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GEOSPATIAL MODELING AS A METHOD FOR FORECASTING OIL-PROSPECTIVE HORIZONS IN THE SECTION OF THE EARTH`S CRUST

Abstract. Modern ideas about the formation of hydrocarbon deposits are based on the results of experimental and theoretical studies of the dynamics of the lithosphere. They are based on the established facts of “instability of fluid systems in the sedimentary cover and basement, as well as migration of fluids through permeable zones resulting from changing stresses in the earth's crust. It follows from this that the geological environment is nonequilibrium. Forces of external action and thermodynamic conditions inside the crust contribute to the extrusion of fluids from the lower horizons to the upper and ensure their movement through the zones of decompression to the places of unloading, which are often fracture zones limited by fluid resistances. And this means that the centers of unloading are not static, but replenished and the process of formation of deposits is essentially geodynamic.

Thus, one of the factors for successfully predicting the oil prospectivity of the study area is the detection and analysis of the morphological features of the weakened zones, which are usually not only faults, but also horizons, which are layers that differ from the host rocks by a relatively high coefficient of porosity and fracture and can serve collectors. As well as adjacent multidirectional formations, essentially representing subvertical channels providing the flow of hydrocarbons into the reservoir.

On the other hand, it is of interest to visualize the section of the geological environment from the standpoint of geomechanical permeability, an indicator of which can be the distribution of the horizontal component of the low lithostatic pressure.

Visualization of the distribution of the stresses that are responsible for possible horizontal fluid movements allows us to differentiate the section from the standpoint of the geometry and intensity of the weakened zones and the possible migration routes of fluids, including hydrocarbons, associated with them.

Obviously, such model constructions will make it possible to draw non-trivial conclusions about the nature of the known reservoir and use this methodological approach in predicting the locations of other possible hydrocarbon accumulations.

In the present work, using the example of a well-known hydrocarbon field, we consider the methodology and the results of parametric modeling of the geological environment – creating a three-dimensional image of the distribution of decompression zones and stress-strain state (SSS) parameters using data previously performed on this area of seismic studies using the common depth point method (MOGT) ..

Presentation of seismic data in the decompression parameters, reinforced by the SSS parameters, makes it possible to obtain a “formalized” section and thereby increase the efficiency of geophysical surveys both at the search stage and at the stage of exploitation of hydrocarbon deposits.

Keywords: density inhomogeneities, hydrocarbons, fluid dynamics.

The search for hydrocarbon deposits both in Kazakhstan and abroad is, as a rule, a traditional set of methods and technologies that allows for a comprehensive analysis of the results obtained using data from geological and geophysical studies, ending with recommendations for drilling exploratory wells.

Among geophysical methods, gravel and seismic exploration are usually dominant. The implementation of the traditional research complex is a very time-consuming and cost-intensive process, the payback of which is justified "under the conditions of exploration of large and medium anticlinal oil and gas bearing structures located at shallow depths" [1]. This is explained by a rather high percentage of “dry” wells with a high cost of drilling itself. Therefore, the use of a well-known set of methods when searching for deposits located at great depths should be approached with some caution.

Consequently, the methods of direct prospecting ground-space observations are unfortunately not a source of complete and unconditional geospatial information about the presence and location of possible hydrocarbon deposits in a geological section. And to fill this gap by reducing the ambiguity of the results obtained, largely succeeds by the method of mechanical and mathematical modeling of the geological environment [2, 3].

Using the data on the distribution of the elastic characteristics of the geological environment, borrowed from the results of seismic observations, the method allows you to develop spatial parametric models of the distribution of density inhomogeneities and values of the parameters of the stress-strain state in the geological space of the study area, regardless of the depth of the proposed reservoir.

In the development of models, the following stages can be distinguished:

Stage 1. Creation of spatial models for the distribution of zones of decompression.

The construction of such models can be used at the search stage, since they allow us to identify, in the context of the studied structure, the areas of decompression, with which the real spatial position and morphology of possible reservoirs, as well as those structural elements of the deep structure that can serve as supply channels, canals migration or areas of possible accumulation of hydrocarbons.

