − Moscow: Oil and Gas Technology, − 2022, №3, − p.50-52.

[77] Kazymov, B.Z. Numerical method of determining the development indicators of non-Newton oil reservoir taking into account the rheology of rocks // Materials of the International Scientific-Practical Conference "Heydar Aliyev and Azerbaijan oil strategy: progress in oil and gas geology and geotechnologies" dedicated to the 100th anniversary of the National Leader of the Azerbaijani people Heydar Aliyev, − Baku: − 23 −26 may, − 2023, − p. 942-946.

[78] Dunyamalyev, M.A., Kazymov, B.Z., Kuliev, A.M., Efendiev, R.M. Modeling of the process of oil and gas fields development in deformable formations taking into account relaxation effects // Proceedings of the International Scientific Conference devoted to the 90th anniversary of G.G. Tumashev "Boundary problems of aerohydromechanics and their applications", − Kazan: − November 21

83 84 85 86 87 88.

− 24, − 2000, − p.304-305.

[79] Kuliev, A.M. Mathematical modeling of the development of oil and gas deposits with a creeping medium / A.M. Kuliev, M.A. Dunyamalyev, R.M. Efendiev [et al.] // News of the ANAS, Series of Earth Sciences, − Baku : – 2001. No. 2, – p. 22-26.

[80] Kuliev, A.M., Efendiev, R.M. Kazymov, B.Z. Mathematical modeling of the process of developing gas and oil deposits taking into account the relaxation of rocks // Abstracts of the Republican scientific conference "Mathematical modeling and computational experiment", − Tashkent: − March 25 − 27, − 2002, − http://mmce -2002.narod.ru/Contents.htm

[81] Kuliev, A.M., Efendiev, R.M., Gadzhiev, M.A., Kazymov, B.Z. Modeling the process of developing gas-oil deposits in creeping media, taking into account the mobility of the gas-oil contact // Proceedings of the Republican Scientific Conference "Modern problems of informatization, cybernetics and information technologies", – Baku: – April 28 – 30, – 2003, – p. 7-9.

[82] Kuliev, A.M., Efendiev, R.M., Kazymov, B.Z., Tagieva, S.E. Modeling the process of developing oil deposits with a gas cap, taking into account the relaxation of rocks // Proceedings of the Republican Scientific Conference "Modern problems of informatization, cybernetics and information technologies", − Baku, − April 28 − 30, − 2003, − p. 32-34.

[83] Kuliev, A.M. Hydrodynamic study of the process of gas-oil contact advancement and gas penetration from one area to another in deposits with a "relaxing" environment / A.M. Kuliev, R.M. Efendiev, B.Z. Kazymov [et al.] // News of ANAS , Earth Science Series, – Baku: – 2003. No. 3, – p.29-37.

[84] Kuliev, A.M. Modeling the process of developing oil and gas deposits with the immobility of the gas-oil contact taking into account the relaxation of rocks / A.M. Kuliev, R.M. Efendiev, B.Z. Kazymov [et al.] // News of the ANAS, Series of Earth Sciences, – Baku: – 2003. No. 3, – p. 23-28.

[85] Kuliev, A.M., Efendiev, R.M., Kazymov, B.Z. Modeling the process of formation of a gas cap during the development of oil deposits, taking into account the relaxation of rocks // − Baku: News of ANAS, Series of Earth Sciences, −2005. No. 2, – p.100-105.

[86] Kuliev, A.M., Efendiev, R.M., Kazymov, B.Z. Modeling the process of developing gas-oil deposits taking into account the relaxation of rocks and gas segregation // Materials of the All-Russian seminar dedicated to the centenary of Aminov Mongim Shakurovich, − Kazan: − February 4 − 5, − 2008, − p.44-45.

[87] Kuliev, A.M. Modeling the process of developing gas and oil fields with rock creep and gas segregation / A.M. Kuliev, R.M. Efendiev, B.Z. Kazymov [et al.] // Mechanics, Mechanical Engineering, – Baku: – 2008. No. 2, – p. 12-17.

[88] Aslanov, M.S., Kazymov, B.Z. Accounting of rock relaxation and gas segregation in the development of gas and oil fields // Materials of the Fourth International Scientific Conference "Functional - differencial equations and their

It is noted that the study of the effect of rock deformation on the indicators of the oil and gas field development process is of great practical interest, because unlike the development of oil fields, the development of gas oil fields is complicated due to the fact that oil and gas parts are involved in operation separately, and in itself a number of relevant management requires solving the issues.

In connection with the mentioned, the issue of working gas and oil deposits in depletion mode was studied, first, taking into account the immobility of the gas-oil contact, and then the mobility, and the corresponding calculation expressions were obtained.

The following calculation results were obtained for the received solutions:

- In case of relaxational deformation of the rocks and the gas-oil contact is inactive:

1. The relaxation period of rock porosity does not have the same effect on individual indicators.

2. Relaxation time has the most noticeable effect on the character of formation porosity change. In beds with a non-linear elastically deformed medium, porosity decreases more slowly during processing than in beds with a relaxed medium. Moreover, the rate of porosity decrease is slower as the relaxation time increases.

3. In formations with high initial formation pressure, the reduction of porosity in formations with both nonlinear elastic deformation medium and relaxation medium occurs faster than in formations with low initial formation pressure.

4. In formations with a relaxed environment, formation pressure and oil saturation decrease faster than in formations with an environment undergoing nonlinear elastic deformation. Moreover, their rate of decrease increases with the increase of relaxation time.

5. At the initial stage of development, the decrease in pressure and oil saturation level occurs in the same way in fields with a non-linear elastic deformation medium and a relaxed medium. and later. as the development continues, [illegible] pressure decrease and saturation is observed in a bed with a non-

applications", – Makhachkala: – September 21 – 24, – 2009, – p.57-66.

linear elastically deformed medium than in a bed with a relaxed medium. This difference increases as the relaxation time increases.

6. The difference between the corresponding values of pressure and oil saturation in bed cases with an increase in the value of the initial formation pressure and a relaxed and non-linear elastic deformation medium is more noticeable, that is, an increase in the initial formation pressure increases the effect of the relaxation of the medium on the determined values of the formation pressure and oil saturation.

7. The values of the gas factor in deposits with a relaxed medium are higher than those with a non-linear elastically deformed medium, and this difference is more significant in deposits with a high initial formation pressure.

8. Changes in gas production from the gas part of the reservoir are similar in nature to changes in the gas factor.

9. In fields with a relaxed environment, total gas production to maintain the immobility of the gas-oil boundary is greater than in an environment undergoing nonlinear elastic deformation. Moreover, the difference between their values is more noticeable in the case of fields with high initial formation pressures.

- In case of creeping deformation of rocks and immobility of gas-oil contact:

1. Rock creep does not have the same effect on individual indicators over time.

2. In formations with high initial formation pressure, the reduction of porosity, formation pressure and oil saturation occurs faster than in formations with low initial formation pressure.

3. In the formations whose rocks undergo nonlinear elastic deformation, the decrease in porosity is slower than in the formations whose rocks undergo creep deformation, and the formation pressure and oil saturation decrease faster.

4. The values of the gas factor in layers whose rocks undergo creep deformation are smaller than in layers whose rocks undergo elastic deformation.

5. Changes in gas production from the gas part of the reservoir are similar in nature to changes in the gas factor.

6. In order to ensure the immobility of the gas-oil boundary from fields whose rocks undergo creep deformation, it is necessary to produce a smaller amount of gas from the gas part than from fields whose rocks undergo elastic deformation.

7. Taking into account the creepiness of the rocks, the characteristics of changes in the development indicators of the fields over time are more noticeable in the fields with high initial formation pressure, that is, it is necessary to take into account the creepiness of the rocks when determining the main development indicators of the deep gas oil fields.

