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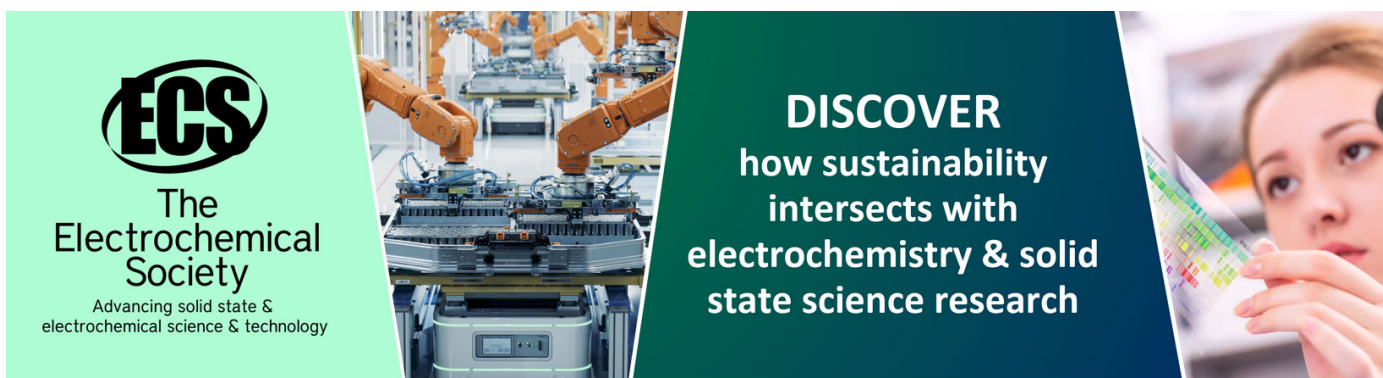
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Analysis of local structure in Mesozoic deposits and their oil and gas content to justify geologic exploration

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Abstract. The paper analyses anticlinal structures identified in Cretaceous deposits of Tersk-Kaspiysk trough in 1970s. They are classified in terms of different parameters (dislocation of rocks, distinctness in section, linear dimensions, etc.). Primary geological objects are chosen for oil and gas geological exploration.

1. Introduction

Shifting from oil well digging to borehole drilling and increase of oil and petrochemicals demand in mid-to-late XIX century necessitated the investigation of oil deposition conditions to seek new deposits of hydrocarbons in different parts of the world. With the accumulation of geological data, national and international researchers have established that petroleum liquids are associated with particular structures: anticlinal structures. This gave birth to anticlinal theory in the end of XIX century. Starting from 30–40s of XX century, main problems of oil and gas geological exploration were connected with the search for anticlinal local structures, first, by geological drilling and then, by seismic survey. Over a recent period, in many regions, a multitude of local structures in different stratigraphic sequences were identified and prepared for drilling [1].

2. Materials and Methods

The paper uses the seismic survey results on identification and preparation of oil and gas prospective local structures in the studied territory and summarizes geological and geophysical drilling data. In addition, other published data were used that bear upon this topic.

Wide implementation of common depth point method—a 1970s modification of seismic reflection survey—enabled identification and preparation of oil and gas prospective local structures in deep-sunk Cretaceous deposits. These works have opened a number of deposits: Severo-Bragunskaya, Severo-Malgobekskaya, Khankalskaya, Lesnaya, Ilyinovskaya, Petropavlovskaya, Severo-Dzhalkinskaya, etc. In general, the exploratory success ratio equaled 0.3. The confirmation factor of the structures equaled 0.8. The confirmation of the structures can be assessed only by the results of drilling two and more



boreholes. Non-confirmed deposits are Terskaya, Rodnikovaya, Yuzhno-Khayankortovskaya and some other.

However, due to the activities in 1990s, a bunch of structures revealed in 80s remained unexplored or underestimated (unfinished drilling or only one borehole drilled).

From 2000s, topical research works began on summarizing and reinterpretation of seismic and drilling data (2004, 2006, 2012), which, as a result, updated the structure of previously identified geological features in Cretaceous deposits and discovered new ones.

