Physical modeling of deformation and filtration processes in low-permeability reservoir rocks when implementing the directional unloading method

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Abstract. This article describes the results of physical modeling of deformation and filtration processes in low-permeability reservoir rocks of the Achimov deposits of the Urengoy gas condensate field. The experiments were carried out on a unique true Triaxial Independent Loading Test System (TILTS) of the Institute for Problems in Mechanics of the Russian Academy of Sciences. The effect of the non-uniform triaxial stress state on the character of deformation and filtration processes in rocks was studied. Real stresses that occur in the bottomhole formation zone when the pressure in the well decreases were created in the rock specimens. Experiments were carried out to simulate the stress state at the walls of the open hole and at the tip of the perforation hole. The geomechanical approach is shown to be promising for creating ways to improve the quality of wells; in particular, the adaptation of the directional unloading method for the conditions of a given reservoir is considered. These studies are essential both in fundamental scientific and practical terms to substantiate technological solutions in the development of fields with low-permeability reservoirs.

1 Introduction

Today, the problem of depletion of hydrocarbon reserves is becoming increasingly urgent around the world. Large and easily accessible deposits are mostly depleted. Under these conditions, the development of deposits with hard-to-recover reserves becomes especially significant [1]. One of the main indicators of "hard-to-recover" reserves is the low permeability of rocks.

The development of hydrocarbon reserves in low-permeability reservoirs, including deep-lying deposits, is complicated by the low productivity of production wells and their high cost. Such reserves cannot be efficiently extracted using traditional development methods due to geological and technological reasons [2]. It is necessary to create new low-cost methods with a long-term effect of increasing the productivity of wells in low-permeability formations. The creation of methods to reduce the risk of uncontrolled destruction of the bottomhole formation zone is equally important.

To develop ways to increase well productivity and oil recovery and to ensure the stability of wellbores, it is necessary to build a geomechanical model of the field. To create a model, it is necessary to know the mechanical and filtration characteristics of the productive formation of a particular field [3, 20]. The flow rate of a particular well significantly depends on the filtration properties of the rocks in its bottomhole zone. A decrease in permeability even in a small vicinity of a well significantly reduces its productivity [4]. This can be due to various processes, including drilling and operation.

It is generally accepted that one of the main reasons for the decrease in permeability is the clogging of filtration channels caused by technical operations on the well [5]. However, a significant change in permeability in the vicinity of the well can also occur due to the effect of mechanical stresses on the filtration properties of the rock [6]. Even though the dependence of permeability on stress concentration has been studied for a long time [7], the role of stresses occurring in the near-wellbore zone is currently insufficiently studied.

Recently, a considerable number of experimental tests of core material have been carried out to determine the regularities of the influence of the stress-strain state on the filtration properties of rocks [8, 9 10]. It is known that many factors are influencing the stresses arising in rocks: lithological composition, deformation and strength properties, depth and structure of rocks, reservoir pressure of oil, the geometry of the well bottom, and well operation mode [11]. A change in the stress-strain state can significantly and irreversibly change the permeability of rocks [12]. Moreover, the permeability of the reservoir rocks with changes in stresses during technological operations can both increase and decrease [13, 23].

Thus, the paper [14] presents a series of triaxial experiments on loading and measuring the permeability of Cobourg limestone specimens. The dependence of the filtration characteristics on the stress-strain state of specimens under load and unloading is determined. It is shown that the permeability decreases with a slight increase in stresses, however, under strong loads, a multiple increase in permeability is observed in comparison with the initial one. Moreover, after complete unloading of the specimens, the permeability remains high. The authors explain this by the appearance of a network of micro and macro cracks in the rock specimens.

