Geodynamic ranking of hydrocarbon fields by example of South Cis-Ural

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Abstract. In this paper is presented hydro-geodynamics and geodynamics in hydrocarbon fields by example of the Southern Cis-Urals. Seismicity and geodynamics induced by hydrocarbon production by summarizing the published case studies are considered. Changes in hydro-and gas dynamics affect changes in the geodynamics of the crust. Natural and technogenic changes in subsoil of the Earth Crust are usually entail deformations and tectonic movements of earth's surface, which is one of the important factors determining environmental changes and requiring attention in geotechnical survey and field development. The method of classification of the geodynamic state of the developed hydrocarbon fields of the oil and gas basin refers to the field of analysis of geophysical processes, its field of application: identification of the geodynamic state of productive strata and developed hydrocarbon fields of the oil and gas basin, identification of dangerous geodynamic processes, selection of a rational mode development of hydrocarbon fields. The predominant field of application is the classification of geodynamic state of the developed hydrocarbon fields of the oil and gas basin.

1. Introduction
Geodynamics of the Southern Cis-Urals region are poorly understood, since the region is located inside the platform, and platform territories are considered to be geodynamically low-active and low-seismic. Until recently, it was believed that earthquakes rarely appear on the earth's surface by shocks of up to 4-5 Richter scale, and most of the oscillations recorded on the platform are only echoes of strong earthquakes from seismically active regions. The greatest attention was paid to areas with active mountain-folded structures. However, at present, it has become clear that the intra-platform territories are also mobile, especially in areas of tectonic disturbances and near folded areas.

The study relates to the field of analysis of geophysical processes, its field of application: identification of the geodynamic state (GDS) of productive strata (PS) and developed hydrocarbon (HC) deposits of an oil and gas basin (OGB), identification of dangerous geodynamic processes, selection of a rational mode of development of HC deposits of OGB The predominant field of application is the classification of the developed hydrocarbon fields of the OGB according to their geodynamic state.

Intensive oil and gas production in such large regions as Groningen gas field in Netherlands, War-Wink Field in USA, Romashkinskoye field and Orenburg oil and gas condensate field in Russia has disrupted natural environment [1-3], has significantly restructured the hydrogeodynamic and geodynamic processes in the earth's crust at a depth of more than ten kilometers over an area of several tens of thousands of square kilometers. Conditions have been created for the emergence of a number
of environmental problems that significantly affect the natural development and quality of life of the region's population.

In large oil and gas regions, dangerous techno-natural processes arise in the upper part of the earth's crust. Such processes develop as a result of an unwanted rock mass response to human technological activity. As a result, seismic activity increases, a hydro geodynamic regime is disrupted and subsidence of an Earth's surface is observed [4-8]. The basis for identifying reasons for increase in seismic activity during hydrocarbon production is based on the results of studies of hydro-gas-dynamic, geodynamic and geophysical processes and water systems dynamics in the regions of developed hydrocarbon fields.

Decrease in pressure in a water system that unites formation waters and surrounding aquifers of a hydrocarbon field, violates natural geodynamic state of the host rocks during hydrocarbons withdrawal and its increase during water injection. It also destabilize dynamic balance between water and a solid part of the Earth's crust [9].

2. The description of the data and methods

There are several methods that solve the problem of assessing the geodynamic activity of oil and gas production areas. For example, method for detecting lithospheric zones of variable geodynamic activity, based on the analysis of data from ionospheric satellite measurements of the magnetic and electric components, therefore to classify the developed deposits with it hydrocarbons on the geodynamic state of the oil and gas basin is not possible.

Method for assessing the influence of factors on the safety of operation of an underground gas storage (UGS) in a porous layer, designed to determine the impact of various natural and man-made processes on the safety of UGS operations.

A method for increasing the reliability and safety of the UGS operation with the determination of the influence of natural-man-made processes, but it does not allow classifying the developed hydrocarbon deposits by the geodynamic state of the entire oil and gas basin, which is its main drawback.

A method for analyzing the results of monitoring at a geodynamic test site built on the basis of a utility model containing a ground test site, a mobile observation device and a center for collecting, registering and processing information. The main disadvantage of the method is the possibility of only studying the territories of oil and gas pipelines, as well as the need for geodetic referencing using a global satellite navigation system.

The closest to the proposed approach is a method for determining the geodynamic activity of the subsoil of a developed hydrocarbon (HC) field by using a seismic stations are combined in a seismic network at the rate of at least three stations for every ten thousands square kilometers, the indicators of the seismic activity of the subsoil of the oil and gas field being developed are summarized, the critical value of the released seismic energy is determined, the data obtained are compared with a given critical energy, and if the critical value is not exceeded, then the summation of the seismic activity indicators continues, and if it is exceeded, then geodynamic zoning of the territory of the developed hydrocarbon fields is performed and areas with anomalously high geodynamic activity are identified.

In such areas, a seismological network is built with a density of at least three seismic stations per hundred square kilometers, with seismic stations located at a distance of 3 to 5 km from each other. Taking into account the found seismically active structures of the geological environment, the deformations of the earth's surface in these areas are determined and the level of geodynamic activity of each area is determined according to the aggregated model using normalized partial indicators of geodynamic activity and their weight coefficients, and the choice of particular indicators of geodynamic activity is carried out taking into account the characteristics of the developed HC field from the proposed list, then the found values of the geodynamic activity are assigned to the selected areas, a vector is constructed, the components of which are taken the obtained values of the geodynamic activity of the selected areas, after which the modulus of the vector is determined, normalized by the number of allocated areas, and the magnitude of the vector modulus is judged in the
range from 0 to 1 on the geodynamic activity of the bowels of the developed HC field with its surroundings [10].

