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# Perspectives of oil field exploration in Middle Cambrian sandstones of Western Lithuania

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The proposed assessment of perspectives of oil exploration in West Lithuanian onshore is based on geochemical analysis of oil and organic matter together with available geological-geophysical data as well as on modelling results. It was established that source rocks of the Baltic Syneclise with the content of organic matter of one or more percent buried at a depth of more than 1500–1600 m, and their degree of catagenesis according to the index of "vitrinite" reflection reaching more than 0.7% generated oil. The territory, which meets the above-mentioned parameters, is prospective for oil exploration. The less prospective zone envelopes the prospective one with a narrow bend. Its eastern boundary is approximately determined by the isoline of –1350 m of the key reflecting horizon (Upper Ordovician – Lower Llandovery). The organic matter of source rocks has reached only a degree of "early oil" maturity in this territory, *i.e.* its oil production potential is very poor.

**Key words**: the Baltic Syneclise, organic matter, oil fields, perspectives

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## INTRODUCTION

After a long interruption, oil inflow was extracted at Uoksai-1 and Antkoptis-1 wells in 2004. Furthermore, several structures prospective for oil-bearing were found. All these facts encourage examining the problem of oil-bearing in Western Lithuania again. While developing scientific research in oil geology and applying the obtained results in production, attention has been focused on forecasts of the most prospective regions and areas, estimation of geological reserves, recommendations as to the directions of oil exploration at the Institute of Geology (the Institute of Geology and Geography at present). The research has been developing in these directions: tectonics of regional and local structures; sedimentology of oil-bearing horizons and caprocks; detection of facies and reservoir properties of rocks; analysis of the geochemical composition of oil and bitumoids as well the origin of oil; forecast assessment of oil fields as well estimation of geological reserves of oil; methodical studies of data application of well logs; gravimetric and magnetometric exploration of the geological structure of Lithuanian territory. The summary of derived data is presented in many reports, monographs and scientific papers, which are most widely listed in the book "Lithuanian Institute of Geology 1941–2001" (ed. Grigelis A., 2001).

Collaboration with scientists from the neighbouring countries (Latvia, Poland, and Russia) and with Scandinavian geochemical laboratories in recent years enabled not only to use modern facilities and to analyse the composition and properties of oil, organic matter and reservoir rocks in more detail, but also to take advantage of databases compiled in different countries. Data from mentioned research are also presented in special reports and a few publications. In 2001–2002, 3-D modelling software SEMI (applied to modelling of micro-oil emigration from source rocks, secondary migration through oil reservoirs and accumulation in traps) with permission of the Norwegian SINTEF Petroleum Research Institute was employed to determine formation and survival conditions of oil fields in the Baltic Syneclise.

## TECHNIQUES APPLIED

All available geological, geochemical and geophysical information has been used in this paper. The zoning of Western Lithuania was carried out by summing up the occurrence of oil source rocks, reservoirs and caprocks, the closeness of Earth's interior, estimated geological reserves of hydrocarbons, and correcting the zones prospective for oil accumulation distinguished earlier (Figure). The original map is compiled in the LKL coordinate system to a scale 1:200,000.

## DISCUSSION

The estimation of the amount of hydrocarbons generated by oil source rocks underlies reseaches of such processes as hydrocarbon emigration, migration and accumulation and also the territorial assessment of perspectives for oil exploration. Volumetric techniques applied to estimate the amount of hydrocarbons are very variable, though some parameters used are derivative and have large calculation errors. However, has been proven that recoverable reserves of oil comprise 10% of the estimated resources only in few cases; as a rule, they reach only few percent of the amount of generated hydrocarbons (McDowel, 1975).