In case of relaxational deformation of rocks and gas-oil contact is mobile:

- If the passage of gas from one part to another is taken into account and not taken into account, the pressure decreases more slowly in the formation whose rocks undergo elastic deformation than in the formation which is deformed by relaxation. In both cases, the decrease in pressure occurs more intensively when the passage of gas is taken into account than when the passage of gas from one area to another is not taken into account;

- If the gas transfer from one part of the gas to another is taken into account and not taken into account, the porosity of the formation during the development process is reduced more significantly in the elastically deformed formation than in the relaxationally deformed formation. the effect of gas transfer from one part of the gas to another is more noticeable in a formation with an elastically deformable medium than in a formation undergoing relaxation deformation;

- The oil content of the pores in the formation with an elastically deformed medium decreases more slowly than in the formation that undergoes relaxation deformation, and this difference is more noticeable if the gas enters from the oil part to the gas part;

- The nature of gas factor changes in layers with elastic and relaxation deformation of rocks is almost the same. If the passage of gas from the oil-rich part to the gas-rich part is not taken into account, the continuous increase in the volume of the oil-rich part can be explained by the fact that as the field is worked, the oil

saturation decreases sharply, as a result, the relative permeability of the pores to gas increases, which leads to an increase in the gas factor;

- The expansion (increase) of the volume of the oil-bearing part in the formation with elastically deformed rocks occurs faster than in the formation with relaxedly deformed rocks, both when considering the passage of gas from one part to another and not taking into account;

If the rocks undergo creep deformation and the gas-oil contact is mobile:

- If the passage of gas from one part to another is taken into account and not taken into account, the pressure in the formation whose rocks are elastically deformed decreases faster than in the creepally deformed formation. In both cases, the decrease in pressure occurs more intensively when the passage of gas is taken into account than when the passage of gas from one area to another is not taken into account;

- Formation porosity decreases more insignificantly in elastically deformed formations than in creepally deformed formations. The effect of gas migration from one part to another is less pronounced in a formation with an elastically deformable medium than in a creepally deformed formation;

- The oil saturation of the pores in the formation with an elastic deformation medium decreases more rapidly than in the formation with creep deformation, and this difference occurs over time, excluding the last stage of development, both in the case of taking into account the transfer of gas from one part to another and not taking into account ;

- If the transition of gas from the oil part to the gas part is not taken into account, the continuous increase in the volume of the oil part, excluding the last stage of processing, occurs more intensively in the fields whose rocks undergo elastic deformation than in the fields undergoing creep deformation;

- The expansion (increase) of the volume of the oil part in the formation with elastically deformed rocks occurs more slowly than in the formation with creeping deformation, both when considering the

passage of gas from one part to another and not taking into account.

The calculation results show that the failure to take into account during the design and analysis calculations of the development of deposits with rocks undergoing relaxation and creep deformation due to the passage of gas from one part to another can lead to certain errors in the calculation of all development indicators.

In this chapter, at the same time, the calculation methods of gas and oil fields operated with a regular network of wells, taking into account the relaxation and creep deformation of rocks and gas segregation, have been created. Based on the created calculation methods, multivariate calculations were carried out according to each case, and the effect of the rheological nature of the rock deformation on the performance parameters considering the nonlinear elastic deformation was evaluated and the corresponding calculation results were formulated. It was determined that the relaxation and creep deformation of the rocks compared to the elastic deformation reduces the effect of gas segregation on the development indicators of gas and oil fields in depletion mode, while gas segregation is not taken into account. The creep of the rock accelerates the volume growth of the oily part.

In the fifth chapter, it is noted that the experience of developing oil and gas fields shows that the rocks that make up them undergo linear or non-linear deformations during the development process, depending on the influence of stress-strain conditions. Such deformation processes, in turn, affect the collector properties of the layers to an appropriate degree, which, as a result, finds its expression in the set values of all the technological indicators of the deposits. The calculated values may differ significantly due to the influence of the linear or non-linear deformation characteristics of the rocks on the development indicators of the oil and gas fields, which is a complex characteristic stress-strain that causes the inelastic deformation of the rocks in the development design issues. made it necessary to take into account the conditions. Taking this into account, in recent years, systematic research in the relevant direction has been given ample space. Thus, the analysis shows that these studies are mostly performed taking into account the rheology

of the rocks. This can be explained by the fact that most of the deposits that have been developed in recent times are located at great depths, and since the rocks that make up such deposits are located under the influence of high geostatic loading, they are affected by complex stress-deformation conditions during the development of the deposits, which makes the development of those deposits impossible. for the purpose of drawing up projects, brought the consideration of the rheology of rocks to the fore in solving the issues involved in the research. On the other hand, prediction methods developed on the basis of complex characteristic deformation models of rocks are often not convenient in terms of practical use. This is primarily due to the unknown parameters included in those models. There is a need to determine those parameters - physical indicators - as a result of separate special studies - based on the interpretation of mining data.

At the same time, traditional experience shows that the reliable processing of mining research results on the study of reservoirs and wells requires the availability of analytical solutions of relevant hydrogasdynamic problems. However, if the given problem contains a large number of unknown parameters that need to be determined, then the solutions that allow the interpretation of mining research data are very complex, which in many cases makes it difficult to use these solutions appropriately. In such cases, there is a need to identify the hydrogas-dynamic model describing the process of seepage in the reservoir due to the high uncertainty of the initial information (due to their quantitative abundance), that is, to adjust it to the bed conditions. In this case, with the help of a special procedure, identification determination of the main filtration-capacity parameters of the layer included in the model is carried out. This process is also known as recovery of development history. By restoring the development history, the parameters that usually have the greatest uncertainty and have the strongest influence on the solution are corrected (especially absolute and phase permeability, volume of the back-contour area, pore compressibility coefficient, productivity and acceptance coefficients of the wells, etc.). However, it is preferable to use the identification approach based on the use of the development data on the recovery of the development history in

solving the problems of adequate evaluation of the reservoir properties of the rocks, including the filtration characteristics during the formation development.

In connection with the mentioned, the methods of determination of seepage-capacity and rheological deformation parameters of oil and gas fields, whose rocks undergo relaxation and creep deformations, developed on the basis of field development and well research data, are described in the chapter [89] [90] [91] [92] [93] [94] [95] [96] [97] [98] [99]

[89] Kuliev, A.M., Kazymov, B.Z., Efendiev, R.M., Nasirova, K.K. On the problem of determining pressure recovery curves in a well in a creeping oil reservoir // Materials of the III International Scientific and Practical Conference "Youth and Science: Reality and Future", – Nevinnomyssk: – May 17 – 20 , 2010, – p. 278-280.

[90] Kazimov, B.Z., Nasirova, K.K. On the method of determination of filtration and rheological parameters of a relaxed homogeneous oil layer // − Baku: Works of young scientists, – 2010. №3, – p. 48-53.

[91] Kazymov, B.Z. Determination of rheological parameters of inelastic deformation models of rocks of oil deposits on the data of development // Proceedings of the International Scientific Conference "Innovative development of oil and gas complex of Kazakhstan", − Aktau: − April 25 −26, − 2013, − part 1, − p. 254-257.

[92] Guliyev, A.M., Kazimov, B.Z. Calculation of the porosity of the Lower Kirmaki suits formation of the "Northern fold"of the Pirallahi field, taking into account the deformation of rocks // – Baku: Scientific Works of the Scientific-Research Institute "Geotechnological problems of oil, gas and chemistry",−2014. v.XV, − p. 135-141.

[93] Kazymov, B.Z. Interpretation equations for determination of rheological and filtration-capacitance parameters of gas reservoir with creeping medium // − Baku: Scientific Works of the Scientific-Research Institute "Geotechnological problems of oil, gas and chemistry", − 2014. v. XV, − p. 87-91.

