Complex geodynamic indicators for forecasting hydrocarbon deposits in the arctic zone

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Abstract. In the article, in relation to the Arctic zone of the Russian Federation, a new method of forecasting hydrocarbon deposits based on computer geodynamic modelling procedures is considered. It is less expensive compared to field and analytical methods. The approbation of the method on the example of the Laptev Sea shelf zone showed a good interpretability of its results and their compliance with the forecast obtained by other methods. The rationality of using six geodynamic indicators for forecasting: the distributions of vortex structures of the velocity vectors of horizontal shear deformations and vortex structures of normal linear deformations; the values of the velocity vectors of horizontal shear deformations and velocity vectors of horizontal normal linear deformations; the distributions of the anomalous gravitational field in isostatic reduction and the reduced temperature. The sequence of stages in determining the potential of hydrocarbon deposits in the studied territories is described, which is associated with the solution of six interrelated sequential tasks: the choice of local territorial areas of optimal size - the calculation of geodynamic indicators – the allocation of homogeneous territorial clusters – the detailing and improvement of geodynamic indicators – the determination of the potential of oil and gas fields in the cluster – the localization of oil and gas fields in each cluster – construction of a digital forecast map of the location of oil and gas fields in the study area.

1. Introduction
In the course of research in the field of geodynamic risk assessment in relation to the Arctic zone of the Russian Federation, the authors have developed a new method for preliminary exploration of hydrocarbon deposits, called the method of computer geodynamic modeling (CGDM) [1 - 7]. It is indicated as expensive of all the methods of use [1], differing from the schemes - field and analytical, and focused on poorly developed territories, such as the Arctic zone, and on underexplored parts of the Earth.

The method is based on the integrated use of six geodynamic indicators identified and tested in the course of research, namely:

1. distribution of vortex structures of horizontal shear strain rates vectors;
2. distribution of vortex structures of normal linear deformations;
3. values of rates of horizontal shear deformations vectors;
4. values of rates of horizontal normal linear deformations of vectors;
5. distribution of anomalous gravitational field in isostatic reduction;
6. reduced temperature distribution.
The first four indicators are based on mathematical modeling of the geo-dynamic state of the geological environment of the territories [1]. And the last two - on the results of the analysis of information contained in the author's database "Digital model of the Earth's lithosphere" [5].

2. Local forecast

Using the indicated geodynamic indicators, the authors identified potential locations of hydrocarbon deposits in the northern part of Yakutia (Figure 1). They are marked with solid red circles.

![Figure 1. Map of potential locations of hydrocarbon deposits (indicated by solid red circles) with the distribution of vortex structures of vectors of horizontal shear rates (depth 2 km). Author's forecast.](image)

The basic geodynamic indicator is the distribution of vortex structures of the vectors of horizontal shear deformations. From Figure 1, it follows that the solid red circles demonstrate vortex structures of the vectors of the rates of horizontal shear deformations having a left-rotation orientation.

We emphasize that only the original author's mathematical model [1] was used to predict hydrocarbon deposits, without any expensive field and analytical studies. To confirm the local forecast, an analysis of studies related to preliminary exploration of oil and gas fields in the north of Yakutia was carried out. In this work, approximately in the region of the bottom of the sedimentary cover in the southern part of the Laptev Sea basin, a site recommended for exploration drilling was found (in [3] this result is confirmed by other methods).

The location of this area (also marked in Figure 1 in blue) is consistent with the location of the places of possible hydrocarbon deposits predicted by the authors - the nearest ones are located at distances of about 30 km to the west and about 80 km to the north. Moreover, according to the authors' calculations, a possible location of hydrocarbon deposits is also located south of this area (it is indicated in 'Figure 1’ by a red circle with a dashed border) - at a distance of about 40 km. Note that in ‘Figure 1’ shows the map in rectangular projection, and therefore visual distortions are observed in the longitudinal and latitudinal directions.
In-depth analysis requires more detailed sources of information on geo-physical fields. This approach will reveal the local left-handed vortex structure of horizontal shear deformation rates and confirm the presence of hydrocarbons in the area recommended for drilling in [8]. Thus, an accurate forecast of hydrocarbon deposits in the considered zone of the Laptev Sea requires verification by other indicators.

3. **Local area forecast: general algorithm**
The general approach to forecasting hydrocarbon deposits in large territories of the Arctic Zone is seen in the implementation of the following integral algorithm shown in Figure 2. From each of its stages, you can return to any previous one to refine the forecast characteristics. Let's make some clarifications for each stage:

![Diagram of algorithm stages](image)

**Figure 2.** Stages of forecasting oil and gas deposits based on the QGDM method.
1. The division of the studied territory into sections of the optimal area is carried out in such a way that, on the one hand, territories that are substantially heterogeneous in geological and geophysical terms do not fall on one section, and on the other hand, the computational difficulties in calculating geo-dynamic indicators and clustering do not increase especially significantly.

2. The detailing of geodynamic indicators (and other informative characteristics), as applied to each selected cluster, is carried out in order to achieve greater accuracy when ranking them according to the potential of hydrocarbon deposits and solving the problem of localizing the latter in the cluster. This solves the problem of constructing a generalized geodynamic indicator of oil and gas bearing deposits.

3. The compilation of a digital forecast map of potential hydrocarbon deposits in the study area is necessary both for planning preliminary exploration, drilling operations and the initial development of future oil and gas fields, and for planning the development of residential, transport and industrial infrastructure associated with them.

4. Conclusion

1. With regard to the Arctic zone of the Russian Federation and other regions of the globe, a new method of preliminary exploration of hydrocarbon deposits - KGDM, based on the procedures of computer geodynamic modeling, is promising. Being less expensive in comparison with other existing methods - field and analytical, it is focused on poorly developed territories (for example, the Arctic zone) and underexplored parts of the Earth.

2. Approbation of the QGDM method on the example of the shelf zone of the Laptev Sea showed good interpretability of its results and compliance with previously obtained results on predicting the territorial local location of an oil and gas field by other methods. At the same time, the KGDM showed the predicted existence of other deposits located in the basin of the Sea of Laptev.

3. It is expedient to base the QGDM method on the complex use of the following geodynamic indicators: distributions of vortex structures of the velocity vectors of horizontal shear deformations and vortex structures of normal linear deformations; the values of the vectors of the rates of horizontal shear deformations and the vectors of the rates of horizontal normal linear deformations; distributions of anomalous gravitational field in isostatic reduction and reduced temperature.

4. When determining the potential of hydrocarbon deposits in large study areas, it is necessary to solve six interrelated sequential tasks: the choice of local territorial areas of the optimal size - the calculation of geodynamic indicators - the identification of homogeneous territorial clusters - the detailing and refinement of geodynamic indicators - the determination of the potential of oil and gas fields in the cluster - the localization of the location oil and gas fields in each cluster - building a digital forecast map of the location of oil and gas fields in the study area.

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