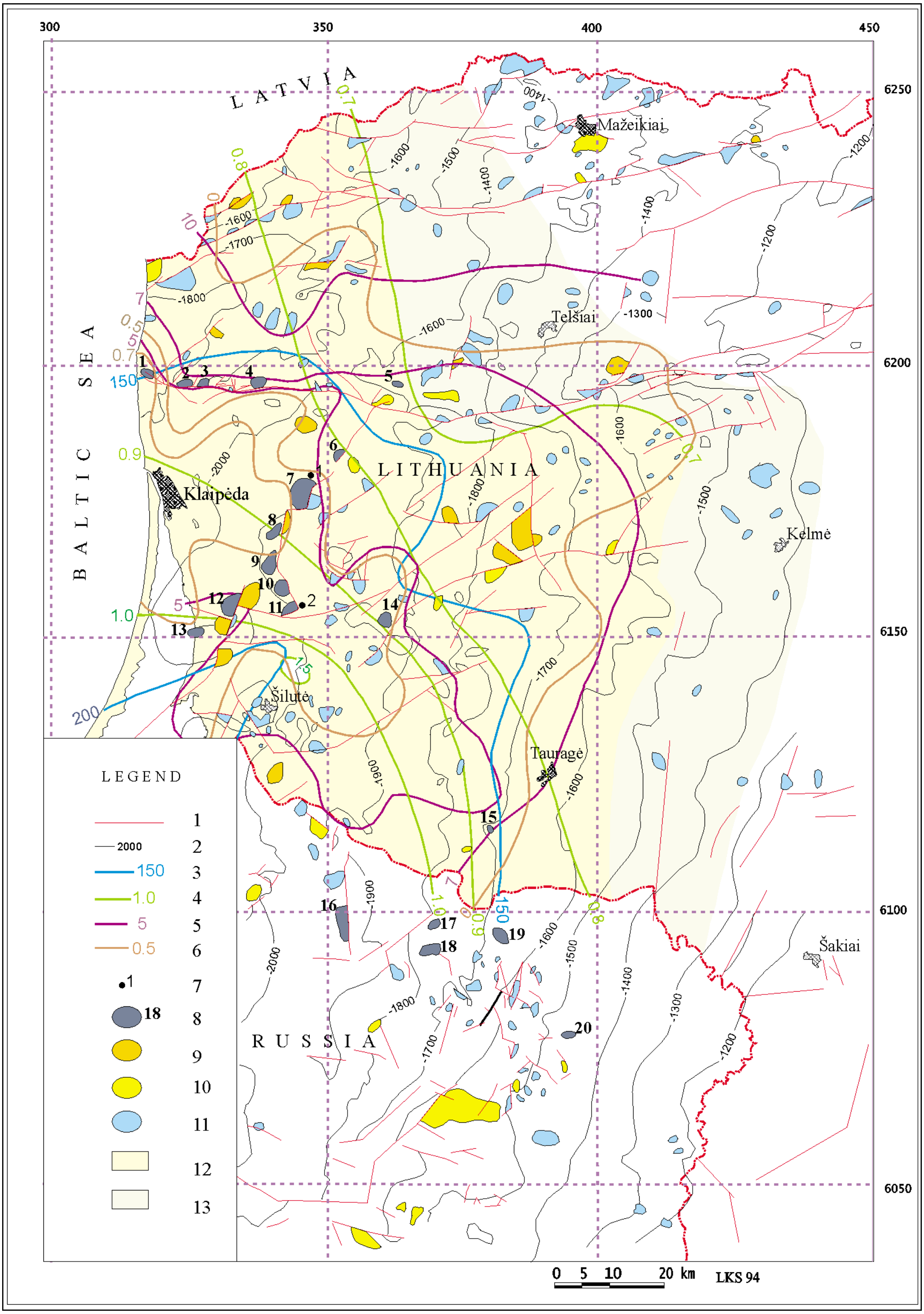
The total amount of 987.94 million t of hydrocarbons were generated from Cambrian oil source rocks in the Lithuanian onshore and offshore (Zdanavièiûtë et al., 2004, calculated by means of J. W. Schmoker‘s technique). Assuming the accumulation coefficient as 0.05, the primary reserves of hydrocarbons in the Cambrian rocks aggregate 49.4 million t. In the Lithuanian onshore and offshore, 1.7 billion t of hydrocarbons emigrated from Ordovician oil source rocks and 5.8 billion t from the Silurian. However, due to a specific lithology of the geological section, only a very small amount of them could accumulate in the traps. E. Kadûnienë (1996) estimated the reserves of emigrated liquid hydrocarbons by means of volumetric genetic technique and presented the following facts: 689.6 million t of hydrocarbons emigrated from Cambrian oil source rocks in the Lithuanian onshore and offshore. Assuming the accumulation coefficient as 0.1, the primary reserves of oil in the Cambrian rocks aggregated 69 million t. In the Lithuanian onshore, 189.2 million t of liquid hydrocarbons emigrated from the Ordovician oil source rocks and 4.7 billion t from the Silurian. Therefore, the amount of generated hydrocarbons calculated by means of two techniques is very similar.

Modelling data have shown that the largest intensity of oil migration flows was in the deepest part of the Baltic Syneclise. Traps are the most fully filled up with hydrocarbons in that territory. The situation for oil generation and migration was optimal by Late Silurian–Lower Devonian, when the spead of Silurian oil source rocks in the central part of the Baltic Syneclise was submerged at a depth of more than 1600 m. Generated hydrocarbons could accumulate in the isolated structures that existed by the end of the Early Silurian, but the majority of oil fields is screened by faults formed during the Early Devonian, accordingly the beginning of oil field formation should be related to the Middle Devonian. The very general modelling results allowed to deduce that not only the Middle Cambrian oil source rocks were involved in oil generation of the Middle Cambrian oil fields in Western Lithuania; there should be additional sources, *i.e.* micro-oil generated from the Ordovician and Silurian oil source rocks (Zdanaviciute, Lazauskiene, 2004).

Let us remind an interesting idea given by J. Calikowski (Calikowski, 1984) about oil migration during the Early Paleozoic. This author attributes the part of hydrocarbons located in the Cambrian reservoir rocks to epigenetic, generated from the Silurian oil source rocks. A. Witkowski (Witkowski, 1989), W. Gorecki et al. (Gorecki et al. 1992) ventilated some reasons against this idea. However, migration of the Silurian hydrocarbons to the Cambrian reservoir rocks could be take place in the south-western part of the territory along the TTZ, where, according to R. Dadlez (1994), Cambrian deposits were contacting with younger rocks by faults of the Caledonian origin.