[94] Kazymov, B.Z. Determination of rheological and filtration-capacitance parameters of gas reservoir with creeping medium according to the data of recovery and downhole pressure drop // Book of Abstracts of the 1st International Scientific Conference of young scientists and specialists "The role of multidisciplinary approach in solution of actual problems of fundamental and applied sciences (Earth, Thechnical and Chemical)". − Baku: − 15 −16 october, − 2014, − p. 74-75.

[95] Kuliev, A.M., Kazymov, B.Z. Towards the determination of filtration-capacitive and rheological parameters of an oil reservoir with a creeping medium // Materials of the international scientific-practical conference "Priority directions for the development of modern science", – Makhachkala: – February 24. – 2015, – p. 15-19.

100 101 102 103 104 105 106 107 108 109 110 111.

[96] Kazymov, B.Z. Algorithm for determining the parameters of relaxation deformation model of rocks of gas deposits according to the data of their development // − Yoshkar-ola: Scientific Journal “Scientist of XXI century”, − 2015. № 5-6, − p. 17-20.

[97] Guliyev, A.M., Kazimov, B.Z. Calculation of oil and gas field reserves taking into account inelastic deformations of rocks // − Baku: Azerbaijan Oil Industry Journal, – 2015. №4, − p. 18-20.

[98] Guliyev, A.M., Kazimov, B.Z. Methods of determination of rheological and filtration-capacity parameters of nonlinear deformed rocks // − Baku: Scientific and Pedagogical News of Odlar Yurdu University. Series “Humanities and Exact Sciences", – 2015. №41. − p. 5-16.

[99] Kazimov, B.Z. On the assessment of oil and gas reserves of deposits taking into account nonlinear deformations of rocks // Materials of the international multidisciplinary forum of young scientists and specialists dedicated to the 70th anniversary of ANAS “Academic Science Week-2015”, – Baku: – 2015, – November 2-4, − p.78-79.

[100] Feyzullayev, Kh.A., Damirov, A.A., Kazimov, B.Z. Parametric identification of filtration-capacity parameters of exhaust gas reservoir // − Baku: Scientific and Pedagogical News of Odlar Yurdu University, – 2016. – №45, – p. 71-77.

[101] Feyzullayev, Kh.A., Damirov, A.A., Kazimov, B.Z. Parametric identification of filtration-capacity parameters of exhaust gas reservoir // − Baku: Scientific and Pedagogical News of Odlar Yurdu University, – 2016. – №45, – p. 71-77.

[102] Feyzullayev, Kh.A., Damirov, A.A, Kazimov, B.Z. Determination of parameters of deformed layer during filtration of gas condensate mixture // − Baku: Scientific and Pedagogical News of Odlar Yurdu University, – 2017. – №47, – p. 46-52.

[103] Feyzullaev, Kh.A., Khalilov, M.S., Kazymov, B. Parametric identification of reservoir properties of a relaxation-deformable gas reservoir // Materials of the international scientific-practical conference “Modern mathematics and its applications”, – Ufa: – May 18–20, – 2017, – p. 307-311

[104] Feyzullaev, X.A. Identification determination of filtration-capacitive parameters of a nonequilibrium-deformable formation during filtration of a gas-condensate mixture / Kh.A. Feizullaev, A.A. Damirov, B.Z. Kazymov [et al.] // Automation, telemechanization and communications in the oil industry, – Moscow: – 2018. No. 9, – p.58-62.

[105] Guliyev, A.M., Kazymov, B.Z., Efendiyev, R.M., Shikhaliyev, K.T. Grapho-analytical and identification methods of determining reservoir parameters of inelastic-deformable gas deposits / Arif Guliyev, Bunyad Kazymov, Ramig Efendiyev [et al.] // Materials of the International Conference “Modern problems of innovative technologies and applied mathematics in oil and gas production” dedicated to the 90th anniversary of Academician Azad Mirzajanzade, – Baku:

The methods based on the processing of the hydrogas-dynamic research results of the wells were developed within the framework of the well pressure reduction and well bottom pressure recovery data, taking into account and not taking into account the variable flow into the well. Historical data obtained for a certain development period of the dynamics of total production extracted from the field are taken as the development data of the field. Although these methods mainly cover single-phase flow cases, they also cover gaseous oil flow cases in many cases. Thus, the identification methods developed for determining the formation's seepage-capacity and deformation parameters based on the field development data take into account the pressure-dependent changes in the physical properties of fluids during the seepage of gaseous oil and gas in the formation.

In this chapter, considering the rheology of the rocks, the features of calculating the balance reserves of oil and gas fields were

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Printing house of ASOİU, – 13 – 14 December, – 2018, – p.411-412.

[106] Kuliev, A.M., Efendiev, R.M., Kazymov, B.Z., Shikhaliev, K.T., Abbas-Alieva, R.T. Methods for determining the rheological parameters of models of inelastic deformation of rocks of gas deposits according to development data // Materials of the international scientific and practical conference "State and prospects for the exploitation of mature fields", – Aktau: –16 – 17 May, – 2019, – 1st volume, – p. 258-263.

[107] Kazymov, B.Z. Graphoanalytic determination of parameters relaxation deformation of rocks by data of development of deposits // – El Oued: Journal of Fundamental and Applied Sciences, – 2019. v.11, No 1, – p. 430-433.

[108] Kazymov, B.Z. Determination of reservoir properties of gas reservoirs in conditions of rock creep with Abel's kernel / B.Z.Kazymov, T.A.Samedov, S.G.Novruzova [et al.] // Oil and Gas Technology, − Moscow: − 2021. №2, − p. 31-33.

[109] Kazimov, B.Z., Damirov, A.A. Identifiable determination of filtration-capacity parameters of a gas layer with creeping deformation of rocks // − Baku: Scientific and Pedagogical News of Odlar Yurdu University, – 2022. №61, – p. 12-18.

[110] Feyzullaev, Kh.A., Khalilov, M.S., Kazymov, B.Z. Identification of reservoir properties of a relaxation-deformable gas reservoir based on development history data // – Peterhof: Differential equations and control processes, – 2023. No. 1, – 11 p.

[111] Kazymov, B.Z., Nasirova, K.K., Shikhaliev, K.T. Algorithm for determining rheological and filtration-capacitive parameters of a limited gas reservoir with a creeping medium // − Moscow: Oil and Gas Technologies, − 2023. No. 2, − p. 44-46.

studied and the relevant results were interpreted.

CONCLUSION

1. Methods have been developed for determination of oil and gas deposits with relaxation and creep deformation on the basis of numerical modeling. By conducting computational experiments, the characteristics of the change of oil and gas field development indicators in relation to the elastic deformation of rocks during the development period were determined. Based on numerical calculations it has been established that:

- The effect of relaxation deformation of rocks on the development indicators of gas fields compared to the development indicators of oil fields is very small.

- In the process of development of the gas field, the current gas yield coefficient of the field is less in the case of relaxation deformation of rocks compared to the case of nonlinear deformation at the same value of the average well pressure on the wells, which is more pronounced when the well pressure decreases more (up to 3%). Compared with nonlinear deformation at the same value of the average well pressure on the wells, the current gas yield coefficient of the field is greater in the case of creep deformation of rocks, which is more pronounced when the well pressure decreases more (up to 17,7%).

- In case of elastic deformation of rocks at all values of well pressure in the process of oil field development, the oil yield coefficient values are higher than in case of relaxation deformation of rocks (up to 18,7% in the case of the considered case). In case of creep deformation of rocks at all values of well pressure, the oil yield coefficient values are higher than in case of nonlinear deformation of rocks (up to 75,2% in the case considered).