3. Results

Generally, along the studied territory in Cretaceous deposits, more than 50 regional promising oil and gas bearing zones were identified. Below, the classification in terms of morphological parameters (dislocation of rocks, distinctness in section, linear dimensions, etc.) and oil and gas content is presented.

There are the following structure types:

- *high-amplitude*, those highly dislocated, linearly elongated, roughly E-W trending structures. They are characterized by the ratio of long and short axes of 15 and amplitude from 600 to 1000 meters and more. Average linear fold dimensions are 4–6x25–35 km. Meso-Cenozoic deposits are morphologically distinguished almost along the whole section. They include Starogroznenskaya, Oktyabrskaya, Bragunskaya, Eldarovskaya, Khayankortovskaya, Malgobek-Gorskaya and other structures located within Terskaya and Sunzhenskaya zones. [2, 3].

- *Satellite structures*, i.e. structures with associated folding that are less dislocated versus the structures of first type. The relation of long and short axes is less than 10; the amplitude of folds ranges from 200 to 700 meters. They are morphologically distinguished along the formations of Mesozoic deposits. They are usually associated with the limbs of the main anticlinals of Terskaya and Sunzhenskaya zones (Severo-Bragunskaya, Severo-Malgobekskaya, Severo-Eldarovskaya and other).

- *Weakly dislocated* structures are presented by mainly brachyanticline folds with the amplitude from 100 up to 600 m. Morphologically they are distinguished in Mesozoic deposits and located in western and eastern parts of Terskaya and Synchenskaya anticlinal zones. They include Arak-Dalatarekskaya, Zamankulskaya, Kharbizhinskaya, Akhlovskaya, Lesnaya, Terskaya, Koshkeldinskaya and other.

- Buried structures within synclinal zones (Alkhanchurtskaya, Petropavlovskaya, Predterskaya) and Chernogorskayamonoclinal. They are mainly presented by small block-anticlinal folds with amplitude up to 300 meters and include Severo-Dzhalkinskaya, Khankalskaya, Suvorovskaya, Sayasanovskaya, Nozhai-Yurtovskaya and other structures. According to summarized geological, geophysical and drilling data, over the recent years, more than 300 new structures of this type were identified in Upper Cretaceous deposits.

- The transition structures, from geosynclinal to platform ones, have linearly elongated or brachyanticline shape and amplitude of 400–600 meter, and are located in Priterechnaya anticlinal zone. They include Pravoberezhnaya, Chervlyonaya, Ischerskaya and other.

- Mainly dome-shaped small platform structures with the amplitude of 50–150 meters.

They are typical for the northern slope of Tersk-Kumskaya tectonic depression (epi-Hercynian platform). They are morphologically pronounced in Cretaceous and Paleogene-Neogene deposits. The examples are Kotlankinskaya, Zapadno-Kotlankinskaya, Severo-Chervlennaya, Barkhannaya, Burunnaya and other structures.

Type of oil and gas content. Local structures identified on the studied territory are characterized by different oil and gas content of the stratigraphic sequences. In terms of oil and gas content, one can distinguish several deposit types.

The *first type* of structures includes deposits with highly productive reserves in Upper Cretaceous and Karagan and Chokrak deposits (Starogroznenskoye, Malgobek-Voznesenskoye, Oktyabrskoye, etc.). Here, thick clayish Maikop stratum acting as seal rock loses its shielding properties; hydrocarbons penetrate it and fill sandy Miocene reservoirs overlaid from top by Sarmatian clayish

sediments. At the sections without Sarmatian sediments or with thin stratum, small deposits have formed in Karagan and Chokrak sediments (Bragunskaya, Goryacheistochenskaya, Khayankortskaya and other areas).

The *second-type* structures are associated with deposits with reserves in smaller Upper Cretaceous sediments. Within such structures, oil and gas can be contained in Lower Cretaceous and deeper sediments.