By the end of the Hercynian tectogenetic stage, tectonic structures in the central part of the Baltic Syneclise and in Gargþdai Elevation Zone (Western Lithuania) were elevated, but good caps preserved fields from their dissolution. Solid asphaltenes found in arches of some structures suggest stages of the oil field formation. In Kaliningrad Region, local structures were in a more favourable situation, since oil migration into them could take place from west and north-west at that time.

By the end of the Alpinian tectogenetic stage, when the western part of Kaliningrad Region and Lithuania was significantly sunk, the focus of oil generation expanded, new oil portions replenished the



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existing oil fields and influenced formation of new ones. This fact, also suggested by water/oil palaeocontacts, was determined by L. Lashkova et al. (Лашкова и др., 1979; Laškova, 1994) in oil fields. Authors deduced that the intensive increase of structure amplitudes was related to the Middle Cambrian, Upper Permian – Lower Triassic. The amplitudes of the oil fields decreased, sometimes very sizeably, in the Middle Jurassic. The further growth of the structures is related to the Cretaceous.

Summing up the tectonic evolution of the territory, the occurrence of oil source rocks, the amount and degree of organic matter catagenesis, occurrence of reservoirs, and closeness of Earth's interior as well other available geological, geochemical and geophysical data, the prospective, less prospective and non-prospective zones for oil accumulation in Western Lithuania are distinguished (Figure). The *zone prospective for oil search* occupies the whole western part of Lithuania, from North-east bounded by the "vitrinite" isoline $R_o$ = 0.7% and from the southeast by the 1650 m isoline of the key reflecting horizon (Upper Ordovician – Lower Llandovery), approximately corresponding with the isoline of –1750 m of the Cambrian top. In the indicated territory, all discovered oil fields and 13 structures prepared for drilling (Viekðniai, Plënakiai, Ðventoji, Þygai, Juodeikiai (drilled one well in this structure gave negative results), Þlibinai, Svirpliai, Urðuliai, Maþuoliai, Þvaginiai, Rambynas and one without name) and quite a great number of structures revealed by seismic data are located. In this territory the Cambrian top occurs at a depth of –1750 – –2000 m. The maturity of oil source rocks (according to the "vitrinite" reflexion, $R_o$) is more than 0.7%. Here the porosity of rocks of the upper part of Deimena Group ranges from <3% in the Toliai–Laugaliai tract up to 14.9% in the Paluknë well. The average porosity of Deimena Group sandstones here is less than 7.0%. The coefficient of silicification ranges from 0 to 0.7. Water salinity is 140–150 g/l and more, the coefficient of sulphatization ($SO_4$/Cl × 100) ranges in the interval of 0.4–0.6, the coefficient of metamorphization (Na/Cl) being 0.1–1.4. In the territory of the wells Ramuèiai-1, 2 and 3 a zone non-prospective for oil search is distinguished. In fact it could be larger, but the drillcore from adjacent wells was not studied. In this zone, organic matter studied is characterized by a very high degree of catagenesis reaching $R_o$ = 1.5%. It corresponds to the postmaturity stage of catagenesis, *i.e.* the Earth's interior is burned out. To carry out oil exploration in this region, it is necessary to accomplish modelling and determine the limits beyond which it is possible to expect the discovery of oil fields.

Let us overview the possibility of discovering oil traps of non-anticlinal and combined type in the Middle Cambrian and the Salantai Formation, Lower Or-

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**Figure.** Prospective exploration of oil fields in the Cambrian deposits of Western Lithuania.

*1* – major tectonic faults; *2* – isohypses of the main reflection horizon of Upper Ordovician–Lower Landover top (according to the map of the Lithuanian area compiled by V. Markðaitienë, 1996 and the maps for the Kaliningrad district compiled by N. Lisovskaja et al., 1984); *3* – total water mineralisation of the Middle Cambrian, g/l; *4* – isolines of organic matter maturity of Cambrian oil source rocks (under "vitrinite"); *5* – isopores; *6* – isolines of the rate of quartz cementation of rocks; *7* – new petroliferous wells; *8* – oil fields. Local structures: *9* – developed for drilling; *10* – drilled; *11* – prospective structures. Area: *12* – prospective; *13* – less prospective.

Oil fields: 1. Girkaliai; 2. Genèiai; 3. Kretinga; 4. Nausodis; 5. Plungë; 6. Ablinga; 7. Vëþaièiai; 8. Ðiûpariai; 9. Pietø Ðiûpariai; 10. Degliai; 11. Pociai; 12. Vilkyèiai; 13. Sakuèiai; 14. Ðilalë; 15. Lauksargiai.

Oil fields discovered in the area of Kaliningrad district shown in the map: 16. Slavskaya; 17. Zapadno-Rakitinskoye; 18. Novo-Iskrinskoye; 19. Vostoèno-Gorinskoye; 20. Novo-Serebrianskoye.

