Technology of testing shale reservoirs of Paleogene age on the territory of the Eastern Ciscaucasia

A G Saltanova, V A Vasiliev, E G Kerimova, V S Kramarenko, V E Sová
North Caucasus Federal University, Stavropol, Kulakova Avenue, 16/1, 355035, Russia
E-mail asaltanova@gmail.com

Abstract. The article demonstrates the technology of testing reservoir layers represented by fractured clay-carbonate rocks in the Eastern Ciscaucasia. Practice shows that if the saturation of permeable rocks is uniform, the reliability of the tests can be ensured if the tested interval does not exceed 25 m. The probability of obtaining an inflow during tests significantly decreases with the increase in the amount of repression of the washing liquid and the duration of its impact on the reservoir. This is caused by clogging of the near-well zone of the reservoir, which results in the hydrodynamic connection of the reservoir with the well deteriorates. Test results are the most reliable if they are performed no later than 3-5 days after opening the reservoir, however, even in this case, the reservoir may be contaminated. For high-quality testing of reservoir layers represented by fractured clay-carbonate rocks, the following processes are required: to make an individual selection of the depression on the formation, to have a priori accurate information about the strength characteristics of the well walls.

Keywords: depression, test, shale reservoirs, packer.

1. Introduction

Until recently, production-geophysical criteria for identifying reservoirs in Paleogene sediments practically had not existed. Therefore, there is a practical need to search for reservoir signs based on geological field research data. The basis for such work may be the results of reservoir tests. The induction of inflow in such sediments, as a rule, is difficult and was carried out with the use of repeated hydrochloric acid treatments and baths. It should be noted that the prevailing majority of tests of Paleogene strata in an open hole turned out to be no inflow, and the pressure build-up curves (PRC) characterized these objects as unpromising in terms of permeability. The lack of inflow is probably due to three main reasons: significant clogging of the bottomhole formation zone (BHZ); lack of a collector; suboptimal technological test parameters.

In the monograph of S.A. Dudaeva and R.S. Dudaev "Khadumites of the Ciscaucasia ..." the authors developed a procedure for testing hadumites and clearly, using the examples of wells in the Eastern Ciscaucasia, the negative effect of increased drawdowns on the test results is described [1]. Continuing to analyze the conditions for testing clay reservoirs, we note that in the wells of the Zhuravsko-Vorobyevskaya zone, the likelihood of significant clogging of fractured clay reservoirs is high, since the clay deposits were opened with drilling mud mixed with fresh water. The contact of fresh water with clay, in particular with montmorillonite, leads to the swelling of clay particles and blockage of the void
Based on the foregoing, to exclude clogging, it is necessary to drill wells on solutions prepared on water with a salinity close to the formation, for the studied deposits such salinity is 40 g/l.

2. Field geophysical research

Reservoir testing is, undoubtedly, one of the most important types of research, therefore, the study of the reasons for the low efficiency of testing of Paleogene reservoirs is a fundamental factor that determines the potential of reservoir layers. The quality of the test is associated with the technology of the primary opening of the formation. The quality of the formation penetration determines the quality of the "well-formation" hydrodynamic connection. It is often observed in practice that the amount of pressure on the reservoir exceeds its optimal value, determined by the regulations, and can reach several MPa. It is possible that excessive pressure can lead to hydraulic fracturing of the formation and to deep penetration of the filtrate of the drilling fluid into the formation, including the solid phase of the mud, the consequences of such penetration will be discussed below. The main thing for the studied sediments, when the magnitude of repression during the opening of productive plastic rocks exceeds its optimal value, is still the fact that irreversible deformation of the reservoir occurs.

When testing or developing oil-saturated objects, the only lever for influencing the reservoir in order to obtain inflow from the fracture is to establish the optimal Pb. The principle of testing an open-hole interval by formation testers on drill pipes (PDT) is to isolate it from the rest of the section with packers lowered on drill pipes and then create a depression in it (the difference between the formation and bottomhole pressures).

