OIL AND GAS GEOLOGY

Express method for determining of residual oil zones at a late stage of field development

UDC 622.276.344

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Presents the method of rapid analysis to identify wild (or little produced) zones of oil deposits at a late stage of development. The method was tested on the example of horizon P-1+2 Gnidyntsi field.

The most of oil fields of PJSC "Ukrnafta" are at the late or final development stage. The deposits are characterized by high water product content. The average water content in most of them is 83-88%.

The main effective method of oil field development of PJSC "Ukrnafta" is the process of maintaining reservoir pressure (MRP) by flooding, which is widely used for a long time in order to provide for high levels of oil production. In the process of oil displacement by stratal and injection water field zones are left that are not covered by drainage. It is important to identify these areas to maximize the production of inventories.

Methods for hydrodynamic modeling of field development are widely used in the world. They allow creation of a detailed hydrodynamic model based on the majority of the factors affecting the development process. This makes it possible to use all source material that accumulates in the oil field as a result of docume8nting the development state of wells and deposits in general.

For most of the fields of "Ukrnafta" PJSC, which are at the late stage and have a long history of development, hydrodynamic modeling leads to great time and labor costs and complicates the process of making operational decisions.

It is necessary to create more simplified methods, the so-called "express methods", in order to perform operational tasks. For example, quick clarification of the the location of the project wells or determination of the appropriateness of the well transfer from other horizons. The availability of objective but integral well indicators complicates to complete the task quickly.

So. in order to address the above challenges the authors proposed an express method for the determination of residual oil zones in late or final stages of development based on limited initial data of integral type.

Initial data for the express method is accumulated samples of oil, water and fluid from the extraction wells, and (with availability of MRP) accumulated water pumping from injection wells. Equally important is the availability of information about the contour performance of the horizon, its effective oil-saturated and total thickness.

The method involves the developmen2t of a base map according to data of accumulated oil, water, liquid and water pumping from wells.

Subsequently, the input data are adjusted to the thickness of the reservoir by mathematical transformations to exclude the impact of oil-saturated thickness variable of the oil reservoir and resulted in values of bulk planar characteristics.

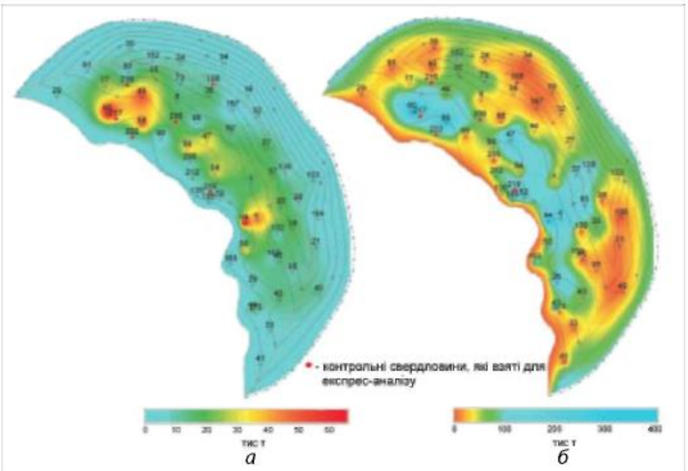

Fig. 1. Maps of accumulated selections: a - oil, - a liquid

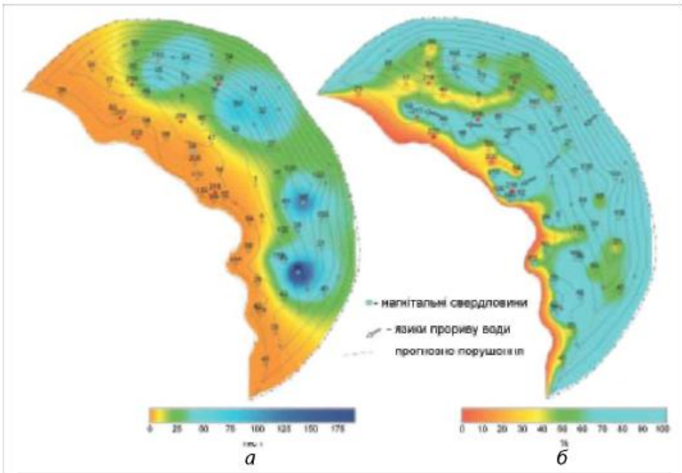

Fig. 2. Maps of planar distribution: a - water injection on the horizon; b - water content horizon