2. Methods of approximate determination of well debit, well pressure, depression in the reservoir and gas segregation, development indicators in accordance with various technological and geological-physical conditions in which the activity of the post-contour water zone of oil and gas fields with relaxation and creep

deformation has been developed. By conducting computational experiments, the characteristics of the change of oil and gas field development indicators in relation to elastic deformation of rocks during the development period under the influence of the mentioned factors were determined.

Based on numerical calculations it has been established that:

- Regardless of the density of the well network, the rocks of the final oil and gas yield coefficient are less in oil and gas deposits with a relaxation environment than in deposits with a nonlinear elastic environment, and more in a creep-deformed environment. According to the calculation results obtained on the sample of the considered hypothetical deposits, the oil yield coefficient may differ by 15-20% in deposits with a relaxable environment and up to 95% in deposits with a creep-deformable environment.

- At all stages of the development of gas fields, the numerical results indicating the required number of wells providing the given production dynamics in the conditions of relaxation and nonlinear elastic deformation of rocks differ slightly from each other.

- The required number of wells providing the given production dynamics in the conditions of relaxation deformation in oil fields exceeds that in a nonlinear elastic layer (in some cases up to 20%);

- As the value of the parameter m_1 characterizing the rheological properties of rocks in gas fields increases, the numerical results indicating the required number of wells corresponding to the conditions of creep deformation and nonlinear elastic deformation of rocks differ significantly from each other (in this case, the number of wells is reduced);

- When taking into account the influence of the creep of rocks on the permeability of the reservoir in oil fields, the number of necessary wells compared to the case of nonlinear elastic deformation of rocks is much higher than if the influence of the creep of rocks on the permeability of the reservoir is not taken into account, which may be due to;

- Formation of gas caps in elastic deformed layers occurs rapidly in relation to creeping layers, and slowly in relation to relaxed deformed layers. when gas segregation is taken into account

and is not taken into account, the final oil recovery coefficient in slipwise deformed layers is higher than in elastically deformed layers. In the case of gas segregation, the increase in the final oil recovery coefficient was greater in elastically deformed layers compared to the case when gas segregation was not taken into account, reaching 58% in the case under consideration.

3. Taking into account the non-isothermal of the flow, numerical solutions have been obtained for the problem of undetected filtration of gaseous oil into the well from the oil reservoir whose rocks are relaxed and creep deformed under the condition of depletion. As a result of the calculation, it was determined that:

- Taking into account the decrease in temperature in the layer, the rate of decrease in well pressure slows down during nonlinear elastic, relaxation and creep deformation of rocks.

- Relaxation and creep deformations of rocks under the conditions of temperature changes in the oil field quantitatively reduce and increase the values of development indicators compared to the case of elastic deformation.

- Compared with elastic deformation of rocks, temperature values are low in relaxated rocks and high in creep rocks. As a result of temperature changes in a layer with a creeping deformation, the values of permeability at the bottom of the well exceed the contour values. In the case of taking into account temperature changes in the oil reservoir with creep deformation, the increase in the gas factor of the well is greater than in the nonlinear elastically deformed reservoir.

4. An approximate approach to determining the development indicators of oil and gas fields undergoing creep deformation, whose rocks have a singular Abelian memory function, has been developed.

5. The methods of approximate determination of the indicators of oil-oil boundary immobility and mobility during the operation of oil and gas sections at different rates of gas oil fields, whose rocks are relaxed and rapidly deformed, and their development in accordance with various technological and geological-physical conditions in which gas segregation occurs have been developed. As a result of the calculation, it was determined that:

- The increase in the price of the initial layer pressure increases the effect of relaxation and creep of the medium on the development indicators.

- In order to maintain the immobility of the gas-oil border in deposits with a relaxed and creeping environment, the rate of oil production from the oil sector should have a pattern of changes analogous to the rate of change in the gas factor.

- Expansion (increase) of the volume of the oil part in a layer with elastic deformation of rocks occurs more rapidly than in a layer with relaxation deformation of rocks, both when taking into account the passage of gas from one part to another and when it is not taken. Taking into account the passage of gas from one part to another in both deformed layers, the rate of increase in the volume of the oil sector slows down. Excluding the latest stage of development, the increase in the volume of the oil part occurs at a greater interval in deposits, the rocks of which are elastically deformed if the gas passes from one part to another.

- Creep and relational deformation of rocks gas segregation compared to elastic deformation reduces the impact of gas oil deposits on development indicators in depletion mode due to the fact that gas segregation is not taken into account. The creep of the rock accelerates the growth of the volume of the oil part.

6. Methods for determining the parameters of filtration-capacity and rheological deformation of oil and gas fields whose rocks are subject to relaxation and creep deformations on the basis of development data and well research data have been established and some of them have been experimentally substantiated by approbation of actual mining research data.

7. The results of the dissertation work were approved in the deposits of AZNEFT PU, and on the basis of these works, the method of recalculation of oil and gas reserves of the deposits in the process of processing taking into account the relaxation and creep deformation of rocks was developed.

The use of the results obtained in the work in the implementation of practical calculations can ensure the improvement of adequacy and reliability in accordance with the real conditions of

formation when determining the indicators of development of deep-lying oil and gas fields with complex stress-deformation conditions in the depletion mode.

The main content of the dissertation is reflected in the following published scientific works:

1. Kuliev, A.M., Efendiev, R.M., Kazymov, B.Z., Tagieva, S.E. Modeling the development of oil fields taking into account the relaxation of rocks // // Theses of the scientific-practical conference dedicated to the 70th anniversary of AOISRPI (Azerbaijan Oil Industry Scientific-Research Project Institute), – Baku: –14 – 15 April, – 1998, – p. 54-55.

2. Kuliev, A.M. Modeling of gas field development taking into account the relaxation of rocks / A.M. Kuliev, M.A. Gadzhiev, B.Z. Kazymov [et al.] // Theses of the scientific-practical conference dedicated to the 70th anniversary of AOISRPI (Azerbaijan Oil Industry Scientific-Research Project Institute), – Baku : – April 14 – 15, – 1998, – s. 60-61.

3. Kuliev, A.M. Modeling the process of developing oil fields in the dissolved gas regime, taking into account the relaxation of rocks / A.M. Kuliev, R.M. Efendiev, B.Z. Kazymov [et al.] // News of the AAS, Series of Earth Sciences, – Baku: – 1998. No. 2, – p. 21-25.

4. Efendiev, R.M., Kazymov, B.Z. Displacement of gas by water in a fractured-porous medium taking into account formation deformation // − Baku: Proceedings of IPDOGD “Issues of development and physical chemistry of oil and gas bearing formations”, – 1999, – p. 36-44.

5. Kuliev, A.M., Kazymov, B.Z. Exact solution to the problem of filtration of an elastic fluid in a creeping porous medium // – Baku: Proceedings of the IPDOGD ASA “Issues of development and physical chemistry of oil and gas bearing formations”, – 1999. – p. 45-51.

6. Kuliev, A.M. Modeling the process of developing oil fields taking into account the relaxation of rocks and pressure / A.M.

Kuliev, I.A. Nasrullaev, R.M. Efendiev [et al.] // News of the ANAS, Series of Earth Sciences, – Baku: – 2000. No. 2, – p. 12-17.

7. Dunyamalyev, M.A., Kazymov, B.Z., Kuliev, A.M., Efendiev, R.M. Modeling of the process of oil and gas fields development in deformable formations taking into account relaxation effects // Proceedings of the International Scientific Conference devoted to the 90th anniversary of G.G. Tumashev "Boundary problems of aerohydromechanics and their applications", − Kazan: − November 21 − 24, − 2000, − p.304-305.