Stage 2. Construction of a spatial model of the geological section in the parameters of the SSS.

The mechanical and mathematical modeling of the geological environment involves the calculation of a set of parameters of the stress-strain state (SSS) with spatial reference of the calculated values. The distribution of the latter in the geological space can be used in solving a wide range of applied problems. Including when performing geodynamic zoning of territories and determining areas of latent energy concentration, identifying areas of increased permeability and assessing the directions of possible fluid movement, etc.

Stage 3. Development of complex parametric models.

The construction of complex models is aimed at performing an analysis of the correspondence of the decompression distribution with the distributions of SSS parameters in the studied block of the earth's crust. In particular, the identification of areas of reduced pressure is one of the main conditions for the movement of fluids in the geological environment. Therefore, it seems important to establish their spatial position and link with the distribution of decompression zones, which, by definition, can be collectors, as well as serve as channels for their migration.

Stage 4. Analysis of intermediate results.

An analysis of the distributions of density inhomogeneities and the anomalous values of the SSS parameters in the volume of the geological environment allows you to:

1. Get a visual spatial representation of the properties of the geological environment and identify new structural forms.

2. A clear idea of the morphology of productive horizons provides the basis for the design of well locations and allows conclusions to be drawn regarding the possible location of new deposits.

The applied methodology was previously tested on the basis of regional seismic observations and showed good convergence of the established decompression zones with the known hydrocarbon deposits of the Caspian region. The main provisions of the proposed methodology are given in [3,4,5].

Below are the results illustrating the above steps of the technology. They are based on 3D seismic data using the OGT method, obtained on the area of the Botahan hydrocarbon field.

The object of this study is a layer of the earth's crust with a thickness of ~ 3.5 km, including well-known ones. productive to hydrocarbons, suprasalt horizons, localized in the depth interval 1.2-1.4 km from the earth's surface.

It is obvious (figure 1A) that the section of the Botahan structure is a complex geological object in which density inhomogeneities are present in an implicit form. An attempt to isolate them showed (figure 1 B, C, D) that in the section there are relatively disaggregated layers localized at the same depths as the productive horizons identified by the MOGT seismic data. These layers are laterally sustained in depth (figure 1 C) and represent a ragged surface with a complex relief. But in general, ~ 2/3 of the area is relatively homogeneous, with the exception of those sections that reflect the position of the faults established earlier. Fault zones are relatively more permeable than productive horizons. It should be noted that the relative decompression of the fault zones when viewed from above (figure 1, D) is clearly lower than when viewed from below (figure 1, E). The last figure also clearly shows a horseshoe-shaped region of increased permeability, apparently adjacent to a dome-shaped structure.