When you create maps of the detailed distribution of geological information in the hydrocarbon field, there is a challenge in spreading of horizon research parameters that are identified in wells throughout the area. Accordingly, the amount of output data is limited, that is why one of the key factors in the process of distribution on the development object is an evaluation of the data distribution uniformity and the choice of this method for data processing in which the visualization accuracy of the initial information would be the best. The task is to examine the homogeneity and density of parameter distribution and logical connection between them. The most reliable results are obtained in the course of solving complex tasks [1, 2].

At the first stage a map of the primary parameter distribution by area is developed. At the second stage math operations are used both for base maps and maps with data from wells..

A wide range of algorithms of data interpolation and extrapolation can be used for developing regular grids, but not everyone is suitable for solving the problem. For example, developing a grid by an algorithm of thin membrane makes it possible to simulate the curvature of the reservoir and to detect in the areas of greatest curvature fracture zones and (with achieving the critical values of geomechanical stresses) tectonic faults. These developments are much more accurately reproduce the spatial configuration of thin layers of a geological model than statistically deterministic algorithms of Kriging method that are usually used.

One of the key factors in the process of developing the model is geologically meaningful and differentiated distribution of parameters for the area.

A modified Shepard's method [3, 4] was used for a base grid development, which is similar to the method of inverse distance to a power. It also uses inverse distance for the calculation of weighting coefficients, by which the weighted value of the experimental data points of disclosure wells are solved. The difference is that during the developing of the interpolation function in the local area the method of least squares is used. This eliminates the appearance of the generated artifacts on the surface such as "bull's eye".

Radius of influence should be large enough to combine wells in the area with mode of sustainable extraction, but also small enough, so that one zone does not affect the other zones. Therefore, the Shepard's method allows during mapping to specify both a radial and local radii of influence.

For example, horizon P-1+2 of Hnidyntsivskuy field is selected for conducting of express method to assess the distribution of residual oil.

Horizon P-1+2 is a lithologic and stratigraphic trap , which is stretched at the plan in the form of a crescent from north to south. Its total thickness varies from zero in the western part of the accumulation up to 70 meters in the east. Horizon is represented by the sandstones, which are intercalated with clay layer and aleurolites.

The peculiarity of the geological structure of the object is to have a lithologic blowout of reservoirs in the western of the vault structure, which greatly complicates the inventory extraction in these areas as a result of deterioration of reservoir properties and significantly reduce its oil-saturated thickness (2-6 m).

The productive part of the horizon P-1+2 is limited by initial oil-bearing contour line and the line of lithologic blowout of reservoirs. Oil-water area is very wide and covers almost one third of deposit.

The development of horizon occurs during the displacement of oil by water from oil-bearing contour line to the line of blowout of productive layers. This pattern of displacement of oil by water creates favorable conditions for the formation of deadlock poorly drained areas between the lines of blowout and the first row of extraction wells. In these areas considerable residual oil are concentrated.