8. Kazymov, B.Z., Efendiev, R.M. Displacement of gas by water in circular deposits taking into account formation deformation // Materials of the international scientific conference dedicated to the 90th anniversary of the birth of G.G. Tumashev "Boundary value problems of aerohydromechanics and their applications", – Kazan: – November 21 – 24, – 2000, – p. 313-314.

9. Kuliev, A.M. Modeling the development of deep-lying deposits taking into account the creep of rocks / A.M. Kuliev, M.A. Dunyamalyev, R.M. Efendiev [et al.] // News of the ASA, Series of Earth Sciences, – Baku: – 2000. No. 2, – p. 18-24.

10. Kuliev, A.M. Mathematical modeling of the development of oil and gas deposits with a creeping medium / A.M. Kuliev, M.A. Dunyamalyev, R.M. Efendiev [et al.] // News of the ANAS, Series of Earth Sciences, − Baku : – 2001. No. 2, – p. 22-26.

11. Kuliev, A.M., Efendiev, R.M. Kazymov, B.Z. Mathematical modeling of the process of developing gas and oil deposits taking into account the relaxation of rocks // Abstracts of the Republican scientific conference "Mathematical modeling and computational experiment", − Tashkent: − March 25 − 27, − 2002, − http://mmce -2002.narod.ru/Contents.htm

12. Kuliev, A.M., Efendiev, R.M., Gadzhiev, M.A., Kazymov, B.Z. Modeling the process of developing gas-oil deposits in creeping media, taking into account the mobility of the gas-oil contact // Proceedings of the Republican Scientific Conference "Modern problems of informatization, cybernetics and information technologies", – Baku: – April 28 – 30, – 2003, – p. 7-9.

13. Kuliev, A.M., Efendiev, R.M., Kazymov, B.Z., Tagieva,

S.E. Modeling the process of developing oil deposits with a gas cap, taking into account the relaxation of rocks // Proceedings of the Republican Scientific Conference “Modern problems of informatization, cybernetics and information technologies”, − Baku, − April 28 − 30, − 2003, − p. 32-34.

14. Babanli, V.Y., Kazimov, B.Z. Mathematical model of gas fields with sliding environment // − Baku: News of Baku University. Physics and Mathematics Series, - 2003. - №4, - s. 91-96.

15. Kuliev, A.M. Hydrodynamic study of the process of gas-oil contact advancement and gas penetration from one area to another in deposits with a “relaxing” environment / A.M. Kuliev, R.M. Efendiev, B.Z. Kazymov [et al.] // News of ANAS , Earth Science Series, – Baku: – 2003. No. 3, – p.29-37.

16. Kuliev, A.M. Modeling the process of developing oil and gas deposits with the immobility of the gas-oil contact taking into account the relaxation of rocks / A.M. Kuliev, R.M. Efendiev, B.Z. Kazymov [et al.] // News of the ANAS, Series of Earth Sciences, – Baku: – 2003. No. 3, – p. 23-28.

17. Kuliev, A.M., Efendiev, R.M., Kazymov, B.Z. Modeling of the process of the development of oil fields taking into account the relaxation of rocks and gas segregation // Proceedings of the II Republican Scientific Conference “Modern problems of informatization, cybernetics and information technologies”, – Baku: – October 26 – 28, – 2004, – p. 11-13.

18. Kuliev, A.M. The influence of well pattern density on gas recovery from deposits with relaxing reservoirs / A.M. Kuliev, R.M. Efendiev, B.Z. Kazymov [et al.] // Oilfield Engineering, – Moscow: – 2005. No. 11, – p. 31-34.

19. Kuliev, A.M., Efendiev, R.M., Kazymov, B.Z. Modeling the process of formation of a gas cap during the development of oil deposits, taking into account the relaxation of rocks // − Baku: News of ANAS, Series of Earth Sciences, −2005. No. 2, – p.100-105.

20. Guliyev, A.M. Solution of the problem of the flow of gaseous liquid into the well in oil fields with a relaxing environment // A.M.Guliyev, R.M.Efendiyev, B.Z.Kazimov [et al.] // Scientific works of AzTU. Series of Fundamental Sciences, − Baku: − 2006. v.

V (18). №2, − p.56-60.

21. Kuliev, A.M. Modeling the process of developing oil fields taking into account gas segregation and rock creep / A.M. Kuliev, R.M. Efendiev, B.Z. Kazymov [et al.] // Scientific works of AzTU. Fundamental sciences series, – Baku: – 2006. v. V (19). No. 3, – p. 39-44.

22. Kuliev A.M. The influence of rock relaxation on the required number of wells for the development of gas fields / A.M. Kuliev, R.M. Efendiev, M.A. Gadzhiev [et al.] // Scientific works of the research institute "Geotechnological problems of oil, gas and chemistry", – Baku: – 2007. v. VIII, – p. 282-291.

23. Aslanov, M.S., Kazymov, B.Z. Determination of the dynamics of the annual input of wells to ensure a given rate of production in the development of gas deposits with creeping medium // Proceedings of the Third International Scientific Conference "Functional-differential equations and their applications", − Makhachkala: − September 24 − 27, − 2007, − p.44-50.

24. Kuliev, A.M. Assessing the influence of rock relaxation on the required number of wells in oil deposits / A.M. Kuliev, B.Z. Kazymov, M.A. Gadzhiev [et al.] // Reports of ANAS, – Baku, – 2007. v. LXIII. No. 5, – p. 81-89.

25. Kazymov, B.Z., Aslanov, M.S., Tagiyeva, S.E. Estimation of accuracy of approximate solutions in case of gas inflow to a well in a deposit with relaxation-compressible porous medium // − Baku: Scientific works of AzTU, series of Fundamental Sciences, − 2007. v. VI (23). №3, − p. 62-65.

26. Kazymov, B.Z., Aslanov, M.S., Taghiyeva, S.E. On estimation of accuracy of approxlized solutions of one problem at relaxation deformation of porous medium // − Baku: Mechanics, Mechanical Engineering, − 2008. №1, − p. 35-37.

27. Kuliev, A.M., Efendiev, R.M., Gadzhiev, M.A., Kazymov, B.Z., Tagieva, S.E. The influence of rock relaxation on the required number of wells of oil deposits when developing them in the dissolved gas mode // Materials of the All-Russian seminar dedicated to the centenary of Aminov Mongim Shakurovich, − Kazan: − February 4 − 5, − 2008, − p. 42-43.

28. Kuliev, A.M., Efendiev, R.M., Kazymov, B.Z. Modeling the process of developing gas-oil deposits taking into account the relaxation of rocks and gas segregation // Materials of the All-Russian seminar dedicated to the centenary of Aminov Mongim Shakurovich, − Kazan: − February 4 − 5, − 2008, − p.44-45.

29. Kazimov, B.Z., Aslanov, M.S., Nasirova, K.K. The method of determining the dynamics of input into operation of wells in sliding medium gas fields that pay for the given production // – Baku: Works of young scientists, − 2008. №1, – p. 75-83.

30. Kuliev, A.M. Modeling the process of developing gas and oil fields with rock creep and gas segregation / A.M. Kuliev, R.M. Efendiev, B.Z. Kazymov [et al.] // Mechanics, Mechanical Engineering, – Baku: – 2008. No. 2, – p. 12-17.

31. Kuliev, A.M., Kazymov, B.Z., Efendiev, R.M. An approximate method for solving the problem of oil inflow to a well in deposits with a creeping medium // Materials of the All-Russian seminar dedicated to the centenary of P.A. Kuzmina, – Kazan: – November 11 – 12, 2008, – p. 75-76.

32. Kuliev, A.M., Efendiev, R.M., Kazymov, B.Z. The influence of well pattern density on oil recovery from reservoirs with a relaxing environment // Materials of the All-Russian seminar dedicated to the centenary of P.A. Kuzmina, – Kazan: – November 11 – 12, – 2008, – p. 77-78.

