ABSTRACT
From the Thesis thesis
Titled

"IMPROVEMENT OF THE SYSTEM FOR THE DEVELOPMENT OF MULTI-LAYER OIL DEPOSITS WITH NON-UNIFORM PERMEABILITY ON THE EXAMPLE OF THE ARYSTAN FIELD",

submitted for the degree of Doctor of Philosophy (PhD),

specialisation 6D070800 - "Oil and Gas Business"

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Rationale for the research

The need in the research is deterioration of filtration capacity in low-permeable formations of oil fields and in the well's bottomhole zone both producing oil for a long time.

Topicality

Efficiency of oil recovery from oil-bearing multilayer reservoirs with uneven permeability by modern, commercially developed methods in all oil-producing countries is currently considered unsatisfactory, while the consumption of oil products worldwide is increasing year by year. The average ultimate oil recovery rate for different countries and regions ranges from 25 to 40%.

For example, the average oil recovery rate in Latin America and South-East Asia is 24-27%, in Iran 16-17%, in the USA, Canada and Saudi Arabia 33-37%, in CIS countries and Russia up to 40%, depending on the structure of oil reserves and development methods applied.

Practice has shown that in multi-horizon fields, including Arystan, the use of hydraulic fracturing with water-based gel fracturing fluids to intensify oil flow to wells is considered ineffective due to the adsorption of gels with long molecules in formation pores and the swelling of clay particles in a reservoir when they interact with water-based fluids.

Therefore, application of other effective oil production technologies, which would considerably increase oil flow to reservoir wellbores, while traditional methods no longer can guarantee the recovery of considerable residual oil reserves, is the task of topical importance.

The thesis objectives

To improve well productivity and intensify oil flow to wells from multilayer reservoirs with uneven permeability by improving field development systems and applying effective methods of hydrodynamic influence on the bottomhole zone of reservoirs.

The research objectives

- To establish the laws of filtration processes during development of multilayer deposits with non-uniform permeability ensuring uniform displacement of oil from reservoirs and combining them into one object in the case of the "Arystan" field.
- To build models of the geological structure of multilayer reservoirs, ensuring the improvement of the system of field development and increase oil and gas reserves by the example of Arystan field.
- To determine the regularities of intensification of oil flow to wells from reservoirs with low permeability using effective methods of hydrodynamic influence on the bottomhole zone of oil reservoirs.
- To develop scientific recommendations for improving the system of development of multilayer deposits with uneven permeability and methods of intensification of hydrodynamic influence on the bottom-hole zone of wells on the example of "Arystan" field.

The object of the study is multilayer oil reservoirs with uneven permeability in the example of the Arystan field in Northern Ustyurt.

The subject of the study is the system of development of multilayer oil reservoirs with uneven permeability and effective methods of intensification of oil flow to the well bottom from low-permeability reservoirs.

Apart from theoretical and laboratory methods, **the research methods** include GIS-Micromine computer technology, Petrel E&P 2015 software platform and Eclipse Reservoir Simulator 2009.

The main points of defense

1. Uniform displacement of oil from multilayer reservoirs with uneven permeability and increased productivity of wells are provided on the basis of the model of geological structure of the field by carrying out hydraulic fracturing in the formations with low permeability from both producing and injecting wells.
2. The efficiency of the fracturing process in a low permeability reservoir is enhanced by the use of hydraulic fracturing fluid based on high-boiling oil components with carbon atoms ≥ C8 in the molecules, which will not adsorb to the reservoir pores and will not cause swelling of the reservoir shale particles.
3. The effectiveness of low-permeability fracturing technology using a fracturing fluid based on high-boiling oil components is enhanced if the fracture fixer is replaced with a complex acid solution.

Scientific novelty

1. The regularities of filtration processes of multilayer reservoir development with non-uniform permeability were established on the example of Arystan field, allowing selective hydraulic fracturing with more effective hydraulic fracturing fluids.
2. Laws of the process of fracturing reservoirs with low permeability by using hydraulic fracturing fluid based on high-boiling oil components with carbon atoms content ≥ C8 in the molecules, that do not adsorb in the pores of the reservoir and do not lead to swelling of the clay particles of the reservoir were determined.
3. Theoretically and experimentally rational parameters and modes of effective fracturing technology for low-permeability reservoirs have been determined using

fracturing fluid based on high-boiling oil components, and a complex acidic solution instead of a fixing agent.

4. Scientific recommendations have been developed to improve the system of development of multilayer reservoirs with uneven permeability and methods of intensification of oil flow to wells on the example of the field "Arystan".

Substantiation of novelty and importance of the obtained results

Rational parameters and modes of effective technology of fracturing reservoirs with low permeability using fracturing fluid based on high-boiling oil components and complex acid solution instead of fixing agent have been theoretically substantiated and experimentally proved, resulting in a significant increase in well productivity.

Practical significance of the work. The research results can be used for increase of well productivity and intensification of oil flow in wells and other fields with complicated geological structure.

Correspondence with science development directions or state programmes

The Thesis work titled "Improvement of the system for the development of multi-layer oil deposits with non-uniform permeability on the example of the Arystan field" is devoted to an urgent problem of enhanced oil recovery and corresponds to the priority direction 6D070800 - "Oil and Gas Business", approved by the Supreme Scientific and Technical Commission under the Government of the Republic of Kazakhstan.

Thesis work was carried out within the framework of state grant project on the theme: "Scientific rationale for development of effective complex technology of reservoir pressure maintenance and increase of well production rate" (program IRN: AP05130484-OT-18) and positive scientific and experimental results were obtained.