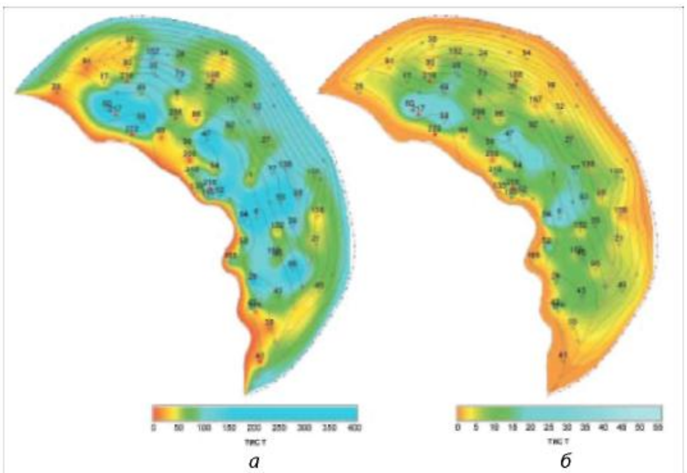

Fig. 3. Maps of planar distribution: a - moving fluid volumes, b - accumulated oil, displaced by water

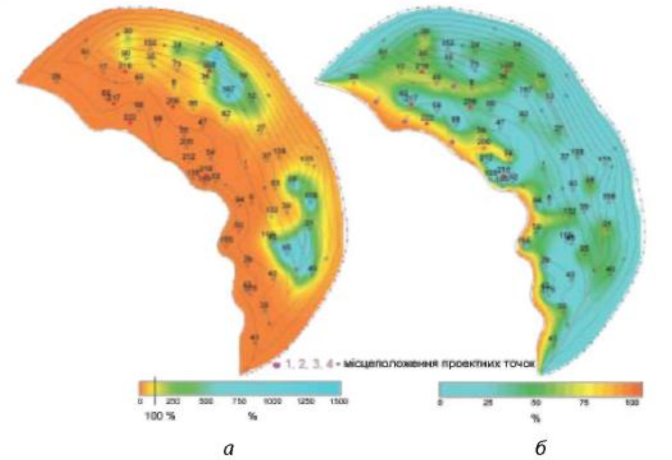

Fig. 4. Maps of planar distribution: a - compensation of selections by blowing; b - residual oil saturation

MRP was performed on the horizon by water injection (1974-2001). In total the horizon P-1+2 developed 57 extraction and 10 injection wells. Reservoir is located at the final stages of development.

The maps of accumulated samples of oil, water and fluids in wells are developed by the initial information. The basic map of accumulated pumping water in wells is developed by the data of water injection.

The same radial radius was chosen for all basic maps - 3,000 m, and the local radii were chosen depending on the goal in front of us. For example, for the map of accumulated oil and liquids it is 100 m (Fig.1, a and b).

The map of pumping water and water content of the horizon (Fig. 2 a and b) was developed with radii of 80 m. The ellipse of anisotropy should be oriented by the fall of the reservoir or from a group of injection wells up to the extraction group.

Screening dislocations were digitalized to create borders of regions on the maps of the zone of lithologic blowout and parameter values on the border are taken equal to 0. An external contour of performance was similarly digitalized, which depending on the tasks that were solved, was given a value of 0 or 100 %.

All further maps were developed as a combination of the above mentioned basic maps and adjusted to the effective thickness:

a map of motive fluid (Fig. 3a) was calculated as the sum of the values of the map of accumulated water injection and maps of accumulated fluid selections;

a map of accumulated oil which is displaced by water (Fig. 3b) was calculated as the product of two grids of the accumulated oil and water content;

a map of selection compensation by water injection was defined as the proportion of values of accumulated injection maps to the values of map of accumulated fluid selections specified in percentage (Fig. 4a);

a map of residual oil saturation was defined as the unit difference and part of the oil amount that is displaced by water, accumulated selections of oil and is specified in percentage (Fig. 4b).

Two seals of grid were carried out by drilling new wells and well transfer from other horizons on the horizon P-1+2. In the period 2011-2012 wells No.216, 217, 218, 222 were put into drilling, and well No.206 was transferred from other horizons. The withdrawal values of oil, water and liquids in new wells were not taken into account during developing of the primary maps of the parameter distribution.

The location and operation of new wells were analyzed in relation to certain areas of residual oil by express methods.