33. Kuliev, A.M., Babanly, V.Yu. Efendiev, R.M., Kazymov, B.Z. The influence of the rheological properties of rocks on the development indicators of a gas field in gas mode // Proceedings of the international conference “Current problems of applied mathematics and information technologies − Al Khorezmi 2009”, − Tashkent: − September 18 − 21, − 2009, − p. 238-241.

34. Aslanov, M.S., Kazymov, B.Z. Accounting of rock relaxation and gas segregation in the development of gas and oil fields // Materials of the Fourth International Scientific Conference “Functional - differencial equations and their applications", − Makhachkala: − September 21 − 24, − 2009, − p.57-66.

35. Kuliev, A.M. The influence of rock creep on the required number of wells for a given gas extraction / A.M. Kuliev, M.S.

Aslanov, R.M. Efendiev [et al.] // Mechanics, Mechanical Engineering, – Baku: – 2009. No. 1, – p.26-30.

36. Kuliev, A.M. Deformation of rocks and its influence on their filtration-capacitive properties and on the processes of filtration and development of oil and gas fields / A.M. Kuliev, B.Z. Kazymov. – Baku: Elm, 2009. – 88 p.

37. Kuliev, A.M. Mathematical modeling of the process of developing oil fields with a creeping medium and its influence on the required number of wells / A.M. Kuliev, V.Yu. Babanly, R.M. Efendiyev [et al.] // News of Baku University. Series of Physical and Mathematical Sciences. – Baku: –2009, No. 3, – p. 67-77.

38. Kazimov, B.Z., Nasirova, K.K. Method of approximate determination of the development indicators of a gas field with a relaxing environment // – Baku: Works of young scientists, − 2009. №2, − p. 81-92.

39. Kazymov, B.Z., Nasirova, K.K. Numerical calculation model for determining the main characteristics of the development of gas deposits with a creeping medium // Materials of the VI Republican Scientific Conference of Young Scientists and Students "Modern Problems of Mathematics and Computer Science", − Brest: − November 26 − 28, − 2009 , – p.133-134.

40. Kuliev, A.M., Kazymov, B.Z., Efendiev, R.M., Nasirova, K.K. On the problem of determining pressure recovery curves in a well in a creeping oil reservoir // Materials of the III International Scientific and Practical Conference "Youth and Science: Reality and Future", – Nevinnomyssk: – May 17 – 20 , 2010, – p. 278-280.

41. Efendiev, R.M., Kazymov, B.Z. Numerical solution of a boundary value problem associated with gas filtration to a well in a relaxation porous medium // Materials of the XI international youth scientific conference "Severgeoecotech-2010" (part IV), – Ukhta: – March 17 – 19, – 2010, – p. 259-262.

42. Nasirova, K.K., Kazymov, B.Z. Method for calculating the influx of real gas to a well in a creeping formation // Abstracts of reports of the VII Azerbaijan International Geophysical Conference on "Ways to improve the efficiency of geophysical research in active geodynamic conditions on the example of the South Caspian

Depression, – Baku: – 11 – 13 May, – 2010, – p. 106.

43. Kazimov, B.Z., Nasirova, K.K. On the method of determination of filtration and rheological parameters of a relaxed homogeneous oil layer // − Baku: Works of young scientists, – 2010. №3, – p. 48-53.

44. Kuliev, A.M. Mathematical modeling of oil deposit development taking into account the rheological properties of rocks / A.M. Kuliev, V.Yu. Babanly, R.M. Efendiyev [et al.] // Jurnal of Qafqaz University, Mathematics and Computer Science, – Baku: – 2011. No. 31, – p. 85-92.

45. Guliyev, A.M. The numerical and approached simulation gas inflow to a well with creeping medium / Arif Guliyev, Vahid Babanly, Bunyad Kazimov [et al.] // Book of Abstracts of 3rd International Conference on Control and Optimization with Industrial Applications, – Ankara: – 22 – 24 August 2011, – p.136-137.

46. Kuliev, A.M., Efendiev, R.M., Kazymov, B.Z. The influence of rock creep on the oil recovery of deposits developed in a natural mode // Abstracts of reports of the II international scientific-practical conference on “New technologies in oil production”, – Baku: – 6 – 7 September, – 2012, – p.169.

47. Kazymov, B.Z. Numerical modeling of gas deposit development by a system of arbitrarily located wells taking into account creeping deformation of rocks // Abstracts of reports of the II international scientific-practical conference on "New technologies in oil production”, − Baku: − 6−7 September, − 2012, − p. 170.

48. Kuliev, A.M., Efendiev, R.M., Kazymov, B.Z. The influence of rock creep on oil recovery from deposits developed in natural mode // – Baku: SOCAR Proceeding, – 2012. No. 3, – p. 32-37.

49. Kazymov, B.Z. Numerical modeling of gas reservoir development by a system of arbitrarily located wells taking into account creeping deformation of rocks // − Baku: SOCAR Proceedings, − 2012. №3, − p.42-46.

50. Guliyev, A.M., Kazimov, B.Z. Study of rhealogical properties of reservoirs during relaxation and creep strain of rocks and usage of these properties for addressing of applied objectives of oil-

gas fields development // Special İssue Papers of 34th İnternational Geological Congress "The modern problems of geology and geophysics of Eastern Caucasus and the South Caspian depression", – Brisbane: Nafta-Press (Baku), – 5 – 10 August, – 2012, – p.117-131.

51. Guliyev, A., Kazimov, B. Numerical Modeling of Development of Oil Deposit with System of Wells Taking into Account the Relaxation of Deformation of Rocks // Materials of the IV International conference "Problems of cybernetics and informatics" (PCİ'2012, vol. III), – Baku: –12 – 14 September, – 2012, – p.135-138.

52. Kazimov, B.Z. Method of numerical determination of indicators of development of gas field with a system of wells with relaxational deformation of rocks // - Baku: News of ANAS. Series of Earth Sciences, - 2013. №2, - p. 63-68.

53. Kazimov, B.Z. Numerical solution of the problem of development of oil field by Wells system taking into account the creeping deformation of rocks // Theses of the 5th International Conference of young scientists and students on the theme "Fundamental and Applied Geology science: achievements, prospects, problems and ways of their solution" dedicated to the 90th anniversary of the National Leader of Azerbaijan Heydar Aliyev,−Baku: −14 −15 November, – 2013, − p. 158.

54. Kuliev, A.M., Efendiev, R.M., Kazymov, B.Z. The influence of rock creep on the development indicators of a gas field under gas conditions // Materials of the international scientific conference "Non-Newtonian systems in the oil and gas industry", dedicated to the 85th anniversary of academician Azad Khalil ogly Mirzajanzade. Baku: – November 21 – 22, – 2013, – p.145-147.

55. Kazimov, B.Z. Numerical calculation algorithm of radial flow of gaseous oil into the well in the oil field taking into account drift deformation of rocks // – Baku: Scientific Works of the Scientific-Research Institute "Geotechnological problems of oil, gas and chemistry", − 2013. v. XIV, – p. 55-64.

56. Kazymov, B.Z. Determination of rheological parameters of inelastic deformation models of rocks of oil deposits on the data of

development // Proceedings of the International Scientific Conference “Innovative development of oil and gas complex of Kazakhstan”, − Aktau: − April 25 −26, − 2013, − part 1, − p. 254-257.

57. Guliyev, A.M. Assessment of the effect of creep deformation of rocks on oil recovery coefficient of the field developed in dissolved gas mode / A.M.Guliyev, B.Z.Kazimov, R.M. Efendiyev [et al.] // – Baku: Scientific Works of the Scientific-Research Institute “Geotexnological problems of oil and gas and chemistry”, −2014. v. XV, − p.81-87.