The evolution of gas permeability as a result of plastic deformations, as well as the influence of the uneven stress state and initial fracturing on the creep of the rock, are considered in another article [15]. Investigations were carried out using a conventionally triaxial load system on cylindrical specimens of red sandstone with a single artificial crack. During the experiment, the axial pressure changed cyclically, creating a long-term uneven load in each of the states, in parallel permeability, elastic and plastic deformations were measured, strength and rheological characteristics were studied. Elastic and viscoelastic deformations increased linearly with an increase in the ratio of axial to radial stress for both intact and cracked specimens, while viscoplastic deformations grew nonlinearly. Creep rates increased nonlinearly at an increase in the stress difference for both types of specimens. The paper concludes that the permeability of rock under study is determined by the stress level, deformation value of specimens, and duration of holding under load. Multistage loading/unloading processes, creep deformations led first to a decrease in permeability, and then to a sudden increase in filtration properties at the transition to the third stage of creep.

In one of the latest works [16], which is a kind of summary of earlier studies, the authors summarized the results of laboratory triaxial tests on clayed limestones accompanied by the measurement of the permeability coefficient. It was found that the evolution of the permeability of specimens under loading follows certain patterns. The initial section of the permeability curves is characterized by higher little changing permeability values (which is a consequence of the slowly increasing load). At the second stage, the filtration properties deteriorate during compression. In the third section, an increase in permeability is noticeable even before the tensile strength is reached, which is associated with the appearance and coalescence of microcracks. At the stage of behind limit deformation, researchers observe an increase or decrease in permeability, depending on which network of microcracks occurs during cracking. The permeability measured after the destruction of some specimens was 2–3 orders of magnitude higher than the initial one. The authors note the need for further detailed study of these processes.

For low-permeability formations, study the influence of the stress state on the permeability of rocks in the vicinity of the well can be a key step towards their successful development.

The Achimov rocks are characterized by low permeability: the maximum values of permeability reach several tens of millidarcy. The Achimov deposits of the Urengoy gas condensate field lie at a depth of about 4 km, characterized by an abnormally high reservoir pressure – from 57 to 64 MPa (the reservoir pressure anomaly ratio is about 1.6, rock pressure is about 92 MPa at a depth of about 3700 m). The last two factors are the reason that complicates the use of traditional technologies for the development of the Achimov deposits [17], in particular, the use of hydraulic fracturing. But they are an advantage in terms of the application of technologies based on the geomechanical approach. The use of traditional technologies such as hydraulic fracturing at great depths and formation pressures is complicated by the need to use special equipment capable of withstanding abnormal pressures, which requires huge energy and material costs (proppant, water, chemicals). Moreover, there is the problem of closing hydraulic fractures after returning to production drawdowns, which leads to a significant decrease in production [18].

In accordance with the above, one of the most promising ways to increase the permeability of the formation rock is the use of huge elastic energy stored in the rock mass [19] due to the weight of the overlying rocks and reservoir pressure. The methods and parameters of such impact are determined on the basis of the geomechanical approach. The use of such technologies will ensure an increase in production efficiency (well flow rate, oil recovery factor) and a decrease in natural and man-made risks during development activities, including a reduction in accidents and possible environmental damage.

The results of experimental studies of core material from the Achimov deposits of the Urengoy gas condensate field using the TILTS are presented. The obtained results confirm the conclusion about the prospects of using technologies based on the geomechanical approach in the field.

2 Directional unloading method

Based on a fundamentally new geomechanical approach to oil and gas recovery from low-permeability and unconventional reservoirs, a new effective and economical method to increase the productivity of oil and gas wells was developed at the Institute for Problems in Mechanics of the Russian Academy of Sciences [20]. This method is called the directional unloading method. The method is environmentally friendly and has no analogs in the world. Technology is based on the phenomenon of a sharp increase in permeability with a decrease in pressure in the well.

It consists of the creation of an artificial system of micro- and macrocracks in the productive formation (new filtration channels) due to both directional unloading of the formation from rock pressure and the use of a certain design of the well bottom. The required drawdown value and bottomhole geometry are determined on the basis of tests of core material using TILTS. The facility allows us to recreate in rock specimens any real stress states that occur in the formation during certain technological operations.

In contrast to the method of hydraulic fracturing, during the implementation of which it is necessary to spend energy on creating a hydraulic fracture to overcome the rock pressure, in this technology a huge energy reserve accumulated in the rock mass is used to create a system of cracks, i.e. filtration channels.