The author's personal contribution is that the main laboratory experiments, calculations and the creation of 3D computer models were obtained personally by the applicant. Statement of tasks and discussion of the results were carried out jointly with scientific advisors.

Reliability of the results

The reliability of the scientific conclusions is proved by reproducibility of the experimental results, by correspondence of the computer results with the experimental data.

Description of the main research results

The following conclusions were drawn from the research materials in the thesis work:

1. Geophysical data from the geological section identified eleven major tectonic faults, which complicate the structure and divide it into twelve blocks (I-XII). The presence of these tectonic faults is confirmed by seismic data, drilling and new well testing data. Thus, the deposit can be classified as block-structural, i.e., a complex deposit.

2. To ensure uniform displacement of oil from multilayer reservoirs of irregular permeability and significantly differing permeability, as well as to unite

the reservoirs, it is possible by selective application of modern methods to stimulate oil flow to wells from low permeability reservoirs. For this purpose we have proposed a new method of hydraulic fracturing with hydraulic fracturing fluid based on high-boiling oil components with atomic content in carbon molecules ≥ C8 and in combination with acidic treatment of wells.

3. The 3D-geological model of multilayered reservoir provides detailed information about the patterns of porosity, permeability, oil and water saturation of reservoirs in the reservoir volume, about vertical and lateral heterogeneity of FCS. Knowing real values of rock reservoir properties, such as permeability, porosity, oil and water saturation in the spatial section, we can choose rational modes and parameters of wellbore fluid inflow stimulation technology.

4. During the fracturing process, process fluids are injected into the oil reservoir in the following sequence: fracturing fluid (high-boiling oil components with atoms in carbon molecules ≥ C8), acid solution and fracturing fluid (degassed oil). Fracturing jobs in the Arystan field need to be used effectively and at an advanced level, taking into account the specifics of the field.

5. A new method of obtaining high-boiling oil components with atoms in carbon molecules ≥ C8 using a two-section single-stage degassed oil distillation unit based on difference in boiling points of their components has been developed. The high-boiling components of oil with carbon atoms ≥ C8 are the most efficient fracturing fluids which can be produced from degassed oil in the field conditions.

6. The average gain of oil flow rate after fracturing is 15.7 t/day, while the average gain of oil flow rate after acid-salt treatment is 7.3 t/day, i.e. twice less. As for duration of the effect, the average duration for hydraulic fracturing is 292 days while the average duration for hydrochloric acid treatment is 413 days. Despite the increase in oil flow rate after hydraulic fracturing, the duration of the effect is lower compared to hydrochloric acid treatment.

7. Based on geological and geophysical and petrophysical data, a geological 3D model of the Arystan deposit has been developed. The model is an approximate description of the object under study using mathematical symbols. The model can be used to select location of new wells, to see location of oil reservoirs, distribution of flows and pressures in the reservoir over time, well flow rates, etc.

8. The hydrodynamic simulation of the model, as well as the static simulation of the field that precedes it, allows us to obtain results in a form that is convenient for us. In our case, wells No. 112 and No. 116 were chosen as wells exploiting the same oil-bearing horizon, with high oil-water ratio. The results of the simulation allowed us to know the cumulative oil flow rate for the 8-year forecast. The cumulative flow rate of the two gas wells increased by 25% compared to the pre-fracture period, while the oil flow rate was 35%.

9. Fracturing jobs with fracturing fluids based on high-boiling oil components and acid solution unambiguously increase well productivity by inducing flow enhancement. High-boiling components of oil, possessing high viscosity under high pressure, can create rather large fractures deep into formations with low permeability, and acid solution, used instead of fixer (sand or proppant), dissolves rock, increasing fracture size and formation pores.

Publications and approbation of the work

As a result of carried out scientific researches 10 articles and reports were published, including 3 papers in the international scientific editions entering into the database of company Scopus and having a non-zero impact factor and 3 articles in the scientific editions recommended by the Ministry of Education and Science of Kazakhstan.

The doctoral student's contribution to each publication

The results of the experimental data are derived from work carried out under laboratory conditions. Cost-effectiveness calculations and 3D modelling have been carried out by the doctoral candidate. Statement of tasks and discussion of the results were carried out under supervision of the scientific advisor.

9 scientific papers were published on materials of dissertation work, including: 2 - in international peer-reviewed scientific journals included in DB Scopus, 4 - in editions recommended by the Committee for Quality Assurance in the RK Ministry of Education and Science, 3 - in collections of international scientific conferences.

Scientific results of the research work have been discussed in published scientific articles on the thesis, at international scientific and practical conferences: Materials of the XI international scientific and practical conference "Science without borders", Science and education Ltd, (England, 2015); the International scientific and practical conference "Mineralogy of Kazakhstan" dedicated to the 90th anniversary of Academician Sh.E. Yesenov (Almaty, 2017).

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2. Tileuberdi N., Ozdoyev S.M. Mashrapova M.A. Prospects of oil and gas prospecting in Triassic and Paleozoic deposits of Ustyurt and Mangyshlak // "Minerageny of Kazakhstan" dedicated to the 90th anniversary of Academician Esenov Sh.E. Collection of articles, 2017, Almaty, pp. 257-260.

3. Mashrapova M.A., Ozdoyev S.M., Tileuberdy N. Geochemistry of organic matter oil and gas parent potential of Mesozoic rocks of Mangyshlak and Ustyurt // "Minerageniya Kazakhstan" dedicated to 90th anniversary of Academician Esenov Sh.E. Collection of articles, 2017, Almaty.