58. Guliyev, A.M., Kazimov, B.Z. Calculation of the porosity of the Lower Kirmaki suits formation of the “Northern fold”of the Pirallahi field, taking into account the deformation of rocks // – Baku: Scientific Works of the Scientific-Research Institute “Geotechnological problems of oil, gas and chemistry”,−2014. v.XV, − p. 135-141.

59. Kazymov, B.Z. Interpretation equations for determination of rheological and filtration-capacitance parameters of gas reservoir with creeping medium // − Baku: Scientific Works of the Scientific-Research Institute “Geotechnological problems of oil, gas and chemistry”, − 2014. v. XV, − p. 87-91.

60. Kuliev, A.M., Efendiev, R.M., Kazymov, B.Z. Determination of gas field development indicators taking into account rock creep // − Baku: News of ANAS, Series of Earth Sciences, – 2014. No. 1-2, – p.65-71.

61. Kazymov, B.Z. Determination of rheological and filtration-capacitance parameters of gas reservoir with creeping medium according to the data of recovery and downhole pressure drop // Book of Abstracts of the 1st International Scientific Conference of young scientists and specialists “The role of multidisciplinary approach in solution of actual problems of fundamental and applied sciences (Earth, Thechnical and Chemical)”. − Baku: − 15 −16 october, − 2014, − p. 74-75.

62. Kuliev, A.M., Kazymov, B.Z. Towards the determination of filtration-capacitive and rheological parameters of an oil reservoir with a creeping medium // Materials of the international scientific-practical conference “Priority directions for the development of

modern science", – Makhachkala: – February 24. – 2015, – p. 15-19.

63. Kazymov, B.Z. Algorithm for determining the parameters of relaxation deformation model of rocks of gas deposits according to the data of their development // − Yoshkar-ola: Scientific Journal "Scientist of XXI century", − 2015. № 5-6, − p. 17-20.

64. Guliyev, A.M., Kazimov, B.Z. Calculation of oil and gas field reserves taking into account inelastic deformations of rocks // − Baku: Azerbaijan Oil Industry Journal, – 2015. №4, − p. 18-20.

65. Guliyev, A.M., Kazimov, B.Z. Methods of determination of rheological and filtration-capacity parameters of nonlinear deformed rocks // − Baku: Scientific and Pedagogical News of Odlar Yurdu University. Series "Humanities and Exact Sciences", – 2015. №41. − p. 5-16.

66. Kazimov, B.Z. On the assessment of oil and gas reserves of deposits taking into account nonlinear deformations of rocks // Materials of the international multidisciplinary forum of young scientists and specialists dedicated to the 70th anniversary of ANAS "Academic Science Week-2015", – Baku: – 2015, – November 2-4, − p.78-79.

67. Kazimov, B.Z. Assessment of the impact of creep deformation of rocks on gas production of gas field // − Baku: Western University. Journal "Scientific news", – 2015. №3, − p. 69-73.

68. Kazimov, B.Z. Numerical definition of reservoir pressure and porosity of creeping gas layer on values of change of an well production // Scientific enquiry in the contemporary world: theoretical basics and innovative approach. Research articles. Natural sciences & technical sciences, – San Francisco: – 2015. v.3, – p. 22-25.

69. Kuliev, A.M., Kazymov, B.Z., Efendiev, R.M. Modeling the process of developing oil fields with a relaxation-deformable porous medium under depletion mode // – Baku: News of ANAS, Series of Earth Sciences, – 2016. No. 3-4, – p. 48-56.

70. Feyzullayev, Kh.A., Damirov, A.A., Kazimov, B.Z. Parametric identification of filtration-capacity parameters of exhaust gas reservoir // − Baku: Scientific and Pedagogical News of Odlar Yurdu

University, – 2016. – №45, – p. 71-77.

71. Kazimov, B.Z. New calculation algorithms for the development of oil fields taking into account rheological models of rock deformations // Collection of articles of the scientific-practical conference “Xezerneftqazyataq-2016”, – Baku: – 22–23 December, − 2016, − p. 418-423.

72. Kuliev, A.M., Efendiev, R.M., Kazymov, B.Z. Inelastic deformation of rocks and their impact on the development indicators of oil and gas fields // Materials of the Scientific Session “Fundamental and applied problems of oil and gas field development” dedicated to the 90th anniversary of Academician M.T.Abasov – Baku: – October 14, – 2016, – p. 209-231.

73. Kazymov, B.Z. Numerical Definition of Indicators of the Development of Creeping Oil Layer on values of Change of an Well Production // – New York: International Journal of Theoretical and Applied Mathematics, – 2017. v. 3. is. 5, – p. 167-173.

74. Feyzullayev, Kh.A., Damirov, A.A, Kazimov, B.Z. Determination of parameters of deformed layer during filtration of gas condensate mixture // − Baku: Scientific and Pedagogical News of Odlar Yurdu University, – 2017. – №47, – p. 46-52.

75. Kuliev, A.M. Mathematical modeling of non-isothermal filtration of carbonated oil taking into account nonequilibrium deformation of rocks / A.M. Kuliev, R.M. Efendiev, B.Z. Kazymov [et al.] // “Automation, telemechanization and communication in the oil industry”, – Moscow: – 2017. No. 9, – p. 17-22.

76. Oil and gas extraction technology: Determination of indicators of development of oil and gas fields taking into account deformation of rocks (methodical instruction) / A.M.Guliyev, T.Sh.Salavatov, T.A. Samadov [et al.]. – Baku: Printing house of ASOİU, − 2018. − 61 p.

77. Feyzullaev, Kh.A., Khalilov, M.S., Kazymov, B. Parametric identification of reservoir properties of a relaxation-deformable gas reservoir // Materials of the international scientific-practical conference “Modern mathematics and its applications”, – Ufa: – May 18–20, – 2017, – p. 307-311.

78. Kazymov, B.Z. Influence of the relaxation deformation of

rocks on the characteristics of nonisothermal filtration of live crude in the stratum // – New York: Journal of Engineering Physics and Thermophysics, – 2018. v. 91. No. 6, – p. 1539-1542

79. Feyzullaev, X.A. Identification determination of filtration-capacitive parameters of a nonequilibrium-deformable formation during filtration of a gas-condensate mixture / Kh.A. Feizullaev, A.A. Damirov, B.Z. Kazymov [et al.] // Automation, telemechanization and communications in the oil industry, – Moscow: – 2018. No. 9, – p.58-62.

80. Guliyev, A.M., Kazymov, B.Z., Efendiyev, R.M., Shikhaliyev, K.T. Graphoanalytical and identification methods of determining reservoir parameters of inelastic-deformable gas deposits / Arif Guliyev, Bunyad Kazymov, Ramig Efendiyev [et al.] // Materials of the International Conference "Modern problems of innovative technologies and applied mathematics in oil and gas production" dedicated to the 90th anniversary of Academician Azad Mirzajanzade, – Baku: Printing house of ASOİU, – 13 – 14 December, – 2018, – p.411-412.

81. Guliyev, A. Inelastic deformations of rocks and their influence on development of the oil and gas fields / Arif Guliyev, Ramiz Hasanov, Bunyad Kazimov [et al.] // Petroleum & Petrochemical Engineering Journal, Michigan – 2018. v.2, is.5, – 7 p.

82. Kazymov, B.Z. Procedure for Determining the Dynamic Characteristics of a Gas Reservoir with a Creeping Porous Medium // – New York: Fluid Dynamics, – 2018. v.53. s.2, – p. s34-s37.

83. Kazymov, B.Z., Efendiev, R.M., Nasirova, K.K. Iterative scheme for determining the development indicators of a gas field in depletion mode, the rocks of which are subject to creeping deformation with an Abel core // Materials of the international scientific and practical conference "Modern methods of developing fields with hard-to-recover reserves and unconventional reservoirs", – Atyrau: – September 5 – 6, – 2019, – p.231-233.