The available data on the development of wells of the Achimov deposits of the Urengoy gas condensate field speaks in favor of the fact that the method can be successfully applied in this formation. This is primarily evidenced by the facts indicating that the productivity of wells in this field is determined not so much by geological criteria as by technological factors, in particular by the wellbore design. As an example, there are two adjacent wells, one of which was uncased and the other was cased-hole with perforation. As a result, the flow rate of the uncased well on a 7 mm choke was 308,000 m^3/day at the pressure drawdown of 60 at, and the flow rate of a cased borehole was 137,000 m^3/day on a 14 mm choke at the drawdown of 518 at.

It should be noted that cracks formed as a result of directional unloading of the formation not only do not close during the transition to production drawdowns (which can happen during hydraulic fracturing under high-pressure conditions) but even further open due to the increase in gas pressure in them [28]. The directional unloading method was successfully applied at a number of fields of LUKOIL-Zapadnaya Sibir, LUKOIL-Perm, RITEK, and Slavneft in West Siberia and Perm region during well completion and workover operations on producing and injecting wells [20]. The developed technology is protected by 10 Russian patents and 1 Eurasian patent.

To apply the directional unloading method for a specific field, as well as other technologies based on the geomechanical approach, and select the optimal parameters for their implementation, it is necessary to determine the deformation, strength, and filtration properties of the reservoir rocks of the field. Also, it is especially important to study the effect of three-dimensional stress states on their permeability.

3 Experimental procedures

3.1 The test facility

Testing of the core material was carried out using the true Triaxial Independent Loading Testing System (TILTS) created at the Institute for Problems in Mechanics of the Russian Academy of Sciences [20]. TILTS is a unique testing facility that allows to study the deformation, strength, and filtration properties of rocks by testing cubic rock specimens with an edge of 40 or 50 mm. The original kinematic scheme used in the design of the TILTS loading unit allows the pressure plates to approach each other in three directions, without creating obstacles to each other, which makes it possible to load the specimen independently along each of the three axes. Thus, TILTS allows to recreate any stress states that occur in rock mass during mining operations and to study the deformation processes and filtration properties of rocks.

3.2 Test specimens preparation

Rock specimens for testing on a true triaxial unit were taken from wells that penetrated the Achimov deposit of the Urengoy gas condensate field. A total of 11 specimens were tested. This article describes in detail the most important research results of 4 of them. Specimens from the Urengoy gas condensate field were made in the form of a cube with an edge of 50 mm. The specimens were marked as follows: axis 1 of the specimen coincided with the axis of the core, the orientation of axes 2 and 3 were arbitrary. After processing the specimens, the non-parallelism of the specimen faces and the deviation from perpendicularity does not exceed 20 μm. A thin sealed polymer shell was applied to four specimen faces parallel to the axis, along which the permeability was measured, to prevent leakage across these faces.

Specimens A-3 and A-10, as well as A-6 and A-11, the test results of which are presented in detail in this article, were made from one piece of core.

3.3 Selecting an elastic model

Before conducting the experiments, the velocities of longitudinal elastic waves propagation along three axes were measured in all specimens to determine the type and degree of anisotropy of the rock. The measurements were carried out using a specially designed facility [20]. In all specimens, the velocities of longitudinal waves along the core axis were slightly less than those along two axes in the horizontal plane. In this plane, the velocities were approximately the same. For example, in one of the studied specimens, the wave propagation velocity along the core axis was 2631 m/s, and along axes 2 and 3 — 2703 m/s. In a specimen made from a different coring interval, the velocity along axis 1 was 2632 m/s, and along the other two axes — 2941 m/s. This suggests that the rock was tested is transversely isotropic with a low degree of anisotropy.

3.4 Specimen loading programs

The specimens were tested using two loading programs. The first program corresponded to a change in stresses in the vicinity of an uncased well when creating a drawdown at the bottomhole, the second one — to a change in stresses near the tip of a perforation hole. The construction of loading programs is described in detail in [20].