List of local structures developed for drilling: 1. Viekðniai; 2. Plënakiai; 3. Ðventosios; 4. Þygai; 5. Juodeikiai; 6. Þlibinai; 7. Svirpliai; 8. Without name; 9. Urðuliai; 10. Þeruèiai; 11. Maþuoliai; 52. Þvaginiai; 80. Rambynas

**Pav.** Naftos telkiniø Vakarø Lietuvos vidurinio kambro uolienose prognozës þemëlapis.

*1* – pagrindiniai tektoniniai lûþiai; *2* – atraminio atspindinèio horizonto virðutinio ordoviko–apatinio landoverio kraigo (pagal 1996 m. V. Markðaitienës Lietuvos teritorijos þemëlapá ir N. Lisovskajos ir kt. 1984 bei vëlesniø metø Kaliningrado srities þemëlapius) izochipsës; *3* – vidurinio kambro sluoksnio vandens bendros mineralizacijos izolinijos g/l; *4* – kambro naftos motininiø uolienø organinës medþiagos katagenezës izolinijos (pagal „vitrinità"); *5* – izoporos; *6* – apkvarcëjimo koeficiento izolinijos; *7* – nauji naftà davæ græþiniai; *8* – naftos telkiniai; vietinës struktûros: *9* – paruoðtos græþimui; *10* – kuriose vykdyti græþimo darbai; *11* – numatomos struktûros; plotai: *12* – perspektyvûs; *13* – maþiau perspektyvûs.

*Naftos telkiniai*: 1. Girkaliai; 2. Genèiai; 3. Kretinga; 4. Nausodis; 5. Plungë; 6. Ablinga; 7. Vëþaièiai; 8. Ðiûpariai; 9. Pietø Ðiûpariai; 10. Degliai; 11. Pociai; 12. Vilkyèiai; 13. Sakuèiai; 14. Ðilalë; 15. Lauksargiai.

*Naftos telkiniai, surasti Kaliningrado srities teritorijoje*: 16. Slavskaja; 17. Zapadno Rakitinskoje; 18. Novo Iskrinskoje; 19. Vostoèno Gorinskoje; 20. Novo Serebrianskoje.

*Paruoðtø græþimui vietiniø struktûrø sàraðas:* 1. Viekðniai; 2. Plënakiai; 3. Ðventosios; 4. Þygai; 5. Juodeikiai; 6. Þlibinai; 7. Svirpliai; 8. Be vardo; 9. Urðuliai; 10. Þeruèiai; 11. Maþuoliai; 52. Þvaginiai; 80. Rambynas dovician oil-bearing complex in this zone. L. Lashkova (Zdanavièiûtë, Laðkova, 2003) has analysed data from more than 200 boreholes and deduced that the sedimentological-facial analysis of deposits from the Cambrian basin shows a paleogeographic environment unfavourable for the formation of non-anticlinal oil traps related with a regional thinning out of sandy and clayey beds, because claystone beds become more sandy to the east and northeast (towards the basin coast) and lose their caprock properties. Oil traps of lithological-structural type in the Cambrian rocks are related with anticlinal elevations, in which oil fields are partly covered by secondary silicification of the reservoir. Traps of this type are discovered in oil fields of Pociai, Girkaliai and Ðilalë areas. The Pociai, Girkaliai and Ðilalë oil fields of lithological-structural type are situated in the silicification zone of the Cambrian sandstone where the silicification coefficient is more than 0.5. They include 14% of oil search areas explored by drilling. Oil fields of such type are expected in the Baltic offshore, within the zone of intensive silicification.

Besides oil traps of lithological-structural type in the Cambrian rocks, oil traps of lithological-stratigraphic (ring) type can be forecasted. Their formation is related with thinning out of the Cambrian rocks in the elevation zones of Precambrian relict landscape. For this purpose, the thickness map of the Cambrian rocks occurring above the bottom of Ablinga Formation was compiled, applying techniques proposed by M. V. Pronicheva et al. (Проничева, Савинова, 1980). The map shows a buried landscape of the Cambrian surface before the Ordovician sediments settled. It is a monocline with inclination to the west and the south-west, complicated with elevations and depressions differing in height from a few up to 30 meters. In the northern part of the territory, the landscape is shaped in south-western and northern direction; in the southern part it is irregular. All local structures known at this moment and located in the landscape elevations are determined by seismic exploration and proved by drilling. Ring-shaped lithological-stratigraphic and structural-lithological-stratigraphic oil traps could be found near the so-called enveloping "naked" structures, in which the Ordovician carbonate succession covers rocks of relict landscape of the crystalline basement. In such cases, oil trap is determined by thinning out of reservoir rocks around the protrusion of the crystalline basement (Veivirþënai, Plungë, Baubliai area). From this point of view, some local structures determined by seismic exploration methods in the elevation zones of relict landscape could be prospective.

The *less prospective zone* envelopes the prospective one by a narrow bend. Its eastern boundary is approximately determined by the –1350 isoline of the key reflecting horizon (Upper Ordovician – Lower Llandovery). Organic matter of the source rocks has reached only the degree of "early oil" maturity in this territory, *i.e.* its oil production potential is very poor, though oil fields could be formed due to migration. The quality of the reservoirs is better because of a shallower setting of Cambrian rocks. In the southern part of this tract the upper part of Deimena Group rocks is denuded; in the northern part their porosity reaches more than 13% and in the lower part 9–17%. The mean porosity of Deimena Group sandstones is about 10% in this zone. Sandstone is not silicified. In this territory, parameters of water formation (water salinity, coefficients of sulphatization and metamorphization) show rather a good closeness of Earth's interior. The perspectives of this territory decrease because of remoteness of the territory from sources of oil generation and absence of "local hydrocarbon kitchens".