The common features of the reviewed technical solution and the prototype are the determination of geodynamic parameters characterizing the geodynamic state (GDS) of productive strata (PS) and developed HC fields of an oil and gas basin. However, the prototype method is aimed at determining the geodynamic activity of the subsoil of a single developed HC field, but it is not possible to classify the developed hydrocarbon fields of an oil and gas basin by geodynamic state, which is its main disadvantage.

3. Results and discussions
A method for classifying the geodynamic state of developed hydrocarbon deposits in an oil and gas basin by determining geodynamic parameters characterizing the geodynamic state (GDS) of productive strata (PS) and developed hydrocarbon deposits of an oil and gas basin (OGB), characterized in that four stages are performed sequentially: geodynamic data; determine GDS PS; find the GDS of the developed hydrocarbon fields in the oil and gas basin and build a classification of the GDS of the developed HC fields in the oil and gas basin, and at the first stage: weed out the mothballed HC fields of the oil and gas basin, calculate the total number of PS and PS in each developed hydrocarbon field, as well as the number of developed HC fields in the oil and gas basin open list of geodynamic parameters, for example: average depth of occurrence; oil / gas content area; the average thickness of the reservoir; average net pay; porosity coefficient; oil saturation coefficient; permeability coefficient; net-to-gross ratio; dismemberment factor; oil viscosity coefficient in reservoir conditions; oil density coefficient in reservoir conditions; volumetric ratio of oil; productivity index; drop in reservoir pressure; fund of drilled wells; and so on, determine the values of the selected geodynamic parameters for each PS, find the maximum values of each selected geodynamic parameter among the corresponding parameters of all productive strata of the oil and gas basin, take the basic values of the list parameters, focusing on the maximum values found and normalize the parameter values for each PS, at the second stage they transform an open list of geodynamic parameters into a limited list of geodynamic parameters ranked according to the degree of importance, the corresponding values are selected for the PS of each field from the found normalized values, the weight coefficients of the geodynamic parameters included in the ranked list are found for the PS of each field, the value of the aggregated model is calculated using the ranking results for of each PS, assign the found values of the aggregated models to the corresponding values of the GDS PS, after which, at the third stage, rank the PS in each HC field of the oil and gas basin according to the found GDS, on the corresponding weight coefficients are allocated for the PS in each HC field of the oil and gas basin, the values of the aggregated models for each oil field are determined, the found values of the aggregated models are matched to the corresponding values of the gas flow rate of the developed oil and gas fields, then at the fourth stage to build the desired classification the optimal number of intervals of the gas flow rate of the developed fields is determined HC NGL, find the range of variation of the GDS of the fields, determine the size of the interval, calculate the boundaries of the intervals, determine the quantity with the names of the fields that fall into each interval, build the corresponding histogram and determine the distribution law of the GDS of the developed hydrocarbon fields of the oil and gas basin using the agreement criteria at the selected confidence level, and after each new determination of the values of geodynamic parameters, the steps and operations are repeated in a given sequence.

As an example of the implementation of the method for classifying the GDS of the developed oil and gas fields, let us consider the oil and gas basin in the western part of the Orenburg region with oil and gas fields belonging to the Volga-Ural and Caspian oil and gas provinces. The analysis includes ranking of more than 50 hydrocarbon deposits.

Classification of the developed HC fields of an oil and gas basin, for which the optimal number of intervals of the geodynamic state of the developed HC fields is determined. The optimal number of intervals into which the observed range of variation of a random variable is divided when constructing
a histogram of its distribution density is determined by the Sturges rule of thumb. The optimal number of intervals \( n \) is determined by:

\[
n = 1 + \lceil \log_2(N) \rceil \tag{1}
\]

Where \( N \) is the total number of observations of the random variable, \( \lceil \cdot \rceil \) - means that you need to take only the integer part of the number.

Substituting our data (\( N = 56 \)), we get \( n = 1 + 5 = 6 \). Next, the range of variation of the GDS of hydrocarbon fields is found by finding the maximum (0.851) and minimum (0.462) values and determining their difference (0.389), determining the value of the interval (0.065) by dividing the range by the optimal number of intervals, calculating the boundaries of the intervals, for example, the boundaries of intervals 2 and 5 are as follows ..., (0.527; 0.592], ..., (0.721; 0.786]; determine the quantity with the names of the fields that fall into each interval, construct the corresponding histogram and determine the distribution law using the goodness of fit criteria at the selected confidence level (figure 1 - a histogram with the number of developed hydrocarbon fields in each of the six intervals, constructed from experimental and theoretical data, in accordance with Pearson's goodness-of-fit criterion.) Moreover, theoretical data with a high 95% confidence probability at three degrees of freedom correspond to the law of normal distribution, in particular \( X_i = 2.221 < X_{kr}(0.05; 3) = 7.8 \).

As a result, a histogram was built with the number of developed hydrocarbon fields that fell into each of the six intervals, built from experimental and theoretical data, in accordance with the Pearson's goodness-of-fit criterion. Moreover, theoretical data with a high 95% confidence level at three degrees of freedom correspond to the law of normal distribution (figure 1).

![Figure 1. Histogram with the number of developed hydrocarbon fields that fell into each of the six intervals, built according to experimental and theoretical data.](image)

4. Conclusion

The developed method for classifying the geodynamic state of the developed hydrocarbon deposits in an oil and gas basin has significant technical and economic advantages, since it allows with sufficient accuracy to identify the geodynamic states of productive strata and developed hydrocarbon deposits in an oil and gas basin, to identify hazardous geodynamic processes in the depths of the oil and gas basin, to choose rational development modes HC fields and classify the GDS of the developed HC fields. In addition, the method allows you to determine the GDS of the entire oil and gas basin, as well as to compare the oil and gas regions by the GDS values, giving preference to the oil and gas region with the best GDS value.
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