Thus, during the tests, stresses were applied to the faces of the specimen, corresponding to the real stress states that arise in the vicinity of the wells with a decrease in pressure at their bottom. In the experiments, the deformations of the specimens along three axes and the permeability in the direction corresponding to the radius of the well were recorded. As a result, the dependence of the rock permeability on the real three-dimensional stresses arising in the specimen was determined.

3.4.1 Loading program for uncased well

In a cylindrical coordinate system, radial stress σ_r, circular stress σ_θ, and stress along the axis of the hole σ_z act ($\sigma_i < 0$) in the vicinity of an uncased borehole. The program for testing specimens in experiments simulating the change in stresses in the vicinity of an uncased well with a decrease in pressure at the bottom of the well for the case of equal component rock pressure is shown in Figure 1.

The stresses shown in it (s_1, s_2, s_3) are the stresses applied to the specimen faces along axes 1, 2, 3 of the loading unit of the TILTS. Their values correspond to the effective stresses s_r, s_θ, s_z ($s_i = \sigma_i + p_w$, $s_i < 0$, $p_w > 0$) acting in the vicinity of the uncased borehole and, according to the solution of the Lamé problem, are determined as $s_r = 0$, $s_\theta = 2(q + p_w)$, $s_z = q + p_w$, where q = rock pressure ($q < 0$), all components of which are assumed to be equal; p_w = pressure at the bottom of the well. When creating a loading program for a vertical well, an isotropic medium model was used, since the main changing stresses act in the isotropic plane of a transversely isotropic rock with a weak degree of anisotropy [21]. In the absence of special geological diastrophism, the rock pressure is equal to the weight of the overlying rocks, i.e. $q = -\gamma h$, where γ = average specific weight of the overlying rocks, h = bedding depth.

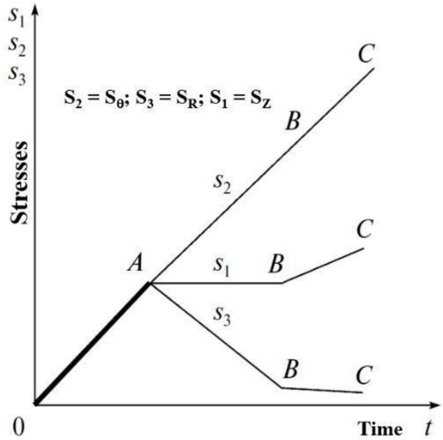

Fig. 1. Test program modeling the stresses in the vicinity of an open borehole.

Stage 1. Point A corresponds to the stresses acting in the soil matrix before the well drilling. A specimen is pressed evenly on all the sides to a stress equal to the difference between the value of rock pressure at the depth and the value of reservoir pressure: $s_1 = s_2 = s_3 = |q| - p_0$, where p_0 = value of reservoir pressure.

Stage 2. One component of stress σ_2 corresponding to s_θ is continuing to grow, the other one, σ_1 corresponding to s_z, remains constant, and the third, σ_3 corresponding to s_r, is decreasing (segments AB). Point B corresponds to the state when the well has been drilled and the pressure at its bottom is equal to the reservoir pressure: $p_w = p_0$. The loading is developed so that the average stress $s = (s_1 + s_2 + s_3)/3$ throughout stage 2 is maintained.

Stage 3. The BC segments correspond to a decrease in pressure at the bottom of the well. The third stage lasts as long as the specimen is not destroyed or stresses do not reach the values corresponding to the maximum possible pressure drawdown (complete draining of the well). In the second case, the specimen is unloaded. The process of unloading is developed in exactly the opposite manner to the loading of the specimen.

3.4.2 Loading program for perforation tip

A good approximation for determining the stresses acting in the immediate vicinity of the tip of the perforation hole is the solution of the problem of stress distribution in the vicinity of a hollow sphere in isotropic material under the action of internal and external pressures[22]. The fact of the weak anisotropy of the rock was neglected. This approximation allows to draw qualitative conclusions about the efficiency of implementing the directional unloading method.