The earlier forecasted two more zones, Akmenë and Maþeikiai, prospective for oil accumulation and located northwards from Telðiai oil accumulation zone (Laškovas et al., 1996), in our opinion, are less prospective for oil exploration in the Cambrian rocks (only a small western part of the mentioned scarps could attract attention), because they are remote from sources of oil generation. We take into consideration a short distance of migration, which is evaluated also by modelling of migration processes, and data of detailed studies of oil composition. It is proved by the chemical composition of oil found in Latvia and in Plungë area. The oil is oxidized, *i.e.* hypergenetically changed. The territory of Telðiai Scarp located eastwards from Plungë area is less prospective, too.

The rest territory of Lithuania located eastwards from the less prospective one, as well the territory including Ramuèiai-1–3 wells, are attributed to the territory non-prospective for oil exploration.

It should be noted that some petroleum geologists of Lithuania consider the search for oil traps in narrow belts of rised ramparts located near fractures (tracks, 3–5 km wide) to be most efficient, because the chains of local structures or even near-fault homoclines, where tectonic screened oil fields may be found, rest against the fractures. Meanwhile, geologists of the Kaliningrad Region are of slightly different opinion that oil fields may be discovered also in local structures uncomplicated by fractures, but usually oil fields found in near-fault local structures are larger. They have proved it by discovery of oil fields southwards from Kaliningrad Rampart as well in the eastern territory adjacent to Lithuania.

We shall try to call attention to the other disputable problem, *i. e.* to availability of so-called "local kitchens of hydrocarbons". The conception that one of them exists in Salantai Trough is apparently misleading. The analysis of organic matter provided by geologists of the Institute of Geology and from

Latvia rejects any serious probability of such kitchens in the Baltic region. True, the organic matter from Cambrian rocks in Salantai Trough is attributed to the degree of early maturity of oil, but its amount is not sufficient for formation of some large oil fields. Besides, the main portion of generated hydrocarbons migrated north-eastwards in a direction of the pressure decrease.

Differently from the previous report of such type (Laškovas et al., 1966), in this work the south-western part of Lithuania is attributed to prospective areas for oil exploration, though in the thinning out zone of Permian anhydrites, structures are found with difficulty, on analogy with the distribution of structures and oil fields in it in Kaliningrad Region it is possible to assert that in the territory of Lithuania they exist too. The complicated geological structure of the territory, for example, the distribution of Permian anhydrites, causes very much trouble, but the modern possibilities of seismic interpretation data may overcome this barrier too.

Over the recent years, the volume of works on oil search decreased very much. To preserve the rate of oil production, it is necessary to intensify search for oil in the south-western part of Lithuania and to start oil search in the Baltic Sea. The exploration degree of the territory is sufficiently high to start new works in the prospective territory; only a skilled evaluation of available geological-geochemical and geophysical information and supplementary seismic works of little volume could be necessary. In the Baltic Sea, the amplitudes of fractures increase, thus the amplitudes and size of near-fault structures increase too. Common geological regularities connect the land and sea territories, so the maximum efficiency of oil search in the sea could be reached already in the first stage of structure drilling.

The primary geological reserves of crude oil within the Cambrian rocks account for approx. 59.8 million t, the average resource density being 4.37 thous. $t/km^2$. Assuming the recovery coefficient as 0.35, recoverable crude oil reserves are approx. 20.9 million t, and gases 0.75 billion $m^3$ (Vosylius, 2004).

The recoverable oil reserves explored and estimated till present aggregate only approx. 8 million t of oil, allowing temporarily increase oil production only up to 400–500 thous. t per year. The amount of about 4 million t of oil is already worked out. Maximum work efficiency in the development of oil resources in the regions with small resources of oil is reached as a rule when the amount of explored reserves is up to 10–20% (Medelevskis ir kt., 1977). The amount of explored and estimated Cambrian oil reserves already reached approx. 30% in the Lithuanian onshore. Therefore oil search efficiency will decrease in the onshore, since it has reached the maximum of main discoveries in Gargþdai and Telšiai scarps. Discovery chances of larger oil fields with more than 1.5 million t of recoverable reserves of oil decrease in the onshore.

## CONCLUSIONS

The available geological, geochemical, geophysical material and modelling data allow some conclusions.

1. In Western Lithuania, oil source rocks occurring at a depth of –1750 m and more are within the main oil generation zone. The Cambrian oil source rocks generated 987.94 million t of hydrocarbons in the Lithuanian onshore and offshore. Assuming the accumulation coefficient to be 0.05, the primary geological reserves of hydrocarbons in the Cambrian rocks aggregate 49.4 million t. In the Lithuanian onshore and offshore, 1.7 billion t of hydrocarbons emigrated from Ordovician oil source rocks and 5.8 billion t from the Silurian; however, due to a specific lithology of the geological section, only very small amount of them could accumulate in the traps.