The formation tester is lowered into the well on drill pipes filled with fluid so that its hydrostatic pressure provides the planned drawdown on the test object. After reaching the specified depth, the rubber elements of the packers are squeezed from the surface and bridged the gap between the PDT body and the borehole wall, isolating the test interval from the rest of the borehole. At the fields of the Eastern Ciscaucasia, two options for testing open wells are used: by isolating the entire bottomhole interval by installing packers in the top of the interval or by isolating a specific interval of the wellbore at its top and bottom. The test cycle consists of the inflow period which is the time of communication of the formation with the cavity of the drill pipes and the pressure build-up period which is the time of pressure build-up in the under-packer space after the shut-off valve is closed [4, 5, 6].

The change in pressure over time, starting from the moment the tester is lowered into the well and ending with its rise to the surface, is recorded by manometers. Usually, at least three pressure gauges are installed: above the shut-off valve, in the PDT filter and below the lower packer.

The test equipment differs in the following features: the nature of valve control (rotation of the drill pipe or axial movement of drill pipes using an expansion joint), the method of isolating the test interval (only from the top, top and bottom), the method of fixing the packer elements in the well, i.e., with the support of the string of drill pipes directly to the bottom or with their support using special anchor devices on the walls of the well.

The reliability of the assessment of saturation and hydrodynamic properties of rocks (all other things being equal) depends on the size of the test interval, its homogeneity in terms of hydraulic conductivity and the nature of saturation. When testing powerful objects, it is very difficult, and in most cases, it is impossible to specifically establish (and, accordingly, to characterize quantitatively) intervals giving off fluid. The viscosities of water and oil are different, therefore, when jointly testing the water and oil-saturated intervals of the section, the percentage of oil in the total volume of the obtained fluid is significantly underestimated. The latter leads to erroneous conclusions about the productivity of the test object. So, when the ratio of the viscosities of oil and water is more than three and the ratio of the capacities of the water-$h_{w}$ and oil-producing $h_{o} \cdot H_{w}/h_{o} > 4$, the oil content in the sampled fluid does not exceed 10%.

Practice shows that with uniformity of saturation of permeable rocks, the reliability of tests can be ensured if the sampled interval does not exceed 25 m. In this case, the volume of inflow into the pipes should exceed 1.5 - 2.0 of the volume of the sub-packer space.
In the case of a single-packer scheme, testing of objects located more than 50 m above the bottom of the well is not recommended.

The likelihood of receiving an inflow during testing with PDT of intergranular reservoirs significantly decreases with an increase in the amount of repression of the drilling fluid and the duration of its impact on the formation. This is due to the clogging of the near-wellbore zone of the reservoir, as a result of which the hydrodynamic connection of the formation with the well deteriorates.

The most reliable are the results of work with PDT, performed no later than 3-5 days after the formation was opened, however, in this case, the formation may be contaminated.

The duration of the action of the drilling fluid on the formation before testing for more than 5 days is permissible for intergranular reservoirs with good reservoir properties; for reservoirs with low reservoir properties, the probability of obtaining an inflow during PDT testing after 5 days upon drilling is significantly reduced.

The effectiveness of the open hole test is also determined by the drawdown value and the duration of the PDT holding in the well. However, the approach to the selection of the drawdown value is different for reservoirs of various types of porosity. For intergranular reservoirs, the efficiency of PDT application increases with increasing depression. The latter creates conditions not only for obtaining fluid without impurities, but also for better cleaning of the bottomhole zone and deeper drainage of the formation. The amount of drawdown is limited by the strength of the drill pipes used in the PDT assembly, the type and number of packers used, as well as the stability of the rocks in the zone of the packers and under the packer space. Modern testing equipment and drilling tools allow testing at crushing pressure drops up to 35 MPa.

The values of the drawdown on the formation are adjusted by filling a part of the pipe string above the tester with water or flushing fluid, a depression device, and installing a choke of the appropriate diameter in the channel of the formation tester.

When testing reservoirs with a developed system of open fractures, when the formation permeability depends mainly on this factor, an increase in drawdown is impractical. The challenge of inflow from a fractured reservoir must be carried out at the lowest possible drawdown on the test object. The permissible drawdown value when testing fractured reservoirs should be determined in each case experimentally or calculated on the basis of the known elastic-mechanical parameters of the rocks composing them. All other things being equal, it depends not only on the properties of each specific reservoir, but also on the depth of its occurrence.