Weakly dislocated structures (third type) are associated with high-output reserves in Upper Jurassic (suprasalt) and Upper Cretaceous sediments, while in upper Karagan sediments there are no deposits.

Within certain structures of fourth and fifth type (buried, low-amplitude, small), the oil and gas content is proved in Upper Cretaceous sediments. Miocene sediments here are monoclinical.

On the territory of Chechen Republic, the oil and gas content of structures of sixth type is not determined.

Up to 1990s, all local structures identified by seismic and other surveys were classified into three pools: pool of identified structures, pool of structures prepared for prospecting and exploration, and pool of currently drilled structures. The zones of prospecting and exploration were the structures from the pool of prepared structures, which was constantly updated from the pool of identified structures. Large choice of structures from these pools allowed selecting the most promising ones [2].

Choice of primary zones using complex of criteria. The main criteria were morphological parameters, position of structures relatively to the accumulation zones with different levels of prospectivity and deep faults, values of secondary porosity of reservoirs within these structures, oil and gas resources, etc.

1. Position of local structures relatively to zones of different prospectivity

In terms of prospectivity, Tersk-Sunzhenskaya oil and gas containing area includes the following zones. *Highly promising* zones are Terskaya and Sunzhenskaya zones (Suvorovskaya, Tostoy-Yurtovskaya, Prirazlomnaya, Severo-Oktyabrskaya, Aldynskaya, Chernorechenskaya, Avturinskaya, Krasnostpovskaya). Moderately promising zones are marginal parts of synclinal zones and troughs. Alkhanchutskaya synclinal, Petropavlovsk trough, Predterskiy trough and Benoyok nose (Severno-Eldarovskaya, Zapadno-Mineralnaya, Zapadno-Khankalskaya, Rassvetnaya, Kirovskaya and Dolinnaya structures), Belorechensk, Rucheiniy. Low promising zones are central parts of synclinals and troughs.

2. Position of local structures relatively to deep faults

Many researchers note the role of deep faults in the formation of anticlinal structures and distribution of oil and gas accumulations. The analysis of actual geological data for a number of oil and gas containing regions has shown that fault-line zones are associated with the largest high-amplitude structures with major accumulation of oil and gas. This, during the choice of primary zones, necessitates the consideration of the position of anticlinal structures relatively to deep faults (Fig. 1).

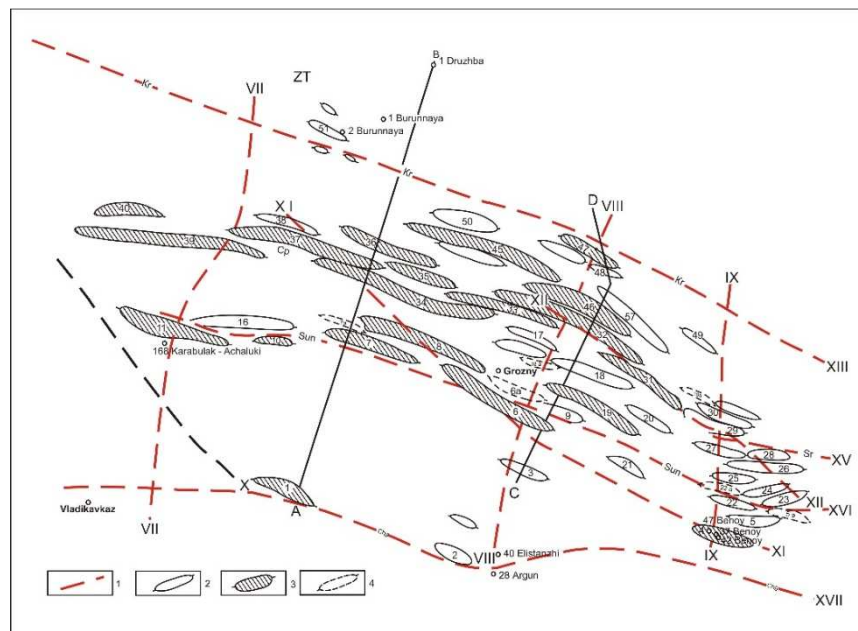
3. Secondary porosity as a factor of oil and gas content in local structures

This criterion is based on the prognostication of secondary porosity using theoretical data and comparison with values of $K_{\text{sec.por.}}$, approved by the State Reserves Committee for estimation of reserves. To increase the adequacy of secondary porosity assessment, we have used the method of multiple correlation to derive equations connecting secondary porosity with at least two parameters; the more the connection complexity, the more adequately $K_{\text{sec.por.}}$ is determined.