2. The formation stages of oil fields for different geological time have been restored according to modelling data of hydrocarbon migration and accumulation. In the Baltic Syneclise, the beginning of oil generation is related to the late Silurian, while the main phase of oil generation is ascribed to the Devonian and Permian time. Slow sedimentation in the whole Baltic Syneclise, ambiguous earth motions conditioned the slow formation of oil fields and in some cases dissolution of earlier formed oil fields. Oil fields during their existence were replenished with new oil portions. Therefore, traps in the Cambrian rocks could accumulate oil generated not only by Cambrian, but also by Ordovician and Silurian source rocks. The survival of oil fields was provided by a favourable hydrogeological regime, and the good cap was ensured by closeness of Earth's interior in the region.

3. Oil traps of not only anticlinal, but also nonstructural type have been discovered and can be discovered in future in the Cambrian oil-bearing complex. All local structures without Cambrian rocks on their top or with reduced thickness (Ðiûpariai, Veivirþënai, Ðilalë, Lauksargiai, Pociai, Pajûris, Baubliai, Plungë, Mamiai local structures) are related with protrusions located on crests of the crystalline basement, traced also in the Middle Cambrian paleolandscape. The oil traps of non-anticlinal type can be related with structures of this type. Oil traps of non-anticlinal or combined type are also expected within the zone of intensive silicification of Cambrian sandstone. Their formation was influenced by reservoirs of a pore type, preserved in tops of oil-bearing structures (Ðilalë, Pociai oil fields).

4. The source rocks of Western Lithuania with the content of organic matter of one or more percent and buried deeper than 1500–1600 m, and in which the degree of catagenesis according to the index of

"vitrinite" reflection reaches more than 0.7%, generated oil. The territory is prospective for oil exploration. Here the porosity of rocks of the upper part of Deimena Formation ranges from <3% to 7%, the coefficient of silicification varying from 0 to 0.7. Water salinity, the coefficient of sulphatization ($SO_4/Cl \times 100$) as well the coefficient of metamorphization (Na/Cl) indicate a good closeness of Earth's interior. The less prospective zone envelopes the prospective one by a narrow bend. Its eastern boundary is approximately determined by the isoline of –1350 m of the key reflecting horizon (Upper Ordovician – Lower Llandovery). Organic matter in the source rocks has reached only the degree of "early oil" maturity in this territory, *i.e.* its oil production potential is very poor.

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**Onytë Zdanavièiûtë**

**NAFTOS TELKINIØ PAIEÐKØ PERSPEKTYVOS VIDURINIO KAMBRO SMILTAINIUOSE VAKARØ LIETUVOJE**

S a n t r a u k a

Kambro naftos motininës uolienos Lietuvos sausumoje ir akvatorijoje generavo 987,94 mln. t angliavandeniliø. Pasirinkus 0,05 akumuliacijos koeficientà, pradiniai prognoziniai angliavandeniliø iðtekliai kambro uolienose sudaro 49,4 mln. t. Pagal angliavandeniliø generacijos, migracijos ir akumuliacijos procesø modeliavimo duomenis atkurtas telkiniø formavimosi etapiðkumas ávairiais geologiniais laikotarpiais. Naftos generacijos pradþia Baltijos sineklizëje siejama su silûro pabaiga, tuo tarpu pagrindinë naftos generacijos fazë – su devono ir permo laikotarpiais. Nedidelis nuosëdø atsiklojimo greitis, nevienareikðmiai þemës plutos judesiai sudarë sàlygas lëtam naftos telkiniø formavimuisi, o kartais ir jø ardymui. Naftos telkiniai per savo egzistencijà pasipildydavo vis naujomis naftos porcijomis, todël kambro uolienose esanèios kaupavietës galëjo akumuliuoti naftà, generuotà ne tik kambro, bet ir ordoviko bei silûro motininiø uolienø. Telkiniø išlikimà lëmë palankus regiono hidrogeologinis reþimas ir geros kokybës dangos, uþtikrinusios gelmiø uþdarumà.

Kambro naftingame komplekse yra aptiktos ir ateityje gali bûti surastos ne tik antiklininës, bet ir nestruktûrinio tipo naftos kaupavietës. Visos vietinës struktûros, kuriø kraige nëra kambro uolienø arba jø storiai redukuoti (Ðiûpariø, Veivirþënø, Ðilalës, Lauksargiø, Pociø, Pajûrio, Baubliø, Plungës, Mamiø struktûros), susijusios su kyðuliais, iðsidëstèiusiais ant kristalinio pamato keterø, randamø ir vidurinio kambro paleoreljefe. Su tokio tipo struktûromis gali bûti susijusios neantiklininio tipo naftos kaupavietës. Kambro smil-

tainiø intensyvaus apkvarcëjimo zonoje taip pat galimos neantiklininio arba miðraus tipo naftos kaupavietës, kuriø susidarymui átakos turëjo naftingø struktûrø kraige iðlikæ (uþsikonservavæ) porinio tipo kolektoriai (Ðilalës, Pociø naftos telkiniai).