The well No.206 began to operate with an initial flow of oil 55.3 tons per day, watering products was 11.4 %. Current oil flow was 17.6 tons per day, water content is 77 %. At the map of residual oil saturation (Fig. 4b) the well is located in the zone with saturation of 38% in the area of washed zone (wells No. 58, 98, 86, 47), indicating that in the short term work (several months) production watering increases significantly.

The well No.216 was kicked off at the horizon with initial flow of 18 tons per day of oil and water content production 1.2%. At end of the year oil production was up to 15.6 tons per day, water content was 0.7 %. On the Figure 2b the well is located in the zone of low water content, at the map of accumulated extraction oil which was superseded by water (see Fig. 3b), in the area of small water displacement. At the map of motion fluid volumes (see Fig. 3a) the well is located on the border of intensive fluid flows and fluid that remains in a static state. Perhaps, it still drains a fixed fluid. On the Fig. 4b the well is located in the area of residual oil saturation 63%. More than half of the oil in the drained area remains in the reservoir.

The well No.217 began to develop horizon with the initial oil flow rate of 4.7 tons per day, and water content products of 1.6%. On the map of residual oil saturation the well is located in the zone with saturation of 32% (Fig. 4b) and can drain the area at the side lines of blowout, where the oil reserves with an initial saturation are concentrated.

The well No.218 was kicked off with an initial oil flow of 8.2 tons of oil per day, and water content of 94.3 %. According to the Fig. 2b, the well is located in the zone of high water content (80%), as evidenced by its actual value. At the map of accumulated oil withdrawal that is displaced by water (see Fig. 3b), the well is located in the flooded area, and well No.185 is located near well No.218, which is on the path of the Water motion of well No.185 (Fig. 2b).

On the Fig. 4b the well is located in an zone of low oil saturation (10%), which corresponds to the well with water content products.

The well No.222 was kicked off with an initial flow of oil of 17.3 tons per day, and watering products of 0.8%. Considering the small thickness of the reservoir (2 meters), the well is successful among the control group. The actual water content corresponds to the zone of minimum water content (Fig. 2b).

On the Fig. 4 it is seen that the well is in the zone outside the area of increased water motion (near wells No.60-58), where the paths of water breakthrough are predicted. On the map of residual oil saturation (see Fig. 4b) the well is located in the zone with the value of 78 %, where from the line of the blowout oil reserves with initial saturation are concentrated.

On the maps of horizon water content, volumes of motive fluid and residual oil saturation the areas of increased of high water content are detected that are connected to the outer contour area and an area of intense pumping water and evaluated as a possible paths of water migration.

It may be concluded on the carried out analysis based on the developed method of construction and calculation of the above maps that the most permeable horizon areas are concentrated in the vaults of the structure. The deterioration of reservoir properties were observed in the north and south terminal structures. Areas of increased water motion correlate to the zones of fracturing in the area of distribution by geomorphological data of possible tectonic disturbances. The residual oil reserves are concentrated near the zone of lithologic blowout of reservoirs (through wells No.29-222-21) and the north-western part of the deposit (near wells No.17-90-49). In this triangle there are is minimum volume of motive fluid.

According to the developed maps of water content of the horizon it can be assumed that wells No.17, 211, 49, 8, 36 are located at the north of screening faults along the south side of which formed the "tongue" of water contour breakthrough.

Developed predictive maps are well supported by the work of new wells. The maps of residual oil saturation that are based on the integral parameters are enable to make a decision when choosing and justifying the project wells location and transfer to the object wells from other horizons.

Based on the express method for selecting a location of wells in order to seal the grid and the residual oil withdrawal of the horizon P-1+2 points 1-4 are offered (see Fig. 4b).

Thus, the approbation of express method for determining the residual oil zones in the example of horizon P-1+2 of Hnidyntsivskyy field confirmed the possibility of its use in the oil reservoirs.

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