Thus, to prognosticate the secondary porosity of surveyed zones, the implementation of regression equation was suggested (Table 1).

Table 1. Types of equations of $K_{\text{sec.por.}}$ dependence on morphological parameters of structure and coefficients of multiple correlation

Equation type	No.	Coefficient of multiple correlation
$K_{\text{sec.por.}} = 0.04789J - 0.21792H + 0.88930$	(1)	0.795
$K_{\text{sec.por.}} = 0.04736J - 0.20801H + 0.10406 \text{ gradP} + 0.70626$	(2)	0.796
$K_{\text{sec.por.}} = 0.04779J - 0.1881H + 0.02487K_{\text{pb}} + 0.03450 \text{ gradP} + 0.66496$	(3)	0.797
$K_{\text{sec.por.}} = 0.00023i + 0.89506 \text{ grad P} + 0.02495J - 0.02577K_{\text{pb}} - 0.06675H - 0.94440$	(4)	0.852

**Figure 1.** Arrangement of local structures, deposits and deep faults of Tersk-Kaspiysk trough. Key: 1) deep faults, 2) oil and gas prospective local structures, 3) oil and gas deposits, 4) primary zones for oil and gas geological exploration

Suggested regression dependence was composed by the least square method using step-by-step linear regression: at each step, we selected the argument, which affected the correlation ratio (R) the most. The analysis shows that the absolute values of partial correlation coefficients (r) is lower than the coefficient of multiple correlation (R). The Fisher's ratio test has shown that the equations composed at each step of step-by-step regression, including the last steps, are adequate with significance level $g = 0.05$.

For 15 structures of the Tersk-Sunzhenskaya oil and gas containing area explored by drilling, the prognosticated calculated secondary porosity values and those approved by the State Reserves Committee (SRC) agree well (Table 2). Absolute discrepancy is less than $\pm 20\%$.

Table 2. Prognosticated secondary porosity for structures of Tersk-Sunzhenskaya oil and gas containing area

No.	Zones	$K_{\text{sec.por.}}^{\text{SRC}}$ (SRC) from calc.	$K_{\text{sec.por.}}$ calc. by eqs.				$\frac{K_{\text{sec.por.}} - K_{\text{sec.por.}}^{\text{SRC}}}{K_{\text{sec.por.}}^{\text{SRC}}} \cdot 100 [\%]$
			1	2	3	4	
1	Malgobek-Gorskaya	0.8	1.03	1.07	1.12	0.7	-12.5
2	Karabulak-	0.66	1.45	1.48	1.7	0.81	+22.7
3	Achalukskaya						
4	Starogroznenskaya	0.67	0.97	0.98	0.98	0.66	-1.5
5	Zamankulskaya	0.57	1.57	1.54	1.74	0.57	0
6	Eldarovskaya	0.62	0.63	0.64	0.65	0.4	-35.5
7	Khayan-Kortovskaya	0.86	1.09	1.1	1.11	0.67	-22.1
8	Severo-	0.57	0.58	0.58	0.58	0.31	-45.6
9	Malgobekskaya						
10	Bragunskaya	0.6	0.61	0.62	0.61	0.51	-16.4
11	Yastrebinaya	0.8	0.85	0.86	0.86	0.59	-26.3
12	Gudermesskaya	0.5	0.73	0.73	0.73	0.4	-20
13	Oktyabrskaya	0.6	0.89	0.89	0.88	0.55	-8.3
14	Mineralnaya	0.38	0.58	0.58	0.58	0.32	-15.8
15	Pravoberezhnaya	0.46	0.43	0.44	0.43	0.29	-36.9
16	Severo-Mineralnaya	0.36	0.61	0.61	0.61	0.32	-11.1
17	Benoykaya	0.65	1.18	1.18	1.34	0.72	+10.8