Ávertinus teritorijos tektoninæ raidà, motininiø uolienø paplitimà, organinës medþiagos kieká ir katagenezës laipsná, kolektoriø paplitimà, gelmiø uþdarumà bei kitus turimus geologinius, geocheminius ir geofizinius duomenis, Vakarø Lietuvoje iðskirta perspektyvi, maþiau perspektyvi ir neperspektyvi zona naftai susikaupti. Naftos paieškoms perspektyvi zona apima visà vakarinæ Lietuvos dalá; ið ðiaurës rytø ji apribojama Ro = 0,7% „vitrinito“ izolinija, ið pietryèiø pravedama pagal atraminio atspindinèio horizonto (virðutinis ordovikas–apatinis landoveris) –1650 m izochipsæ, maþdaug atitinkanèià kambro kraigo –1750 m izohipsæ. Nurodytoje teritorijoje yra visi ðiuo metu atrasti naftos telkiniai bei 13 græþimui paruoðtø struktûrø (Viekðniø, Plënakiø, Ðventosios, Þygø, Juodeikiø (ðioje struktûroje yra pragræþtas vienas græþinys, kurio rezultatai neigiami), Ðlibinø, Svirpliø, Urðuliø, Þeruèiø, Maþuoliø, Þvaginiø, Rambyno, viena be vardo), taip pat pakankamai daug struktûrø su iðryðkintais seisminiais duomenimis. Naftos motininiø uolienø katagenezës laipsnis (pagal „vitrinito“ atspindþio rodiklá – Ro) yra didesnis nei 0,7%. Deimenos serijos virðutinës dalies uolienø poringumas èia kinta nuo <3% Toliø–Laugaliø ruoþe iki 14,5% Paluknës græþinyje. Vidutinis Deimenos serijos smiltainiø poringumas maþesnis nei 7%. Apkvarcëjimo koeficientas kinta nuo 0 iki 0,7. Vandens mineralizacija yra 140–150 g/l ir daugiau, sulfatizacijos koeficientas ($SO_4$/Cl × 100) kinta 0,4–0,6 ribose, metamorfizacijos koeficientas (Na/Cl) – 0,1–1,4. Ramuèiø-1, 2, 3 græþiniø teritorijoje yra iðskirta naftos paieðkoms neperspektyvi zona, kuri praktiðkai gali bûti ir didesnë, bet aplinkiniø græþiniø kernas nebuvo tirtas. Minëtoje zonoje tirta organinë medþiaga turi labai aukðtà katagenezës laipsná, siekiantá Ro = 1,5%, ir tai atitinka organinës medþiagos aukðèiausià katagenezës stadijà, t. y. gelmës yra iðdegintos. Norint ðiame rajone vykdyti naftos paieðkas, bûtina atlikti modeliavimà ir nustatyti ribas, uþ kuriø galima tikëtis naftos telkiniø.

Maþiau perspektyvi zona siauru lanku apgaubia jau aptaðytà perspektyviàjà. Jos rytinë riba pravedama apytikriai pagal atraminio atspindinèio horizonto –1350 m izohipsæ. Motininiø uolienø organinë medþiaga ðioje teritorijoje yra pasiekusi tik „ankstyvosios naftos“ subrendimo laipsná, t. y. jos galimybë produkuoti naftà yra labai maþa, nors telkiniai dël migracijos ir gali bûti susiformavæ. Kolektoriø kokybë dël seklesniø kambro uolienø slûgsojimo sàlygø yra geresnë. Deimenos serijos virðutinës dalies uolienos ðios juostos pietinëje dalyje yra denuduotos, ðiaurinëje dalyje jø poringumas virðija 13%, o apatinëje dalyje siekia 9–17%. Deimenos serijos smiltainiø poringumo vidurkis ðioje zonoje – apie 10%. Smiltainis neapkvarcëjæs. Sluoksnio vandens parametrai (mineralizacija, sulfatizacijos ir metamorfizacijos koeficientai) rodo pakankamai uþdaras gelmes. Ðios teritorijos perspektyvas maþina jos nutolimas nuo naftos generacijos þidiniø ir „vietiniø angliavandeniliø virtuviø“ nebuvimas.

Neperspektyviai naftos paieðkoms vidurinio kambro uolienø zonai priskiriama visa likusi Lietuvos teritorija, iðsidësèiusi á rytus nuo minëtos maþiau perspektyvios teritorijos, taip pat teritorija, apimanti Ramuèiø-1–3 græþinius.

Iki ðiol iðþvalgyti ir ávertinti iðgaunami naftos iðtekliai (tik apie 8 mln. t) leidþia laikinai padidinti naftos gavybà tik iki 400–500 tûkst. t per metus. Jau iðeksploatuota apie 4 mln. t naftos. Maksimalus darbø efektyvumas ásisavinant naftà nedideliø iðtekliø rajonuose paprastai pasiekiamas, kai iðþvalgyti iðtekliai sudaro 10–20%. Paieðkø efektyvumas sausumoje maþës, kadangi jau yra pasiektas pagrindiniø atradimø maksimumas Gargþdø ir Telðiø pakopose. Maþëja stambesniø telkiniø, talpinanèiø daugiau nei 1,5 mln. t iðgaunamos naftos, tikimybë.