The efficiency of assessing the nature of reservoir saturation according to IPT data can be increased by taking sealed fluid samples with their subsequent analysis.

The informative value of the data obtained from the results of studies of downhole samples is due to their exact binding to the test interval and the preservation of the composition of the formation fluid during its extraction to the surface. The representativeness of the selected sample is assessed by the pressure in the sampler, the component composition of the gas dissolved in it, and the salt composition of its liquid phase.

Physicochemical analysis of a sample for operational purposes is performed on the well immediately after the formation test using the equipment of a gas-logging station or a mobile geochemical laboratory. Degassing of the well sample from the storage sampler is carried out directly at the wellhead using special equipment. The study of samples is carried out, as in gas logging, using a chromatograph. The composition of the gas determines the nature of the fluid that saturates the formation.

In each case, testing a well using PDT should be preceded by a detailed plan for carrying out these works. Such a plan is based on the tasks to be solved: confirming the presence of a reservoir section in a given interval, determining the nature of saturation of a reservoir selected according to certain data, assessing its hydrodynamic characteristics, etc.

The procedure for assigning objects for testing in an open wellbore is mainly determined by the reliability of identifying reservoirs in the section and evaluating their productivity based on logging data.

In the general case, test objects with PDT in an open hole are assigned according to the data of geological observation of the well drilling process. At the same time, the greatest efficiency of tests is
ensured, carrying them out in the best conditions. Such an order is undoubtedly necessary when studying sections with reservoirs of a complex structure, in prospecting wells in poorly studied areas, in many cases when studying sections of deep (with bottomholes of 4 km or more) wells. In some cases, the desired effect can be obtained as a result of the analysis of a reduced set of observations of well drilling (study of drilling fluid, filtration logs, etc.). In practice, both oil-containing and aquifers are usually tested, the latter for assessing their hydrodynamic parameters, flow rate, as well as sampling formation water.

Reservoirs with porosity less than 15% (the presence of caverns and cracks is often noted) are characterized by deep zones of penetration, which are formed within a short period of time after they have been opened by drilling. The effectiveness of geophysical surveys in the study of such reservoirs is low. In many cases, only open hole test data allow identifying such a reservoir in the well section and assessing the nature of its saturation. Tests of such a section should be carried out after a minimum period of time for opening the drilling object with the obligatory selection of a sealed liquid sample and analysis of the composition of the gas dissolved in it.

Based on the analysis of the available geological and geophysical information and the accumulated experience of work in the studied fields, the test interval, installation locations and the number of packers, the permissible time of the PDT stay in the well, the number of test cycles, the duration of the inflow and recovery periods, the drawdown value, the number and locations taking sealed samples of formation fluid, etc.

In any case, before testing in the well measurements should be made with a profiler and one or another geophysical method to assess the condition of the wellbore and clarify the locations of the packers [7, 8].

Providing reliable packers is one of the most critical open hole testing issues. The following options for installing packers are possible: in the impermeable top of the test object what is the most rational option, in the stable part of the wellbore above the cavernous roof of the test object (possible only if there are no permeable intervals in the cavernous part of the section under the packer, except for the tested permeable intervals), in the upper permeable parts of the test interval. The last scheme for installing the packer is carried out in cases when the wellbore is located above the test object for a large extent of cavernous or when another permeable horizon is located above it and the interlayer between them is cavernous or small in thickness. In this case, the test can be successful if the thickness of the impermeable part of the interval exceeds the minimum allowable length of the site for installing the packer by at least 2 times. The choice of the location for installing the lower packer when isolating the object from below and from above is made from the same considerations. The number of packers installed at the boundaries of the test object is determined by the depth of its location.

The duration of flushing the well before testing should be two to three cycles. Increasing the duration of wellbore flushing for more than three cycles is practically useless. When it is impossible to prepare the well for the tool to stay safely in it for the required time, one should not expect positive results from the test. Subject to the necessary testing conditions and obtaining reservoir fluid samples and quality pressure curves, the nature of reservoir saturation, the average volumetric flow rate, reservoir pressure, transmissibility, permeability, potential and actual productivity factors, and permeability reduction factors of the near-wellbore zone are established.

