Methodological developments for taking into account of layer heterogeneity at the design stage of underground gas storage

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SUMMARY

The article presents the developed method of taking into account the heterogeneity of layers at the stage of designing underground gas storage facilities. The optimal set of methods for studying geological heterogeneity was selected. The application of the developed methodology in the study of the geological structure of the Ugerske and Oparske USG was analyzed. It was established that the productive horizons LD-8, LD-9 of the Ugerske USG and horizon LD-7 of the Oparske USG are characterized by significant variability of parameters (of effective thickness, porosity, permeability, sandiness) on the section and on the area of both structures. A conclusion was made about the importance of taking into account the heterogeneity of the collector layers of depleted gas fields at the stage of designing the gas field, as this will help to more reliably determine the technological indicators that are included in the projects of the operation of the gas field, which will help to avoid significant economic losses and increase the efficiency of underground gas storages.

Keywords: underground gas storage, layer-collector, geological heterogeneity, USG operation
Introduction

For the study of a number of important technological indicators that characterize the processes of development of gas fields and operation of underground gas storage facilities, it is of great importance not only to analyze the average values of reservoir properties of the reservoir, but also the nature and degree of their variability, that is, the heterogeneity of the reservoir, because from reliable information about the object of operation depends on the efficiency of the underground gas storage.

For the study of geological heterogeneity, it is necessary to have a sufficiently proven methodology, terminology, and classification. The goal is to develop a methodology for taking into account the heterogeneity of layers at the stage of designing underground gas storage facilities.

Tasks of research:
- to develop an optimal set of methods for studying geological heterogeneity;
- to analyze the application of the developed methodology in the study of the geological structure of the Ugerske and Oparske UGS;
- draw a conclusion about the importance of studying the heterogeneity of reservoir layers of depleted gas fields at the stage of Oparske UGS. design.

Method and Theory

Research method: lithology - facial analysis; systematization and completing of geological and geophysical information; graphical and analytical methods of geological and geophysical data processing; mathematical and statistical methods of assessing the degree of heterogeneity of collectors.

As a result of the analysis of a large number of works by scientists, it was concluded that geological heterogeneity should be studied by section and by area, since deposits are mainly multi-layered and, as a rule, a single operational object contains a significant number of layers and interlayers.

Geological heterogeneity is studied using methods that can be grouped into three groups:
1) geological and geophysical;
2) laboratory-experimental;
3) industrial-hydrodynamic.

All techniques and methods of studying heterogeneity are based mainly on statistical processing and generalization of actual material.

The first and most important stage in the study of the heterogeneity of layers by geological and geophysical methods is the dissection of the productive horizon into separate layers, as well as their correlation by area, which will make it possible to clarify the spread over the area of each separate general interval, to determine the limits of its distribution, the variability of reservoir properties.

In parallel with the correlation of layers, it is necessary to build geological profiles.

The geological and industrial practice of studying the geological structure of deposits has shown the expediency of constructing such maps: general thicknesses of the horizon; effective horizon thicknesses; distribution of collectors or zonal intervals; porosity and permeability; geophysical parameters characterizing reservoir properties of layers.

However, the listed maps are not a necessary minimum when studying the geological heterogeneity of layers. In each specific case, based on the features of the geological structure of the deposit, graphic material is selected that most fully reflects the picture of heterogeneity.

With the help of geological and geophysical methods, it is fashionable to reveal the heterogeneity of strata in sufficient detail, however, with such a study, it is not possible to obtain criteria that would
allow us to quantitatively assess the heterogeneity of different strata. In this regard, some methods of studying the heterogeneity of layers were proposed, which are based on statistical processing and generalization of the initial geological and industrial data.

With frequent and irregular variability of the parameters in the area, their values can be presented in the form of a variation series, and graphically in the form of histograms, polygons and distribution curves. Thanks to such graphs, it is possible to judge not only the limits of fluctuation of parameter values, but also the quantitative ratio between them by area. With a large volume of actual data, polygons and histograms can be transformed into a distribution curve.

A number of statistical characteristics and indicators, such as the average value of the studied parameter, dispersion, root mean square deviation, coefficient of variation, etc., can be used to assess the degree of heterogeneity of the reservoir.

The heterogeneity of layers can be expressed and evaluated using indicators that reflect the features of the geological structure of the studied object. Among them, the most widespread are the following indicators: coefficient of relative sandiness, dismemberment, wedging, endurance, spreading, discontinuity, lithological connectivity, as well as the coefficient of heterogeneity.

Therefore, a large number of different criteria and characteristics are proposed to assess the geological heterogeneity of layers, therefore it is important to choose the optimal set of indicators that would allow the most complete study of the heterogeneity of layers of a geological object.

The described methods were applied in practice in the analysis of the geological structure and assessment of the impact of geological heterogeneity on the processes of exploitation of underground gas storages in the Western Ukrainian oil and gas region (Himer, Himer, & Derkach 2007).

This technique can also be used in the modeling of gas-prospective areas and deposits (Venger et al., 2017). The study of the geological features of the formations is also used to establish the reasons for the negative results of drilling wells in the deposits of the outer zone of the Precarpathian depression (Boiko, Mykhailiv, & Karpenko, 2019).