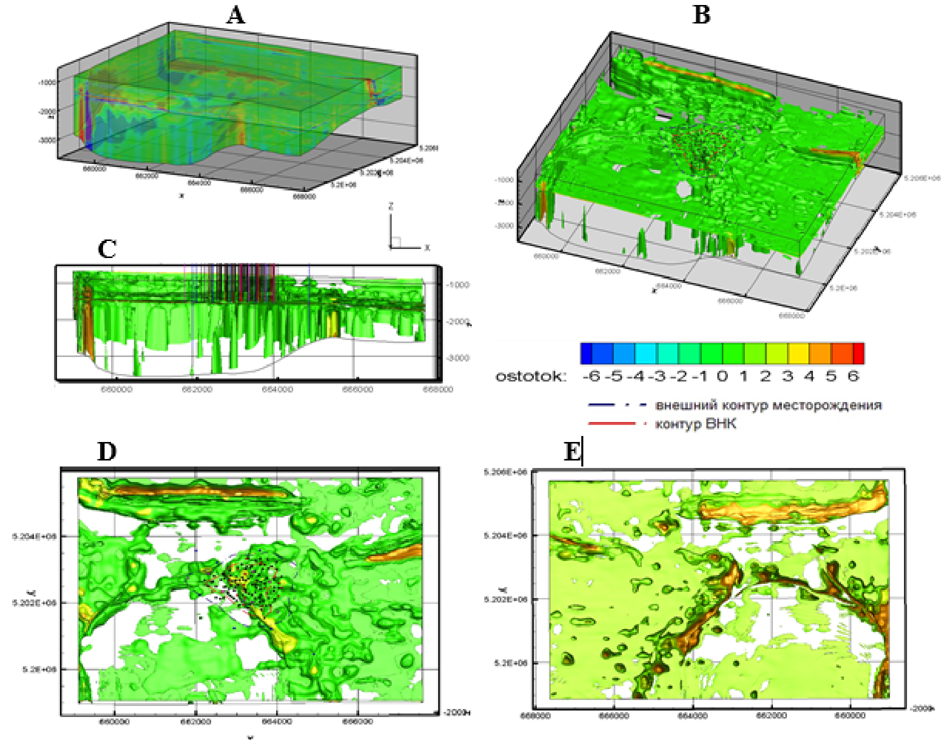

Figure 1 - Projections of the spatial position of decompression zones in a section Botany structures. A - summary section; B-3D projection of the productive horizon; C- side view in the direction of ZV (vertical lines - the position of the wells); D- top view; E- bottom view (mirror image)

From the description of the results illustrated in figure 1, it follows that all the established areas of decompression are interconnected and form a single fluid dynamic system of the Botahan field.

The abnormal values of the SSS parameters carry direct information about the features of the physical state of the geological environment. It was established that the distribution of the identified areas is not chaotic, but is confined to the position of the faults and the contour associated with the boundary of the host rocks, which has a dome-shaped structure. These elements of the geological structure are associated with the lowest possible average pressure values. At the same time, in the section there are areas of a slight decrease in average pressure, which indicates heterogeneity and increased permeability of the medium as a whole.

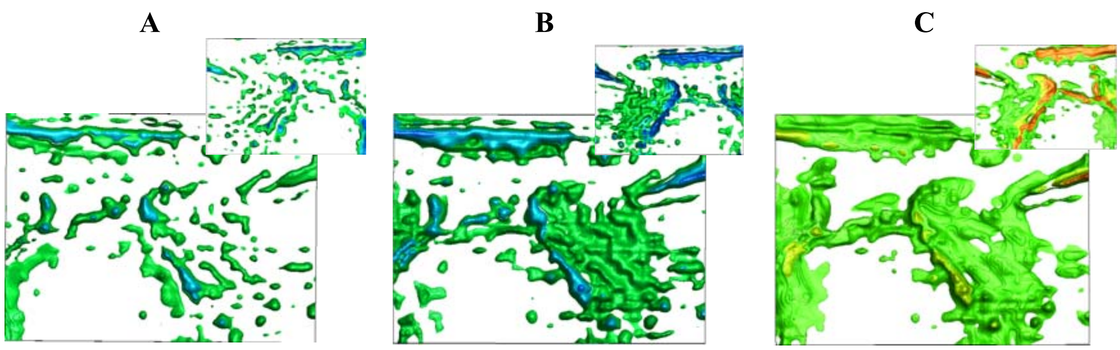

Figure 2 - Distribution of anomalous values of the SSS parameters (in Pa 105): A– average pressure; B - vertical pressure; C is the intensity of shear stresses. On each of the distributions, values of 20, 60 and 100 are shown. In the upper right corner Shows a bottom view (mirror image and 180 ° rotation)

A similar, but more contrasting picture of the distributions is observed in the analysis of anomalous values of vertical pressure and shear stress intensity. It is obvious that concentrated and relatively more significant accumulations of potential strain energy are associated precisely with weakened structural elements of the geological section. And relatively smaller - with adjacent sections. A comparison of the distributions presented in an integrated form (figure 2) suggests that the anomalous values of the parameters of the stress-strain state (SSS) can be used to identify areas of increased permeability and energy saturation of the geological environment, which is an integral part of geodynamic zoning.

The same properties of the geological environment must be taken into account when conducting prospecting for oil and gas. An analysis of the spatial distribution of the anomalous values of the SSS parameters showed that the intensity of permeability and energy saturation of the medium increase with depth, which is clearly seen in the color saturation of the structural elements of the same name in the inset (upper right corner) of figure 2.