**Îíèòå Çäàíàâè÷þòå**

## ÏÅÐÑÏÅÊÒÈÂÛ ÏÎÈÑÊÎÂ ÍÅÔÒßÍÛÕ ÌÅÑÒÎÐÎÆÄÅÍÈÉ Â ÏÅÑ×ÀÍÈÊÀÕ ÑÐÅÄÍÅÃÎ ÊÅÌÁÐÈß ÇÀÏÀÄÍÎÉ ËÈÒÂÛ

Ðåçþìå

Íåôòåìàòåðèíñêèå ïîðîäû êåìáðèÿ ñóøè è àêâàòîðèè Ëèòâû ãåíåðèðîâàëè îêîëî 987,94 ìëí. ò óãëåâîäîðîäîâ. Ïðè êîýôôèöèåíòå àêêóìóëÿöèè, ðàâíîì 0,05, ïåðâè÷íûå ïðîãíîçíûå çàïàñû óãëåâîäîðîäîâ â îòëîæåíèÿõ êåìáðèÿ ñîñòàâëÿþò 49,4 ìëí. ò. Ðåçóëüòàòû ìîäåëèðîâàíèÿ ïðîöåññîâ ãåíåðàöèè, àêêóìóëÿöèè è ìèãðàöèè óãëåâîäîðîäîâ ïîçâîëèëè âîññîçäàòü ýòàïíîñòü ôîðìèðîâàíèÿ ìåñòîðîæäåíèé â ðàçëè÷íûå ãåîëîãè÷åñêèå ïðîìåæóòêè âðåìåíè. Íà÷àëî ïðîöåññà ãåíåðàöèè íåôòè â Áàëòèéñêîé ñèíåêëèçå ñîîòíîñèòñÿ ñ êîíöîì ñèëóðà, â òî âðåìÿ êàê îñíîâíaÿ ôàça ãåíåðàöèè – ñ äåâîíñêèì è ïåðìñêèì âðåìåíåì. Íåáîëüøàÿ ñêîðîñòü îñàäêîíàêîïëåíèÿ, íåîäíîçíà÷íûå äâèæåíèÿ çåìíîé êîðû ñîçäàëè óñëîâèÿ äëÿ ìåäëåííîãî ôîðìèðîâàíèÿ íåôòÿíûõ ìåñòîðîæäåíèé, à èíîãäà è îáóñëîâèëè èõ ðàçðóøåíèå. Íåôòÿíûå ìåñòîðîæäåíèÿ çà âðåìÿ ñóùåñòâîâàíèÿ ïîïîëíÿëèñü íîâûìè ïîðöèÿìè íåôòè, ïîýòîìó ëîâóøêè â êåìáðèéñêèõ îòëîæåíèÿõ ìîãëè àêêóìóëèðîâàòü íåôòü, ãåíåðèðîâàííóþ íå òîëüêî êåìáðèéñêèìè, íî è îðäîâèêñêèìè è ñèëóðèéñêèìè ìàòåðèíñêèìè ïîðîäaìè. Ñîõðàíåíèþ ñóùåñòâóþùèõ ìåñòîðîæäåíèé ñïîñîáñòâîâàëè áëàãîïðèÿòíûé ãèäðîãåîëîãè÷åñêèé ðåæèì ðåãèîíà è õîðîøèå êà÷åñòâà ïåðåêðûâàþùåé òîëùè, ÷òî ãàðàíòèðîâàëî çàêðûòîñòü íåäð.

Â êåìáðèéñêîì íåôòÿíîì êîìïëåêñå âûÿâëåíû è â äàëüíåéøåì ìîãóò áûòü íàéäåíû ëîâóøêè íåôòè íå òîëüêî àíòèêëèíàëüíîãî, íî è íåñòðóêòóðíîãî òèïà. Âñå ëîêàëüíûå ñòðóêòóðû, â ñâîäîâîé ÷àñòè êîòîðûõ íåò êåìáðèéñêèõ îòëîæåíèé èëè æå ìîùíîñòè ïîñëåäíèõ ðåäóöèðîâàíû (Øþïàðÿéñêàÿ, Âåéâèðæåíñêàÿ, Øèëàëüñêàÿ, Ëàóêñàðãÿéñêàÿ, Ïîöÿéñêàÿ,

Ïàþðñêàÿ, Áàóáëÿéñêàÿ, Ïëóíãåñêàÿ, Ìàìÿéñêàÿ ñòðóêòóðû), ñâÿçàíû ñ âûñòóïàìè, ðàñïîëîæåííûìè íà ãðåáíÿõ êðèñòàëëè÷åñêîãî ôóíäàìåíòà, è ïðîñëåæèâàþòñÿ â ïàëåîðåëüåôå ñðåäíåãî êåìáðèÿ. Ñî ñòðóêòóðàìè òàêîãî òèïà ìîãóò áûòü ñâÿçàíû ëîâóøêè íåôòè íåàíòèêëèíàëüíîãî òèïà. Â çîíå èíòåíñèâíîãî îêâàðöåâàíèÿ êåìáðèéñêèõ ïåñ÷àíèêîâ òàêæå âîçìîæíû ëîâóøêè íåàíòèêëèíàëüíîãî èëè ñìåøàííîãî òèïà, íà ñîçäàíèå êîòîðûõ âëèÿëè ñîõðàíèâøèåñÿ (çàêîíñåðâèðîâàííûå) â êðîâëå íåôòