OIL AND GAS GEOLOGY

Oil and gas potential of Ukrainian sector of the Sea of Azov by a comprehensive assessment of aerospace research data

УДК 528.8.04: (553.98.041:551.351)] (262.54)

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One of the lines of optimization of prediction and exploration of oil and gas fields in the offshore area is involvement of new unconventional data sources, in particular materials of multispectral satellite imagery. A rating assessment of oil-and-gas promising areas in the Ukrainian sector of the Sea of Azov was carried out, taking into account the results obtained in determining the rank of OGPA according to the structural and geomorphological, neotectonic, spectral and brightness, and structural and geological criteria.

In 1976 a gas spouter was obtained in the area of the Sea of Azov at the Pivnichnokerchenskaya structure. From now on a significant part of scientists and producers research for the oil and gas potential and directions of further works in the area of the Sea of Azov [1].

In 1998 after the long break the well No. 1 was drilled at the Pivnichnokazantypskaya structure and the gas field Pivnichnokazantypskoye was opened, which was related to the upper part of the Maikopian sediments. In 1999 Skhidnokazantupskoye gas field was opened in Meiotic sediments of upper Miocene, and in 2000 Pivnichnobulganatske gas field was opened, which was connected with carbonate formations of Badenian strata. Recently there was supplementary exploration of Pivnichnokerchenskoye gas field in Badenian sediments.

So, the expectations are rewarded with positive results and discovering of the fields in case of geological exploration (GE) growth and complex approach to the study of predicting, perspective and prepared sites. The relevance of comprehensive assessment of oil and gas potential areas, sectors, sites, objects according to all possible methods remains high. It includes also the application of complex prediction method of oil and gas potential objects using data of Earth remote sensing (ERS) in the assessment of chosen areas.

One of the lines of optimization of prediction and exploration of oil and gas fields in the offshore area is an involvement of new unconventional data sources, in particular materials of multispectral satellite imagery. Unlike the traditional complex of geological and geophysical exploration based on method of "multi-stage generalization" (a generalization of data obtained in different areas), aerospacegeological studies (ASGS) help to obtain a complete picture of the structure of large-sized elements of the earth's surface on space images (SI) with further specification of individual sections on materials of aerial survey or SI with high resolution.

Use of aerospace information provides the update of geological structure of oil and gas potential areas, study and tracing of various structural forms, which may be associated with oil

and gas fields, identification and prediction of new potential objects for goal-oriented setting of oil and gas exploration activities. The unified complex of low-cost methods is appropriate at all stages of hydrocarbon (HC) search: predictive, prospecting, reconnaissance [2], which increases the efficiency of oil and gas potential of the Ukrainian sector of the Azov and the Black Sea waters of Ukraine.

The theoretical basis for data use of remote shooting for the study of oil and gas potential areas both onshore and offshore is the concept of information transfer about the underlying structure of the Earth's surface (bottom surface). This transfer can be carried out both during the mechanical displacements and foundation block vibrations and deformations of sedimentation mass, and through the geochemical transformations of the individual components of the landscape under the influence of deep fluids [3]. The distinctive features of deep structure also appear in geophysical fields (electromagnetic, gravitational, thermal, etc.), and hydrodynamic regime and the stress-deformed state of the rocks, as well as in a variety of landscape indicators that are fixed on the distance shooting materials.

On the basis of the analysis of previous studies in shelf zones [4] and based on experience of the activities performed in CASRE for the period from 1992 to 2012 [3, 5, 6] the conclusions about various forms of geological bodies and processes in the bottom landscapes, as well as in the water column and on the sea surface are made.

First of all, it should be noted that a significant part of indicators peculiar to the land can be used to decrypt the submarine relief. Thus, the reconstruction of an ancient drainage system allows to identify a number of patterns peculiar to neotectonic uplift and disjunctive dislocations. Large morphostructures are allocated by direct occurence on relief. The uplifts, deeps, sharp bends at the bottom are fixed clearly enough by the change of the picture and the density of fractures (lineaments). Massive disjunctive dislocations may correspond to horst- and graben-like deformation of the bottom, raising uplifts and stretched along one axis uplift chains (both modern and ancient), various abnormalities in the structure of underwater landscapes, which occur along certain lines, etc. Grouping of bottom gas ocurrence indicates the geological dislocation.

In order to assess neotectonic activity of selected local morphological abnormalities we performed structural and geomorphological studies: we built maps of vertical and horizontal compartmentalization and determined the amplitude of current tectonic movements.

As a result of joint analysis of ERS data and structural and geomorphological analysis in the water areas 6 areas of anomaly concentration were identified from these data (Figure): 1 - Chynhulska, 2 - Oktyabrsko-Morske-1-Obruchyevska (subzone: 2a - Oktyabrsko-Morske and 2b - Obruchyevska), 3 - Litolohichna, 4 - Mysova-1-Pivnichnokerchenska, 5 - Pivdennoberdyansko-Olimpijska, 6 - Strilkova. The territorial concentration fields of HC, oil and gas potential objects (OGPO) and preidiction and prospective objects (PPO), the impact of regional and local tectonic disturbances on their allocation were analyzed separately. Each selected area is a zone of territorial concentration fields of HC, OGPO and PPO, as well as the area of anomaly concentration detected by the remote data and during structural and geomorphological studies.

Oil and gas potential objects (OGPO) were selected for local analysis, which are the part of the fund structure of the State Geological Survey of Ukraine as of 01.01.2012: structures prepared for deep drilling (2 - Pivnichnobiryucha, 3 - Shidnobiryucha, 4 - Obytichna-1, 5 - Obytichna-2) and and detected by seismic survey (6 - Tsentralna, 8 - Blokova, 9 - Heofizychna, 10 - Pivdennoberdyanska, 12 - Bilosarajska, 13 - Udarna, 14 - Olimpijska, 17 - Obruchyeva-2, 18 - Obruchyeva-3, 22 - Morska, 26 - Litolohichna, 29 - Zahidnobulhanatska, 32 - Mysova-1, 34 - Sonyachna, 35 - Kytenska) (See Figure).

It was necessary to determine by rating assessment the priority of oil and gas potential objects that are prepared for drilling and are detected by seismic survey in order to obtain

conclusions and recommendations for further geological exploration for oil and gas in the Ukrainian sector of the Sea of Azov.

For calculating the coefficients of the drilling priority (Kge) or preparations for it the most accurate parameters that are closely related to the results of the seismic survey were used: area (Ka) and type of trap (Ktt), the depth of predictive productive horizons (Kh), and also driling, category C_3 resources or $D_{1лок}$ (КР), the degree of oil and gas potential depth (Kogpd). The accuracy of determination of the last two depends largely on the waters of drilling scrutiny.

Evaluation system for each oil and gas potential object was chosen so that the maximum numerical value of the coefficient sequence corresponds to the most effective indicator achieved after positive results of drilling (open field) and its further exploration.

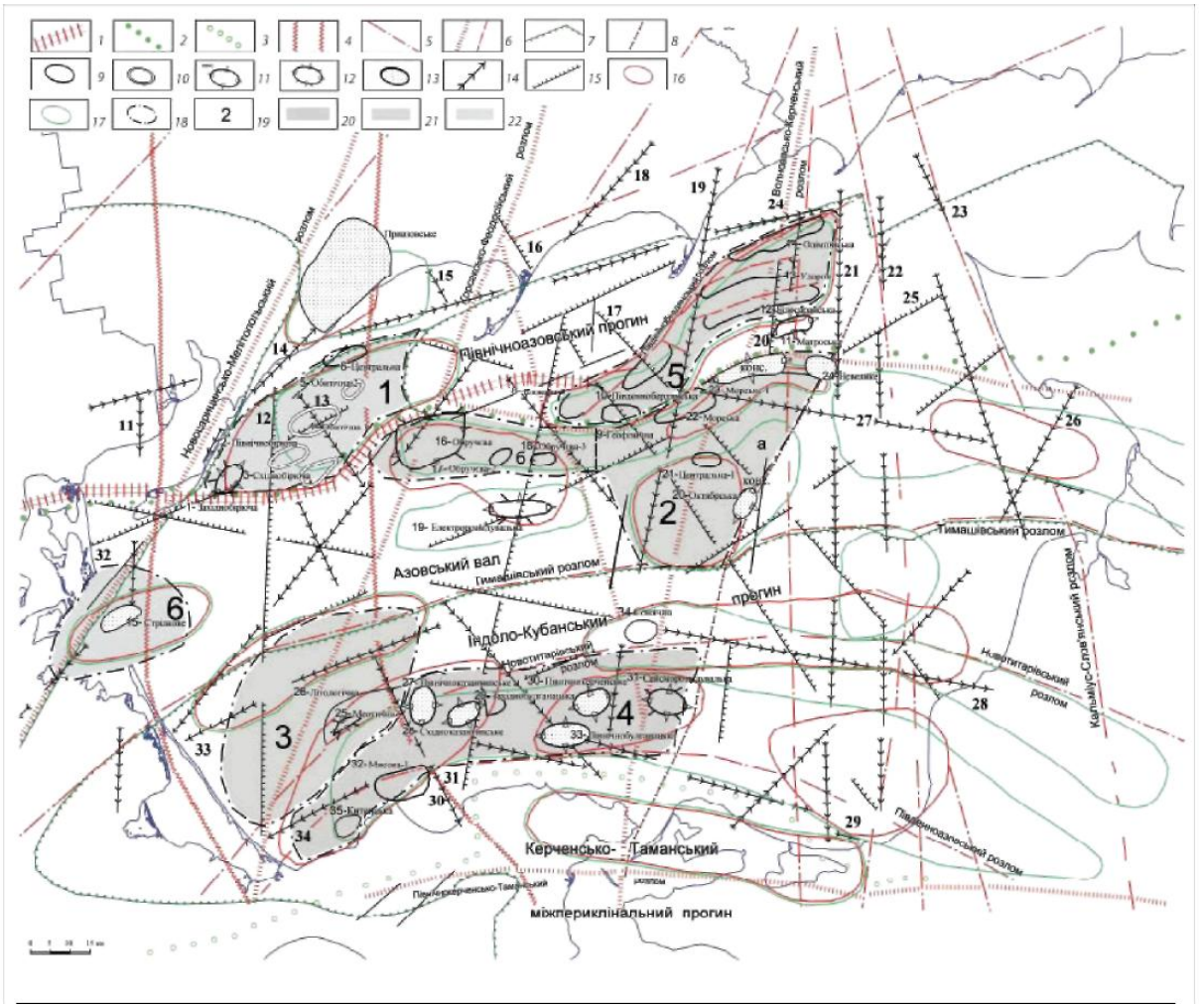
The integrated index of drilling priority or preparations for it - Kge (rating assessment) of OGPO of Ukrainian sector of the Sea of Azov is calculated by multiplying the above five coefficients [7, 8]:

$$K_{ge} = K_a \cdot K_h \cdot K_{tt} \cdot K_p \cdot K_{ogpd}$$

The top-priority objects are considered the objects with Kge more than 0.4. These are the structures, which by the above criteria can be recommended for introduction in drilling or preparation in the first place. The objects with second priority with Kge 0.3–0.4 are the structures, the search results of which are estimated to be less effective than the top-priority structures. The structures with third priority with Kge less than 0.3 are the structures that should be avoided from the introduction of exploratory drilling and seismic survey.

Four objects prepared for exploration drilling in the Ukrainian sector of the Sea of Azov (Pivnichnobiryucha, Shidnobiryucha, Obytichna-1, Obytichna-2) are located only at the Chynhulskiy saddle of Eastern European Platform (EEP) and don't solve problems and prospects of oil and gas potential of the sector as a whole. The integrated index of priority drilling or preparing for it, Kge, was determined in the range 0.308 – 0.4 for these structures (according to some data 0.495) that corresponds to the II range of the objects.

Among identified oil and gas potential objects five of them (Obruchyeva-2, Litolohichna, Sonyachna, Zahidnobulhanatska, Mysova-1) have a rank I that corresponds to the structure assessment that by the above criteria can be recommended for introduction in drilling or preparation first.



Map of the spatial layout of zones of territorial concentration fields of HC, oil and gas potentaial objects (OGPO), predictive and prospective objects (PPO) based on the results of complex prediction methods of oil and gas potential objects as on 01.01.2012:

1- the border of East European Platform (EEP) and Scythian plate (SP) under the surface Moho (according to Deep Seismic Sounding (DSS) data); 2 - the border of EEP and SP under the surface of the Precambrian crystalline basement (according to DSS); 3 - the border of SP and meganticlinorium of Crimean Mountains; 4 - fault zones under the surface Moho (according to DSS); 5 - deep faults according to DSS; 6 - regional faults from geological and geophysical data; 7 - the borders of geostructural elements, 8 - conventional boundary of sectors of Ukraine and Russia in the Sea of Azov; oil and gas potential objects (OGPO): 9 - detected by seismic survey, 10 - prepared for deep drilling, 11 - objects in the fund of drilling or preservation, 12 - liquidated objects; fields of HC: 13 - gas; 14 - lineaments identified by the decoding of space images (SI) that are compared with deep faults; 15 - Trans-Azov and Trans-Black Sea lineaments identified by the decryption of SI the nature of which is not clear, 16 - zones of of territorial concentration fields of HC, OGPO, PPO according to P.Y. Masksymchuk and others, 2004; 17 - zones of of territorial concentration fields of HC, OGPO, PPO according to P.F. Hozhyk, 2006 [7]; 18 - prospective areas of concentration fields of HC, OGPO, PPO according to the results of complex approach of oil and gas potential object prediction; 19 - numbers of concentration areas, studied sites: 1 - Chynhulska, 2 - Oktyabrsko-Morske-1-Obruchyevska (subzone: 2a - Oktyabrsko-Morske-1 and 2b - Obruchyevska), 3 - Litolohichna, 4 - Mysovo-1-Pivnichnokerchenska, 5 - Pivdennoberdyansko-Olimpijska, 6 - Strilkova; 20 - top-priority prospective areas; 21 - prospective areas, 22 - areas, which need additional geological exploration. Lineaments are marked with numbers (symbols 14 and 15): 11 - Melitopolsko-Nizhnogirskiy, 12 - Feodosijsko-Melitopolskyj, 13 - Kerchensko-Melitopolskyj, 14 - Zahidnopryazovskyj, 15 - Sergiyevsko-Temryutskyj, 16 - Primorsko-Temryutskyj, 17 - Primorsko-Achuyevskyj, 18 - Sevastopolsko-Kazanskuj, 19 - Berdyanskyj, 20 - Bilosaraysko-Tamanskyj, 21 - Hubkinsko-Tsentralnoazovskyj, 22 - Kalmius-Dzhyhynskyj, 23 - Slovjansko-Akhtyrskyj, 24 - Henichesko-Berdyansko-Kalmiuskyj, 25 - Dzhankojskyj-Eyskyj, 26 - Pohranuchno-Eyskyj, 27 - Holovnuj Azovskyj (Eastern fragment), 28 - Henichesko-Achuyevskyj, 29 - Pivdennoazovskyj (Eastern fragment), 30 - Hornostayevskyy, 31 - Kazantyp-Prumorskuj, 32 - Holovnuj Azovskyj (western fragment), 33 - Sovyetsko-Achuyevskyj (western fragment), 34 - Arabatsko-Eyskyj

Seven more identified structures (Morska, Obruchyeva-3, Kytenska, Pivdennoberdyanska, Bilosaraiska, Udarna, Olimpijska) have rank II. Possible results of these structures are estimated to be less effective than the structure of the first stage.

Three identified patterns, Centralna, Blockova-3 and Geofizychna, obtained the III rank with coefficients Kge from 0.134 to 0.277.

In a similar way it was calculated the priority coefficient by criteria complex of Earth remote sensing: an integrated spectral coefficient (Ksc), complicated object with lineament zones (Kl) and area concentration of structural and geomorphological anomalies (SGA): display of structured in relief of the seabed (Kr), neotectonic activity (Kna), the coefficient of horizontal compartmentalization (Kh), the coefficient of vertical compartmentalization (Kv), the heredity of the structure (Khs).

Obtained as the product of these seven coefficients an integral coefficient Kers allows to divide 4 prepared and 15 identified structures into three groups, defining a certain rank for each. The top priority targets are considered objects with Kers more than 0.5. Objects of the second stage are with Kres 0.4-0.5. The structures of third stage are with Kers less than 0.4..

So, we have identified the most perspective structures of I rank: among prepared is Obytichna-1, among detected - Litolohichna, Obruchyeva-3 Bilosaraiska, Pivdenno-Berdyanska.

Objects with fewer potential (II rank): among prepared are Pivnichnobiryucha, Shidnobiryucha, Obytichna-2, among detected are Morska, Obruchyeva-2, Olimpijska, Udarna, Zahidnobulhanatska, Sonyachna, Mysova-1, Kytenska.

The least prospective objects can be considered the objects of III rank. These are detected structure Centralna, Blokova-3, Geofizychna.

The accuracy of calculation parameters for objects of Cretaceous and Cenozoic of Pivnichnoazovskyj, Indolo-Kubanskuj basin and Azov shaft is different because of insufficient knowledge of the Sea of Azov by modern seismic survey by method of joint depth point (MJDP) and drilling. Therefore, the obtained results can be a powerful argument during the selection of top-priority sites considering the new geological and geophysical results and other geological studies.

The uncertainty of the boundaries between tectonic elements from south to north in the Ukrainian sector of the Sea of Azov, the lack of factual material on deep seismic horizons and their stratigraphic relation, the ascertainment of the influence of tectonics of lithospheric plates, and thus, oil and gas geological zoning requires clarification of oil and gas potential of the territory by providing regional seismic studies, direct and unconventional methods of searching HC, Earth remote sensing.

Rating assessment of oil and gas potential objects was carried on the basis of five oil and gas geological criteria (Kge) and seven criteria of ERS and structural geomorphological abnormalities SGA (Kers) and it showed that the obtained results are somewhat divergent, particularly in relation to the objects of the first rank.

Thus, carrying out of rating assessment (table) is offered with regard to the weight of structural and tectonic elements (Kste), basic oil and gas geological elements (Kogge) and calculated density of undiscovered resources of HC (Kd) with integrated index of priority drilling or preparing for it (Kge) and the weight coefficient (Kers). Integral coefficient is defined as the product:

$$K_I = K_{STE} \cdot K_{OGGE} \cdot K_D \cdot K_{GE} \cdot K_{ERS}.$$

Therefore, based on the extracted integral coefficient (Ki) the priority objects are specified and objects of the second and third rank are identified (see Table).

Results of data interpretation have shown that among four prepared objects for deep drilling located on Chynhulskiy saddle, EEP, it is recommended to set parametric drilling for structure of the II rank Obytichna-1. Because of negative result at the well 1-Zahidnobiryucha objects Obytichna-2, Pivnichnobiryucha and Shidnobiryucha should remain in reserve until the results of the parametric drilling at the well 1-Obytichna.

Identified structures (objects) of I rank require formulation of detailed seismic survey by

MJDP (Morska, Kytenska) detailed seismic survey by MJDP and exploratory drilling (Zahidnobulhanatska and Mysova-1).

Identified structures of II rank are based on geological and geophysical data and evaluation according to ERS data that are recommended for parametric drilling (Litologichna and Pivdennoberdyanska); for search and detailed seismic survey by MJDP (Obruchyeva-2 and Obruchyeva-3); for detailed seismic survey by MJDP exploratory drilling (Sonyachna); for search and detailed seismic survey by MJDP and parametric drilling (Bilosaraiska).

Rank III includes Centralna, Blokova-3, Geofizychna, Udarna, Olimpijska structures because they are in the reserve, it is recommended to perform detailed activities and alternative methods of hydrocarbons search, primarily aerospace, structural and geomorphological research.

Specialists of SE «Naukanaftogaz» [9] carried out a rating assessment of objects of the Sea of Azov, Prikerchenskyj and north-western Black Sea shelf which are prepared for drilling. As a basis of determining the parameters of a rating assessment in this publication three groups of factors has been selected: search, exploration and economics. According to the experts [9] the ***prepared structures*** within the Azov shelf have the lowest ratings, in particular, the coefficient of success and zonal coefficient are the smallest, and the performance of chalk sediments, which are prospective for these two structures (*meaning prepared for exploratory drilling of Pivnichnobiryucha and Shidnobiryucha structures - auth.*) within the Ukrainian sector of Azov shelf yet to be established [9].

Rating evaluation and recommendations concerning oil and gas potential objects (OGPO), prepared and identified (prospective), of the Ukrainian sector of the Sea of Azov including the materials odf ERS [1] with updates as amended as of 01.01.2012

No. of	Oil and gas potential objects (structures) (OGPO) as of 01.01.2008 by Ukrainian sector of the Sea of Azov	Coefficients							Object rating (structures)	Recommendations for the study of OGPO in the Ukrainian sector of the Sea of Azov as of 01.01.2010
		importance of major structural and tectonic elements of the Ukrainian sector of the Sea of Azov	importance of basic oil and gas geological elements		importance of density of undiscovered resources of HC	importance of rating assessment OGPO according to GE	importance of rating assessment OGPO according to	integral indicator of priority (ranking score) of OGPO of Ukrainian sector of the Sea of		
		K_{STE}	K_{OGGE}		K_d	K_{GE}	K_{ERS}	K_I		
OGPO prepared for deep drilling										
2	Pinichnobiryucha	0.8 (Chyn. s.)[1]	0.8	Birucho-Zahidnoazovska area of predictive oil and gas accumulation	0.9	0.9	0.9	0.466	III	reserve
3	Shidnobiryucha	0.8 (Chyn. s.)	0.8		0.9	0.9	0.9	0.466	III	reserve
4	Obytichna-1	0.8 (Chyn. s.)	0.8		0.9	1.0	1.0	0.576	II	parametric drilling
5	Obytichna-2	0.8 (Chyn. s.)	0.8		0.9	0.9	0.9	0.466	III	reserve
OGPO identified by seismic survey (prospective)										
6	Centralna	0.8 (Chyn. s.)	0.8	B-ZA pr. o/g/a [2]	0.9	0.8	0.8	0.368	III	reserve
8	Blokova-3	0.8 (PAD)	0.8	Pivnichnoazovskyj perspective (gas-bearing) region	0.9	0.8	0.8	0.368	III	reserve
9	Geofizychna	0.8 (PAD)	0.8		0.9	0.8	0.8	0.368	III	reserve
10	Pivdennoberdyanska	0.8 (PAD)	0.8		0.9	0.9	1.0	0.518	II	parametric drilling
12	Bilosaraiska	0.8 (PAD)	0.8		0.9	0.9	1.0	0.518	II	search and detailed seismic survey by MJDP, parametric
13	Udarna	0.8 (PAD)	0.8		0.9	0.9	0.9	0.466	III	reserve
14	Olimpijska	0.8 (PAD)	0.8		0.9	0.9	0.9	0.466	III	reserve
17	Obruchyeva-2	0.9 (AS)	0.9	Tsentralnoazovskyj gas-bearing area	0.8	1,0	0.9	0.583	II	search and detailed seismic survey by MJDP
18	Obruchyeva-3	0.9 (AS)	0.9		0.8	0.9	1.0	0.583	II	search and detailed seismic survey by MJDP
22	Morska	0.9 (AS)	0.9		0.9	0.9	0.9	0.729	I	detailed seismic survey by MJDP
26	Litolohichna	0.8 (Tym.d.)	0.8	PdSyv-Tim. p (g-b) r	1.0	1.0	1.0	0.640	II	parametric drilling
34	Sonyachna	0.8 (Tym.d.)	0.8		1.0	1.0	0.9	0.576	II	detailed seismic survey by MJDP, parametric drilling
29	Zahidnobulhanatska	1.0 (IKB)	1.0	TT-PnK ogr	1.0	1.0	0.9	0.9	I	detailed seismic survey by MJDP, parametric drilling
32	Mysova-1	1.0 (IKB)	1.0		1.0	1.0	0.9	0.9	I	detailed seismic survey by MJDP, parametric drilling
35	Kytenska	1.0 (IKB)	1.0		1.0	1.0	0.9	0.9	I	detailed seismic survey by MJDP, parametric drilling

Notes [1] tectonic elements (abbreviation): Chyn. s. – Chynhulska saddle, Pivnichnoazovskyj downfold, AS - Azov shaft (Serednoazovske uplift), Tim. d. - Tymashivska degree, IKB - Indolo-Kubanska basin;

[2] oil and gas geological elements (abbreviation): B-ZA pr. o/g/a - Birucho-Zahidnoazovska area of predictive oil and gas accumulation; PdSyv-Tim. p (g-b) r - Pivdennosyvasko-Tymashivskyj perspective (gas-bearing) region;

TT-PnK ogr - Tamansko-Temryutsko-Pivnichnokerchenskyj oil and gas region

Two more structures prepared for exploratory drilling were not even considered in the article [9]: Obytichna-1 and Obytichna-2. These categorical and disappointing findings reaffirm the need for more detailed and comprehensive approach to the preparation of objects for drilling, the involvement of obtained research results from using both geological and geophysical, as well as aerospace methods.

From all described above the following conclusions can be made.

The uncertainty of the boundaries between tectonic elements from south to north in the Ukrainian sector of the Sea of Azov, the lack of deep factual material on seismic horizons and their stratigraphic relation, the ascertainment of the influence of tectonics and geological fluid dynamics, and hence oil and gas zoning requires the use of uncoventional methods of searching HC and methods of ERS.

A rating assessment of oil and gas objects was provided, taking into account the data obtained during the determination of rank OGPO by structural and geomorphological, tectonic, structural and geological criteria and spectral brightness criteria. The obtained results make it possible to determine the ranking of prepared for deep drilling and seismic detected (prospective) structures.

Significant prospects of oil and gas potential areas of the Sea of Azov are established, Morska, Kytenska, Zahidnobulhanatska and Mysova-1 are defined as top priority structures, all four are at the fund of structures on 01.01.2012 listed as detected, and have the lowest rank. Among the prepared structures, only one (Obytichna-1) got a second rank.

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