As already noted, the identification of areas of low pressure is one of the main conditions for the movement of fluids in the geological environment. Therefore, it seems important to establish the spatial correlation of the position of the anomalous values of the SSS parameters and to link the decompression zones, which by definition can be collectors, and also serve as channels for their migration.

Obviously, the spatial overlap of the distributions of the compared parameters revealed their full agreement, indicating that in the decompression zones there are objective geodynamic conditions for the movement of fluid flows. Moreover, the intensity of the anomalous values increases with depth, thereby providing the necessary pressure drop for squeezing the fluids from the bottom up (figure 3 C, D).

Finally, the distribution of abnormal values of the intensity of tangential stresses characterizing the energy saturation of the geological environment shows that in the vertical zones of increased permeability, which are faults and a horseshoe-shaped region of the junction of the dome-shaped structure with host rocks, the largest reserves of potential energy accumulated during deformation are concentrated (figure 4). Moreover, areas of increased concentration of torsion (shear) energy with depth occupy a significantly larger area (figure 4B), which suggests that the largest reserves of latent shear energy are concentrated in the lower part of the studied volume of the geological environment

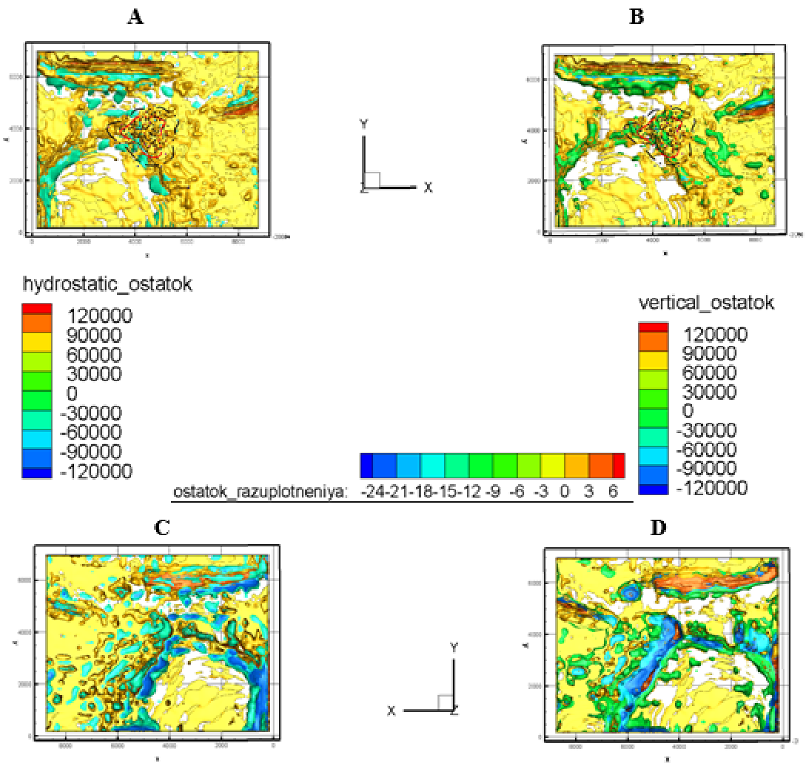

Figure 3 - Vertical projections of distributions relatively low values of hydrostatic (A, C) and vertical (B, D) pressures in combined with the distribution of decompression values. A, B – view from above. C, D - bottom view (projection is rotated 180°)

Three-dimensional parametric visualization of productive horizons in combination with geological and geophysical data allows us to use the proposed methodological approach to seismic data to identify oil-prospective structures, as well as to select the location of exploration wells.

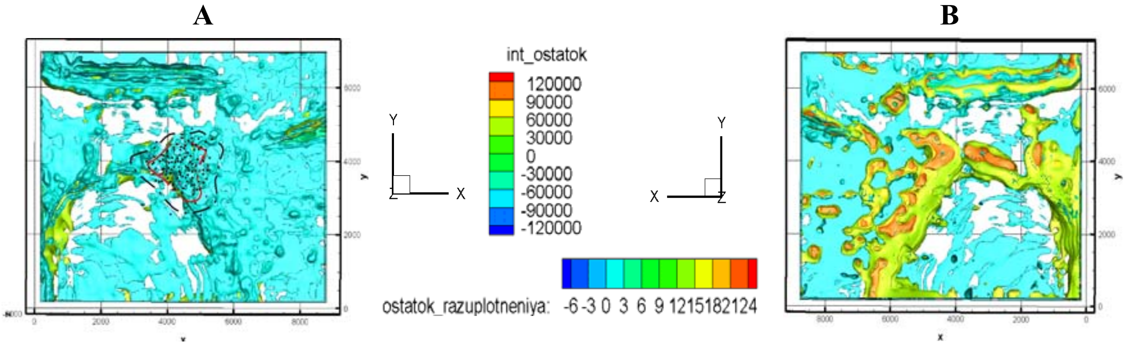

Figure 4 - Vertical projections of relatively low distribution values of intensity of tangential stresses in combination with distribution of decompression values.
A - top view. B - bottom view (projection is rotated 180°)

Development of models for the distribution of zones of possible directivity of fluid flows.

To obtain an objective idea of the distribution in the context of the values of stresses responsible for the fluid permeability and directivity of fluid flows, it is necessary to exclude stresses due to vertical pressure from the calculations. The latter will allow visualizing the distribution of only those stresses that are responsible for possible horizontal mass movements and differentiating the section from the standpoint of the geometry and intensity of the weakened zones and the possible migration routes of fluids, including hydrocarbons, associated with them.

Obviously, such model constructions will make it possible to draw non-trivial conclusions about the nature of the known reservoir and use this methodological approach in predicting the locations of other possible hydrocarbon accumulations.

Confirmation of the foregoing is figure 5, illustrating the spatial distribution of the horizontal component values of the zones of reduced pressure. Obviously, the areas of reduced pressure, displayed in shades of light yellow and green colors, having a funnel shape, are fan-shaped diverging normalized values of their intensity, rising from the lower part of the section and flattening in the upper one. These areas can be interpreted as channels of possible migration through which fluids enter their places of accumulation.

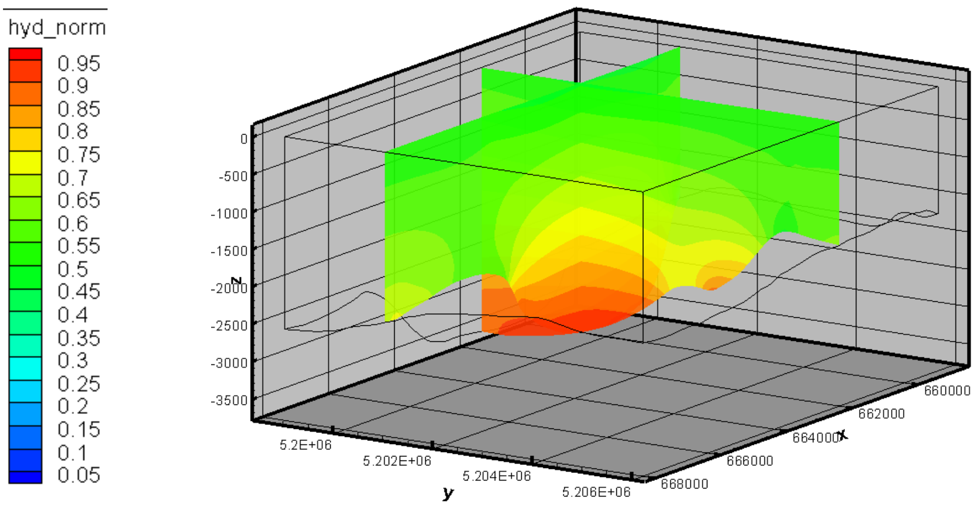

Figure 5 - Spatial projections of vertostatic pressure in the context of the Botahan structureical sections of the distribution of values the horizontal component of lith

A comprehensive interpretation of the obtained distributions and the data of geological and geophysical studies will help to identify the places of possible accumulation of hydrocarbons.

Thus, the distribution of the SSS parameters in the geological half-space can be used in solving a wide range of applied problems. Including when performing geodynamic zoning of territories and determining areas of latent energy concentration, identifying areas of increased permeability and assessing the directions of possible fluid movement, etc.