84. Kuliev, A.M. Study of the influence of well pattern density on the natural and technological indicators of oil field development taking into account creeping deformation of rocks / A.M. Kuliev, R.M. Efendiev, B.Z. Kazymov [et al.] // "Automation, telemecha-

nization and communications in the oil industry", – Moscow: – 2019. No. 2, – p. 38-45.

85. Guliyev, A.M., Kazimov, B.Z., Efendiyev, R.M. Determination of indicators of development of oil fields with inclined wells whose rocks are subject to relaxation and creep deformation // – Baku: "Oil and gas problems",–2019. №1, − p. 37-46.

86. Kazymov, B.Z. Study of the process of oil filtration to the well in relaxation-deformed heterogeneous oil reservoir in the dissolved gas mode // Proceedings of the International Scientific and Practical Conference "State and prospects of exploitation of mature fields", − Aktau: − 16 −17 May, − 2019, − p.232-237.

87. Kuliev, A.M., Efendiev, R.M., Kazymov, B.Z., Shikhaliev, K.T., Abbas-Alieva, R.T. Methods for determining the rheological parameters of models of inelastic deformation of rocks of gas deposits according to development data // Materials of the international scientific and practical conference "State and prospects for the exploitation of mature fields", – Aktau: –16 – 17 May, – 2019, – 1st volume, – p. 258-263.

88. Kazymov, B.Z. Graphoanalytic determination of parameters relaxation deformation of rocks by data of development of deposits // – El Oued: Journal of Fundamental and Applied Sciences, – 2019. v.11, No 1, – p. 430-433.

89. Mammadov, E.V., Kazimov, B.Z. Methodology for determining the optimal operating mode of a gas condensate well taking into account the deformation of reservoir rocks // International Scientific Journal "Scientist of the XXI century", – 2020. № 6-3(65), – p. 3-7.

90. Kazimov, B.Z. Determination of oil field development indicators whose rocks are subject to Abel core creep deformation / B.Z.Kazimov, A.A. Damirov, R.M. Efendiyev [et al.] // Scientific and Pedagogical News of Odlar Yurdu University, – Baku: – 2020. № 56, – p. 30-34.

91. Kazymov, B.Z., Kerimova, I.M. Methodology for choosing the optimal operating mode for a gas well, taking into account rock deformation // − Moscow: "Automation, telemechanization and communication in the oil industry", – 2020. No. 10, – p. 30-33.

92. Kazymov, B.Z., Zeynalov, R.M. Selection of the optimal mode of operation of the gas well taking into account creeping deformation of rocks // Proceedings of the III International Scientific and Practical Conference on the topic “Modern Programming”, − Nizhnevartovsk: − November 27 − 29, − 2020, − 2021, − p. 159-162.

93. Kazymov, B.Z. Study of the process of gas filtration to the well in relaxation-deformed heterogeneous gas reservoir // Proceedings of the International Scientific and Practical Online Conference, timed to the 30th anniversary of Independence of the Republic of Kazakhstan “Modern technologies in science and education” (Kazakhstan, April 28, 2021), − Aktau: − April 28, − 2021, − p. 172-175.

94. Kazymov, B.Z. Determination of reservoir properties of gas reservoirs in conditions of rock creep with Abel's kernel / B.Z.Kazymov, T.A.Samedov, S.G.Novruzova [et al.] // Oil and Gas Technology, − Moscow: − 2021. №2, − p. 31-33.

95. Samedov, T.A., Kazymov, B.Z., Novruzova, S.G. Selection of the optimal operating mode of a gas-condensate well, taking into account the relaxation deformation of rocks // − Moscow: Oil and Gas Technologies, − 2021. No. 3, − p. 50-54.

96. Kazymov, B.Z., Nasirova, K.K., Bunyatov, A.A. Determination of the dynamics of the required number of wells when developing oil deposits in the dissolved gas mode // − Yoshkar-ola: Scientific journal “Scientist of the XXI Century”, – 2021. No. 6, – p. 3-8.

97. Kazymov, B.Z., Nasirova, K.K. An approximate method for calculating pressure changes in a nonequilibrium-deformable formation in the case of real gas flow to a well // − Moscow: Oil and Gas Technologies, − 2021. No. 4, − p. 36-39.

98. Kazymov, B.Z. Methodology of calculation of pressure changes in the non-equilibrium-deformed reservoir in the case of single-phase fluid flow to the well // − Moscow: “Automation, telemechanization and communication in oil industry”, − 2021. №10, − p.37-41.

99. Zeynalov, R.M., Kazimov, B.Z. Determination of natural-technological indicators of relaxated deformed rocks under the

condition of single - phase filtration of liquid // Materials of the IV Republican scientific conference on “Application issues of mathematics and new information technologies”, – Sumgayit: −9 – 10 December, – 2021, − p.114-116.

100.Kazymov, B.Z., Zeynalov, R.M. A method for approximate determination of the indicators of development of a reservoir with rocks subjected to relaxation deformation in single-phase fluid flow // – Baku: Transactions of ANAS, Series of Physical-Technical and Mathematical Sciences. Informatics and Control Problems, – 2022. №2, – p. 73-79.

101.Kazymov, B.Z., Zeynalov, R.M. Determination of the dynamics of the required number of wells when developing deep oil deposits in the dissolved gas mode // Materials of the IV International Scientific and Practical Conference on the topic “Modern Programming”, – Nizhnevartovsk: – December 8, – 2021, – 2022, – p. 133-137.

102.Kazimov, B.Z., Damirov, A.A. Identifiable determination of filtration-capacity parameters of a gas layer with creeping deformation of rocks // − Baku: Scientific and Pedagogical News of Odlar Yurdu University, – 2022. №61, – p. 12-18.

103.Kazimov, B.Z., Zeynalov, R.M. Determination of oil reservoir development indicators on the first phase of filtration with relaxation of rocks // Materials of the II Republican scientific conference dedicated to the 60th anniversary of Sumgayit State University on the topic “Fundamental problems of mathematics and application of intellectual technologies in education”, – Sumgayit: – December 15 – 16, 2022, – p.94-97.

104.Kazymov, B.Z. Scheme for determining the filtration characteristics of filtration on the first phase of single-phase liquid in the formations, rocks which are subjected to deformation with creeping character // − Moscow: Oil and Gas Technology, − 2022, №3, − p.50-52.

105.Kazymov, B.Z. Influence of changes in permeability of formations on the determination of the predicted value of the required number of wells in the development of gas deposits / B.Z.Kazymov, S.G.Novruzova, E.V.Gadasheva [et al.] // Oilfield

Engineering, − Moscow: − 2022. №6, − p. 31-34.

106.Feyzullaev, Kh.A., Khalilov, M.S., Kazymov, B.Z. Identification of reservoir properties of a relaxation-deformable gas reservoir based on development history data // – Peterhof: Differential equations and control processes, – 2023. No. 1, – 11 p.

107.Kazymov, B.Z., Nasirova, K.K., Shikhaliev, K.T. Algorithm for determining rheological and filtration-capacitive parameters of a limited gas reservoir with a creeping medium // − Moscow: Oil and Gas Technologies, − 2023. No. 2, − p. 44-46.

108.Kazymov, B.Z. Numerical method of determining the development indicators of non-Newton oil reservoir taking into account the rheology of rocks // Materials of the International Scientific-Practical Conference “Heydar Aliyev and Azerbaijan oil strategy: progress in oil and gas geology and geotechnologies” dedicated to the 100th anniversary of the National Leader of the Azerbaijani people Heydar Aliyev, − Baku: − 23 −26 may, − 2023, − p. 942-946.

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