Results

The analysis of the heterogeneity of reservoir reservoirs was carried out for the productive horizons LD-8 and LD-9 of the Ugerske UGS and horizon LD-7 of the Oparske UGS (Dubci, 2019). Geological and geological-geophysical profiles were built for a detailed study of the section of the deposits, their dissection, taking into account the lithological-petrographic and industrial-geophysical characteristics of the rocks.

A peculiarity of the Sarmatian sediments is the alternation of sand and clay rocks. To a greater extent, this refers to the productive horizon LD-9 of the Ugerske UGS and the productive horizon LD-7 of the Oparske UGS, which are characterized by significant dismemberment along the section. Sandstones are often wedged along their course, or the layers of clayey rocks separating them are wedged. The thickness of sandstones and siltstones is very variable (Seredyuk, Savkiv 2015).

The productivity of the formation is primarily determined by its effective thickness, sand content, porosity and permeability. The materials of industrial-geophysical research in drilled wells and the results of laboratory analyzes of core material were used to study the specified parameters.

The value of the effective thickness, sandiness, porosity, and permeability of the productive strata in the conditions of the Ugerske and Oparske UGS, associated with the terrigenous deposits of the Sarmatian layer, vary significantly along the cross-section and over the area. So, for example, in the section of well 252 (Ugerske UGS), according to materials (Voitsitskyi, 2003), the effective thickness of individual strata varies from 0.7 to 10 m, the value of porosity - from 16 to 26%, permeability -
from $3 \times 10^{-15}$ m$^2$ to $400 \times 10^{-15}$ m$^2$. The following limits of the main indicators have been established for the Oparske UGS along well 95 in the section of the productive horizon LD-7: effective thickness - 2.6 - 8 m; porosity - 16 - 27%; permeability - $3 \times 10^{-15}$ m$^2$ - $700 \times 10^{-15}$ m$^2$. This fluctuation of the listed parameters is typical for the sections of the remaining wells. Comparing the characteristics of the productive reservoirs along the sections of the wells of the Ugerske and Oparske UGS on the basis of the analysis of geological and geophysical profiles and the actual material, it can be concluded that the significant heterogeneity of the reservoir reservoirs along the section is a characteristic feature of both gas reservoirs, but it is somewhat more pronounced at the Oparske gas reservoir UGS.

The variability of reservoir parameters by area for the Ugerske and Oparske UGS also deserves considerable attention. What is the nature of this variability and how regular are these or other changes in parameters across the area. These issues, which are part of the general problem of the heterogeneity of productive layers, can to some extent be clarified with the help of graphs of changes in the effective thickness of sandstones and siltstones of the operational objects LD-8 and LD-9 of the Ugersky UGS and the productive horizon LD-7 of the Oparske UGS, as well as with the help of maps of sandiness, porosity and permeability.

To construct the above schedule for the Ugerske UGS, the actual material of the productive horizons LD-8 and LD-9 was combined, since these two horizons work as a single operational object. The graphs of changes in the effective thickness of reservoir reservoirs of productive horizons LD-8 and LD-9 of the Ugerske UGS are plotted along the line of wells 150, 7, 93, 252, 177, 74, 108a along the extension of the Ugerska structure and along the line of wells 255, 79, 93, 252, 33, 102 across the square in question.

Following the changes in the effective thickness of the collectors of the operational facility of the Ugerske UGS, the following conclusions can be drawn:
1) the value of the effective thickness of the productive deposits varies a lot over the area, that is, the general heterogeneity is clearly expressed;
2) a certain regularity can be observed in the change of the effective thickness over the area: its highest values - 63.9 m, 62.5 m in wells 252, 177, respectively - are observed in vaulted structures; with distance from the central part of the Ugerska structure, the effective thickness decreases to 20 m; in the north-eastern direction, the collectors are wedged out.

Maps of sandiness, porosity (Figure 1), and permeability were constructed to study the nature and regularities of changes in reservoir properties. From the compiled maps, it can be seen that the isolines of sandiness, porosity, and permeability have approximately the same shape, which indicates that the change of the listed reservoir properties over the area has a general regularity for all three indicators.

![Figure 1 Ugerske UGS. Horizon LD-8. Porosity map](image-url)
The maximum values of the listed parameters are noted in the vaulted and vaulted parts of the Ugerska structure. The amount of sand content is 0.6 - 0.7, porosity is 23 - 25%, permeability is $160 \cdot 10^{-15}$ m² - $170 \cdot 10^{-15}$ m². Moreover, the sharpest decrease in the values of all indicators occurs in the direction of the eastern part of Ugerska Square, where sandstones and siltstones of the productive horizon are replaced by clays.

Characteristic for all three maps is a certain increase in the values of collector properties in the southern part of the structure within the limits of the South-Ugersko block located there. From the conditional boundaries of the block to its center, the sandiness values vary from 0.35 to 0.50; porosity - from 19 to 20%; permeability - from $20 \cdot 10^{-15}$ m² to $40 \cdot 10^{-15}$ m² (Voitsitskyi, 2003).

Conclusions

1. A methodology for studying the geological heterogeneity of reservoir layers in depleted gas fields has been developed.

2. An analysis of the geological heterogeneity of the productive layers of the Ugerske and Oparske UGS was performed using the developed methodology.

3. When designing new gas storage facilities and when correcting technological projects for UGS that are in operation, it is recommended to take into account the heterogeneity of reservoir layers in terms of area and cross-section, since it significantly affects the filtering properties of rocks and, accordingly, on the productivity of production wells and volumes of active gas in UGS.

References

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