An analysis of the distributions of the values of the decompression parameters and the SSS in the volume of the geological environment of the Botahan field made it possible to draw several important methodological conclusions of an applied nature.

1. The proposed methodology for the analysis of seismic data allows you to get a visual spatial representation of the properties of the geological environment. In particular, in the area of the Botahan field, a new zone of increased permeability has been established adjacent to the deposit.

2. A clear idea of the morphology of productive horizons provides the basis for the design of wells and allows us to draw conclusions about the possible location of new deposits.

3. The proposed methodology can be used as one of the stages of the search and exploration of hydrocarbon deposits in the projected areas in order to identify productive horizons in the context of the earth's crust.

As a general conclusion, we can say that the presentation of seismic data in decompression parameters reinforced by the SSS parameters allows one to obtain a clear spatial image of the geological environment section and thereby increase the efficiency of geophysical studies both at the search stage and at the stage of exploitation of hydrocarbon deposits.

This work was carried out according to RBP-002 “Applied scientific research in the field of space activity” under the theme “To develop technologies for ground-space monitoring observations of the development of geodynamic processes in the territory of the Caspian region and forecasting hydrocarbon deposits”.

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ЖЕР ҚЫРТЫСЫНЫҢ ҚИМАСЫНДА МҰНАЙ-ПЕРСПЕКТИВТІ ГОРИЗОНТТАРДЫ БОЛЖАУ ҮШІН ГЕОКЕҢІСТІКТІК МОДЕЛЬДЕУ ӘДІСІН ПАЙДАЛАНУ

Аннотация. Көмірсутек кен орындарын қалыптастыру туралы қазіргі идеялар литосфера динамикасын эксперименттік және теориялық зерттеулердің нәтижелеріне негізделген. Олар «шөгінді жамылғы мен жертөледегі сұйықтық жүйелерінің тұрақсыздығы», сондай-ақ жер қыртысының кернеулерінің өзгеруі салдарынан сұйықтықтың өткізгіш аймақтар арқылы ауысуы фактілеріне негізделген. Осыдан геологиялық орта тепе-теңдікке жатпайтыны белгілі болады. Сыртқы әсер етуші күштер және жер қыртысының ішіндегі термодинамикалық жағдайлар сұйықтықтың төменгі горизонттан жоғарғыға қарай ағып кетуіне ықпал етеді және олардың көбінесе сұйықтыққа төзімділігімен шектелген сыну аймақтары болып табылатын түсіру орындарына түсетін жерлерге түсуін қамтамасыз етеді. Бұл дегеніміз, түсіру орталықтары тұрақты емес, бірақ толықтырылған және кен орындарын қалыптастыру процесі геодинамикалық сипатқа ие.

Осылайша, зерттеу аймағының мұнай перспективасын сәтті болжаудың факторларының бірі әлсіреген аймақтардың морфологиялық ерекшеліктерін анықтау және талдау болып табылады, олар әдетте тек бұзылулар ғана емес, сонымен қатар горизонттардың негізгі жыныстардан салыстырмалы түрде жоғары кеуектілік және сыну коэффициентімен ерекшеленетін және қызмет ете алатын қабаттары болып табылады. жинаушылар. Мұнымен қатар іргелес көп бағытты формациялар, олар коллекторға көмірсутектердің ағынын қамтамасыз ететін субтвертативті арналарды білдіреді.

Екінші жағынан, геомеханикалық өткізгіштік тұрғысынан геологиялық ортаның бөлігін визуализация қызықтырады, оның көрсеткіші төменгі литостатикалық қысымның көлденең компонентінің таралуы болуы мүмкін.

Сұйықтықтың мүмкін горизонтальды қозғалысына жауап беретін кернеулердің таралуын визуализация бөлімді геометрия мен әлсіреген аймақтардың қарқындылығынан және сұйықтықтардың, соның ішінде олармен байланысты көмірсутектердің көші-қон бағыттарынан бөлуге мүмкіндік береді.