In the vicinity of the spherical perforation tip, a radial stress σ_r and two circular stresses σ_θ and σ_φ arise. Accordingly, the soil matrix of the rock is loaded with effective stresses s_r, s_θ, s_φ. Figure 2 shows a specimen loading program that simulates the change in stresses on the surface of the perforation hole with a decrease in pressure p_c at the bottom of the well. The stresses s_1, s_2, s_3, depicted on it are the stresses acting along axes 1, 2, 3 of the loading unit of the TILTS. Their values correspond to the stresses s_θ, s_φ, s_r acting on the perforation hole vicinity.

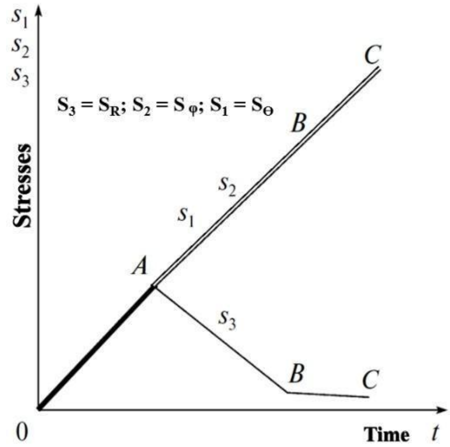

Fig. 2. Test program modeling the stresses in the vicinity of a tip of perforation.

Point A corresponds to the stresses acting in the soil matrix before drilling the well, i.e. $s_1 = s_2 = s_3 = |q| - p_0$ in it, where p_0 = initial reservoir pressure. Point B corresponds to the state when the well is drilled and the pressure at its bottom is equal to the reservoir pressure. Distribution of stresses at point B is as follows: $s_3 = 0$, $s_1 = s_2 = 3/2(|q| - p_w)$. The average stress $s = (s_1 + s_2 + s_3)/3$ is kept constant throughout stage 2. The BC segments correspond to a decrease in pressure at the bottom of the well.

4 Results

4.1 Results of modeling uncased borehole

The results of modeling stresses arising on the walls of an uncased hole are presented in Figures 3-4. The graphs show the loading program for each specimen, as well as the curve of the change in permeability during loading in relation to the initial value. Stresses are plotted on the left axis of the graphs, and relative permeability is plotted on the right axis. During the experiment, loading was carried out stepwise, at each stop, the creep deformation was measured.

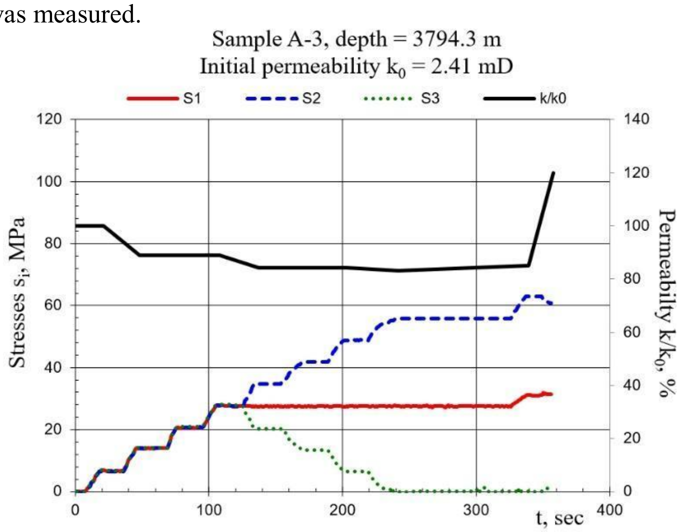

Fig. 3. Change of the stress components and permeability during testing specimen A-3.

Specimen A-3 was made from a core from the depth of 3794.3 m and had an initial permeability of 2.41 mD. Figure 3 shows that the permeability of specimen A-3 at the section of all-round compression decreased by about 15%. This value should be taken as the initial permeability of the specimen in reservoir conditions. Subsequently, when modeling the pressure decrease in the well, the permeability of the specimen practically did not change, but at the moment before the destruction of the specimen, an increase in permeability occurred due to cracking of the rock and the appearance of a network of cracks. The final permeability is not always possible to measure due to a breaking of the tightness of the specimen shell, however, the appearance of macrocracks indicates a multiple increase in permeability. The fracture of the specimen occurred at the value of the increasing stress component s_2 = 63 MPa, which corresponds to the drawdown in the well equal to 22 MPa.

The initial permeability of the next specimen A-6 was 3.7 mD. The specimen was made from a core from a depth of 3836 meters. Figure 4 shows that the permeability of the A-6 specimen at the section of all-round compression decreased by 24% from the initial value. Subsequently, when modeling a decrease in pressure in the well, the permeability of the specimen did not change, but with intense deformation of the specimen and its destruction, it increased sharply and irreversibly. The fracture of the specimen occurred at the value of the increasing stress component s_2 = 115 MPa, which corresponds to a drawdown in the well equal to 24 MPa.

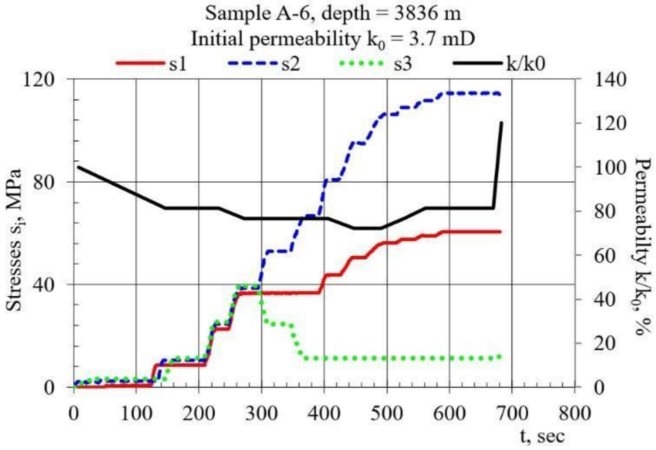

Fig. 4. Change of the stress components and permeability during testing specimen A-6.

The permeability of the other tested specimens changed similarly during loading (Table 1). The results of testing the specimens showed that by creating a certain stress field in the vicinity of the wells by using the directional unloading method, it is possible to cause cracking the Achimov deposit rock leading to an increase in its permeability.

4.2 Results of modeling perforation tip

The results of modeling stresses at the tip of the perforation are presented in Figures 5-6. As stated above, the graphs show the loading program for each specimen, as well as the curve of the change in permeability during loading in relation to the initial value. Stresses are plotted on the left axis of the graphs, and relative permeability is plotted on the right axis.

Figure 5 shows the results of testing a specimen A-10 made from core material from a depth of 3794.2 m. Its initial permeability was 2.41 mD. When modeling the initial state of all-round compression by rock pressure, the permeability of the specimen decreased by 6%. During the simulation of the pressure decrease in the well, the permeability remained at about the same level. At the moment of intense deformation and fracture, a sharp increase in permeability was seen. This indicates the appearance of a network of cracks forming a new system of filtration channels. The fracture of the specimen occurred at the value of the stress component s_2 = 82 MPa, which corresponds to a drawdown in the well equal to 25.4 MPa.

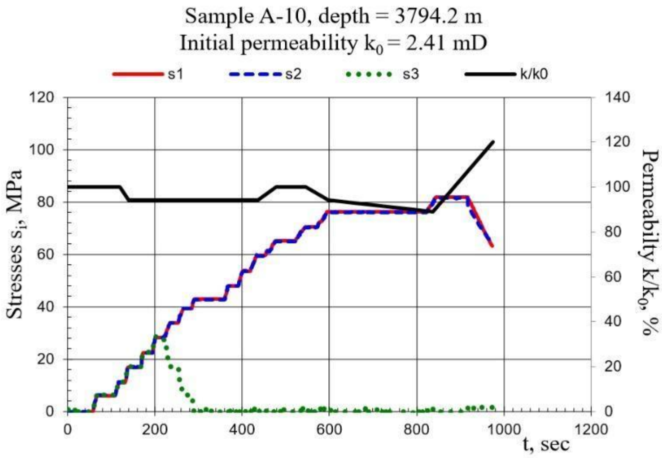

Fig. 5. Change of the stress components and permeability during testing specimen A-10.

The test results for another specimen A-11 are shown in Figure 6. The specimen had a negligible initial permeability of 0.20 mD. The core sampling depth is 3836.1 m. Its permeability during the all-around compression decreased to 80% of the initial one. When modeling a drawdown value gain was seen a gradual slow increase in permeability to values of 90% of the initial. At the moment of fracture, there was an abrupt increase in permeability. As mentioned earlier, the final permeability is not always possible to register due to the violation of the film tightness, however, even the recorded value was approximately 120% of the original. The fracture of the specimen occurred at the value of the stress component s_2 = 85 MPa, which corresponds to a drawdown in the well equal to 21.6 MPa.

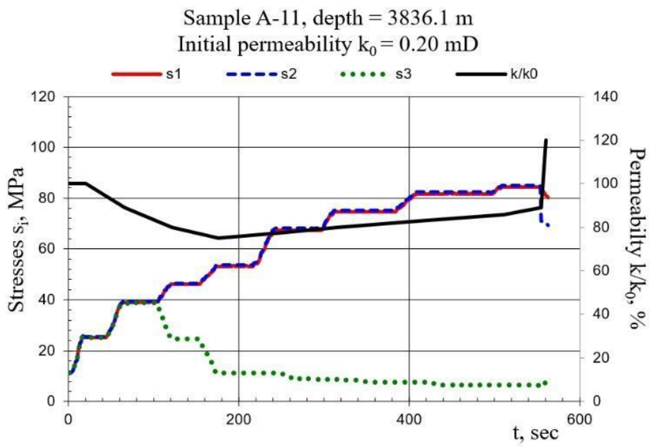

Fig. 6. Change of the stress components and permeability during testing specimen A-11.

The summary results of tests of the specimens are shown in Table 1. The table shows the coring interval of each specimen, the loading program, the limiting values of the increasing stress along the corresponding axis of the specimen s_θ; drawdown leading to destruction Δp, initial permeability k_0, and ratio of final recorded permeability to initial permeability k/k_0.

Table 1. Summary results of tests.

№	Specimen number	Loading program	Coring interval	S_θ	Δp	k_0	k/k_0
			m	MPa	MPa	mD	
1.	A-6	Open hole	3836	115	24	3.7	1.2
2.	A-11	Perforation	3836	85	21.6	0.2	1.2
3.	A-4	Perforation	3825	90	30	0.18	1.1
4.	A-5	Open hole	3825	92	16	0.13	1.2
5.	A-8	Open hole	3825	113	26.5	0.14	1.4
6.	A-10	Perforation	3794	82	25.4	2.41	1.2
7.	A-3	Open hole	3794	63	22	2.41	1.2
8.	A-2	Open hole	3793	68	4.8	1.61	1.2
9.	A-7	Open hole	3793	81	11.3	1.61	10
10.	A-1	Open hole	3766	110	26.4	0.02	1.3
11.	A-9	Perforation	3766	105	38.8	0.04	1.2

An increase in permeability was observed in all tested specimens for both loading programs. The deformations of the specimens for both constructions of the bottomhole were mainly elastic up to failure. Moreover, the nature of the destruction of rocks is predominantly brittle. The permeability of the specimens changed insignificantly during the change in the stress-strain state up to cracking. Creep was mainly manifested when approaching the critical values of stresses and led to cracking, i.e. destruction of the rock.

5 Discussion

It should be noted that an increase in permeability caused by an increase in the number of microcracks in a brittle material, described in the article [23], was not observed during the experiments. The above-mentioned work describes the mechanisms of permeability growth during loading for brittle materials. The first of them is the growth of the number of microcracks, during which a gradual improvement of filtration properties is initiated. The orientation, growth, and connectivity of such cracks depend on the properties of the material and the method of loading. As can be seen from the experiments, the increase in permeability for the studied rocks occurred mainly in an abrupt manner, which can only be associated with the appearance of macrocracks. The stage of development of microcracks in the studied rocks can be insignificant due to its short duration and rapid growth, the opening of microcracks, or particular orientation of emerging cracks due to a specific loading trajectory. The role of this stage can be more pronounced with prolonged loading of the rock at subcritical loads.

The results obtained correlate well with the studies of brittle basaltic rocks in [24], despite the differences in the applied stress fields. The authors describe the change in the permeability of the specimens in three stages as an uneven load is applied: a slight decrease in permeability associated with the initial closure of microcracks in the rock and/or their low initial density; the absence of changes in permeability associated with elastic deformation of the specimens; a significant gradual increase in permeability caused by the opening and merging of microcracks and their connection with the network of original filtration channels. As described earlier, the rapid development of the third stage and a sharp transition to the occurrence of macrocracks in the studied rocks of the Achimov deposits can be associated both with the peculiarities of the internal structure of the studied rock and with a significant non-uniformity of the stress field during the implementation of the directional unloading method.

The results of physical modeling of deformation and filtration processes in the rocks of the Achimov deposits show that by creating the required stress state in the vicinity of the well using the directional unloading method, it is possible to cause rock cracking, leading to a significant increase in permeability. During well operation, the bottomhole drawdown is 24-26 MPa. Besides, according to the adopted well development technology at the Urengoy gas condensate field, after completion, a blowing of well is performed. In this case, gas is flared through the borehole collar. At the same time, the depression at the bottomhole reaches 50 MPa and more. Therefore, the drawdown values 20-40 MPa obtained as a result of testing the core material at the TILTS facility are quite attainable for the conditions of the Urengoy gas condensate field. The conclusion about the possibility of increasing the permeability of the bottomhole zone by creating a pressure drawdown of a sufficiently high level is also confirmed by the cases observed in practice. Sometimes during drilling (the wells have not been cased yet), emergencies occurred associated with significant absorption of drilling fluid at the bottom of the well and, as a result, leading to significant decreases in bottomhole pressure. This led to the return of rock from the wells and a sharp increase in well production. As a result, the production rate of emergency wells during operation reached 2 million cubic meters of gas, while the usual flow rates are an order of magnitude less.

One of the factors in the implementation of the method is the correct choice of the well bottom geometry. The destruction of rocks during the modeling of an open wellbore, on average, occurred at lower drawdowns, however, for an unambiguous conclusion about the optimal bottomhole design for these conditions, a more tests are required. The most effective application of the method may also require a number of preliminary technological operations. Such as, for example, cutting out a section of the casing in the productive interval of the wellbore, perforating a certain type and density, cutting of fissure of a given orientation, etc [9, 26, 27]. The necessary technological operations are determined by testing the reservoir rock using TILTS.

6 Conclusions

A laboratory modeling method for studying the effect of the stress-strain state that occurs near a well with different bottomhole designs on the filtration characteristics of reservoir rocks is described in this paper.

The results of testing rock specimens from the Achimov deposits of the Urengoy gas condensate field on the TILTS allow to draw a number of practically important conclusions.

Physical modeling of processes of deformation, fracture, and filtration in the vicinity of an uncased borehole and perforation hole under the conditions of true three-dimensional stress states showed that by creating a certain stress state in the vicinity of the wells by using the directional unloading method, it is possible to cause cracking and fracture of rocks, leading to an increase in its permeability.

The research results show that the directional unloading method can be implemented for Achimov deposit rocks for the conditions of both an open hole and a cased hole with perforation. A preliminary assessment of the drawdown values necessary for the implementation of the method has been made. The tests showed that to initiate the process of rock cracking at the bottom of the well and increase its permeability, it is necessary to create a drawdown not less than 25 MPa. Cracking of specimens tested according to the open hole program, mainly occurred at lower drawdown values, but for an unambiguous conclusion about the preferred bottom hole geometry for these conditions, further studies of these rocks are necessary.

Summarizing the results of the experiments, we can conclude that the geomechanical approach using physical modeling of the processes of deformation, fracture, and filtration in a reservoir can serve as a basis for the development of new efficient and environmentally friendly technologies for increasing the productivity of wells and enhancing recovery from low-permeability formations.

This work was financially supported by the grant of the ministry of science and higher education of the russian federation no. 13.1902.21.0018 "fundamental problems of the development of the mineral resources base of the high-tech industry and energy of russia".

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