The detailed analysis of prognosticated secondary porosity values, to estimate an effective trap with fissured carbonate reservoir in anticlinal structures, has shown that theoretically calculated secondary porosity is confirmed by the log information (Severo-Starogroznenskaya, Andreevskaya, Severo-Bragunskaya, etc.) [4].

The analysis of calculated prognosticated secondary porosity within poorly surveyed structures has shown that the most promising from the perspective of reservoir presence are Upper Cretaceous sediments of the following zones: Sayanovskaya, Mesketinskaya, Severo-Benoykaya, Belorechenskaya, Vostochno-Gudermesskaya, Petropavlovskaya, Yuzhno-Pravoberezhnaya, Severo-Bragunskaya. Their prognosticated secondary porosity is 0.5–0.75% and more. The promising zones ($K_{\text{sec.por.}} = 0.25\%$) are Nozhaiy-Yurtovskaya, Koshkeldinskaya, Severo-Khankalskaya, Dzhalkinskaya, Severo-Dzhalkinskaya, Andreevskaya, Severo-Zamankulskaya, Severo-Zakanovskaya, Yuzhno-Hayan-Kortovskaya, Yuzhno-Petropavlovskaya, Severo-Starogroznenskaya and Chervlennaya. Little promising ($K_{\text{sec.por.}} < 0.25\%$) are Vostochno-Hankalskaya, Zandakskaya, Severo-Eldarovskaya, Yuzhno-Hankalskaya, Severo-Starogroznenskaya, etc.

4. Distribution of new prospective zones according to the reservoir size:

- more than 3 mln tons of oil: no structures;
- from 1 to 3 mln tons: Zapadno-Mineralnyi, Dolinnyi, Zapadno-Hankalskiy, Avturinskiy, Severo-Oktyabrskiy, Tolstoyurtovskiy, Vostochno-Pravoberezhnyi (eastern block), Suvorovskiy, Severo-Suvorovskiy, Rucheinyi, Belorechenskiy;
- from 0.5 to 1 mln tons: Belorechenskiy (eastern block), Zapadno-Mesketinskiy, Nozhaiyurtovskiy, Rassvetnyi, Aldynskiy, Kirovskiy, Krasnostepnoi, Severo-Eldarovskiy);
- less than 0.5 mln tons: Prirazlomnyi, Chernorechenskiy, Vostochno-Pravoberezhnyi (central block), Yuzhno-Nozhaiyurtovskiy.

4. Conclusions

To determine the level of structure prospectivity, preparation (exploration) and priority of bringing into drilling, the structures were ranked to optimize the oil and gas geological exploration. The analyzed local structures can be divided into three groups: 1) poorly promising structures that are not reasonable to be developed: Rodnikovaya, Alpatovskaya, Terskaya, Severo-Chatargroznenskaya, Zandakskaya, Vostochno-Khankalskaya; 2) structures with unclear oil and gas content: Burunnaya, Basskaya; 3) newly identified structures over recent years after summarizing geological and geophysical data.

From structures of 2 and 3 type, primary geological zones were selected for geological exploration. In terms of favorability of all considered criteria, the primary zones for oil and gas geological exploration are: Severo-Oktyabrskaya, Sayasanovskaya, Dolinnaya, Belorechenskaya, Suvorovskaya, Tolstoy-Yurtovskaya, etc. Geological exploration of selected primary geological zones and consequent exploration of other above mentioned local structures located within oil and gas prospective zones will enable the incremental growth of prospected resources of oil and gas, and hence change the ratio of non-discovered and discovered reserves of hydrocarbons to the good of the latter [5].

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