Мұндай модельдік конструкциялар белгілі резервуардың табиғаты туралы тривиальды емес тұжырым жасауға және осы әдіс тәсілін көмірсутектердің басқа ықтимал жинақталатын жерлерін болжауда қолдануға мүмкіндік беретіні анық.

Осы жұмыста, белгілі көмірсутек кен орны мысалын қолдана отырып, геологиялық ортаны параметрлік модельдеудің әдістемесі мен нәтижелерін қарастырамыз - жалпы тереңдік нүктесінің әдісін (MOGT) қолдана отырып, сейсмикалық зерттеулердің осы аймағында бұрын жасалған деректерді пайдалана отырып, декомпрессионды аймақтардың таралуы мен кернеуленген-деформацияланған күйінің (КДС) параметрлерінің үш өлшемді бейнесін жасау.

КДС параметрлерімен күшейтілген декомпрессия параметрлерінде сейсмикалық мәліметтерді ұсыну «формаланған» бөлім алуға мүмкіндік береді және сол арқылы іздеу сатысында да, көмірсутек кен орындарын пайдалану сатысында да геофизикалық зерттеулердің тиімділігін арттырады.

Түйін сөздер: біртекті емес тығыздық, көмірсутектер, флюидодинамика.

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ГЕОПРОСТРАНСТВЕННОЕ МОДЕЛИРОВАНИЕ КАК МЕТОД ПРОГНОЗИРОВАНИЯ НЕФТЕПЕРСПЕКТИВНЫХ ГОРИЗОНТОВ В РАЗРЕЗЕ ЗЕМНОЙ КОРЫ

Аннотация. Современные представления о формировании месторождений углеводородов базируются на результатах экспериментальных и теоретических исследований динамики литосферы. В их основе лежат установленные факты «нестабильности флюидных систем в осадочном чехле и фундаменте, а также миграции флюидов по проницаемым зонам, возникающим в результате меняющихся напряжений в земной коре». Из этого следует, что геологическая среда неравновесна. Силы внешнего воздействия и термодинамические условия внутри коры способствуют выдавливанию флюидов из нижних горизонтов в верхние и обеспечивают их передвижение по зонам разуплотнения до мест разгрузки, в качестве которых часто выступают приразломные зоны, ограниченные флюидоупорами. А это значит, что очаги разгрузки являются не статичными, но пополняемыми и процесс формирования месторождений по существу геодинамический.

Таким образом, одним из факторов успешного прогноза нефтеперспективности исследуемой территории является обнаружение и анализ морфологических особенностей ослабленных зон, в качестве которых обычно выступают не только разломы, но и горизонты, представляющие собой слои, отличающиеся от вмещающих пород относительно высоким коэффициентом пористости и трещиноватости и могущие служить коллекторами. А также смежные с ними разнонаправленные образования, по существу, представляющие собой субвертикальные каналы, обеспечивающие поступление углеводородов в коллектор.

С другой стороны, представляет интерес визуализация разреза геологической среды с позиций геомеханической проницаемости, индикатором которой могут служить распределения значений горизонтальной составляющей пониженного литостатического давления.

Визуализация распределения тех напряжений, которые ответственны за возможные горизонтальные перемещения флюидов позволяет дифференцировать разрез с позиций геометрии и интенсивности ослабленных зон и связанных с ними возможных путей миграции флюидов, в том числе углеводородов.

Очевидно, что такие модельные построения позволят сделать нетривиальные выводы о природе известной залежи и использовать этот методический подход в прогнозе мест других возможных скоплений углеводородов.

В предлагаемой работе на примере известного месторождения углеводородов рассмотрены методика и результаты параметрического моделирования геологической среды – создания трёхмерного образа распределения зон разуплотнения и параметров напряжённо-деформированного состояния (НДС) с использованием данных, ранее выполненных на этой площади сейсмических исследований методом общей глубинной точки (МОГТ).

Представление данных сейсмических исследований в параметрах разуплотнения, усиленных параметрами НДС позволяет получить «офизиченный» разрез и тем самым повысить эффективность геофизических исследований как на стадии поиска, так и на этапе эксплуатации месторождений углеводородов.

Ключевые слова: плотностные неоднородности, углеводороды, флюидодинамика.

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