For testing while drilling, horizons are recommended that are assessed as productive or possibly productive [9, 10]:

• on oil and gas showings observed at the wellhead during circulation of drilling mud.
• by oil saturation of samples of drilled rocks (core or cuttings).
• by the content of hydrocarbon gases in the drilling fluid (gas logging).
• according to the results of the luminescent bituminological analysis of the flushing liquid or sludge.

Before running the PDT, the uncased part of the wellbore should be worked out at a rate of no more than 25 m / h to the bottom with a bit of nominal diameter and flushed for at least 1.5 cycles with drilling fluid in order to eliminate ledges, abrupt transitions, oil seals and prevent possible tool landings when descent of PDT.
The characteristics of the drilling fluid must correspond to those specified in the geological and technological order and ensure the trouble-free presence of the PDT at the bottomhole during the well test (at least 3 - 4 hours).

The first signs characterizing the potential of the reservoir: productivity, the state of the bottomhole zone, plugging of the pores of the reservoir and its complete absence, can be detected already at the well by visual viewing the pressure cartograms recorded by pressure gauges installed in the test tool kit.

After closing the inlet valve, the pressure build-up quickly reaches a pressure value close to the formation pressure from P3 to P4.

The exact methods of processing the pressure cartogram are complex, so they are processed on an expedition basis.

When the reservoirs are opened, several zones of penetration are formed due to the introduction of mud filtrate into the reservoir. It should be noted that, depending on reservoir pressure, oil viscosity and reservoir porosity in the washed zone of oil-saturated reservoirs, the residual oil saturation can exceed 25% and reach 40% for high-viscosity oil.

3. Conclusion

The results of the analysis of the effectiveness of testing shale reservoirs in the open wellbore indicate the frequent lack of fluid flow. In addition to the above reasons for this circumstance, the authors believe that this may also be associated with an unjustifiably high depression in the reservoir, leading to deformation of the reservoir frame - leading to the closure of cracks or unreasonably short standing time on the inflow due to the fear of sticking to the rock.

To perform high-quality testing of reservoir formations, represented by fractured clay-carbonate rocks, it is necessary: to make an individual selection of the depression on the formation and to have a priori accurate information about the strength characteristics of the wellbore walls.

References

[1] Dudaev S A and Dudaev R S 2015 Khadumites of Ciscaucasia: New in geological and geophysical study, secondary opening and development (Moscow: Nedra) p 204
[2] Proceedings of the II All-Union Meeting on Fractured Oil and Gas Reservoirs 1965 (Moscow: Nedra) p 505
[3] Shnurman G A and Itenberg S S 1979 Study of complex reservoirs of the Eastern Ciscaucasia according to the data of field geophysics (Rostov: Publishing house of Rostov University) p 240
[4] Dudaev S A 1989 Features of the structure of clay reservoirs of the Paleogene of the Stavropol region and the improvement of the technology of their testing, isolation and development (Moscow: Reports of the All-Union meeting "Modern technical means and technologies for geophysical research of wells.") pp 38-41
[5] Misikov T K, Skripkin A P and Dudaev S A 1993 Features of the structure and testing of complex reservoirs of the Stavropol Territory with the help of formation testers on pipes (Moscow: VIEMS, Perforating-blasting and impulse types of work in wells) pp 106-112
[6] Dudaev S A and Dudaev R S 2006 Study of complex reservoirs in the process of drilling by reservoir testers on pipes (PDT) (NTV "Karotazhnik") pp 140-152
[7] Dudaev S A and Dudaev R S 2006 Rational complex of geophysical studies of complex reservoirs of the Ciscaucasia (NTV "Karotazhnik") pp 88-103
[8] Dudaev S A 2011 Informative value of gamma-spectrometry of wells in the study of clay reservoirs of the Ciscaucasia (NTV "Karotazhnik") No. 7 pp 84-101
[9] Sova V E and Kerimov A-G 2019 Large undiscovered oil resources are predicted south of Russia (Journal of Petroleum Exploration and Production Technology) volume 9, issue 3
[10] Sova V E, Sova E V and Kerimov A-G Prospects for the development and development of oil deposits of the gratefulnensky subsoil area (Problems of Economics and Management of the Oil and Gas Complex: scientific and economic journal, issue 17-24. DOI: 10.30713/1999-6942-2018-11-17-24)
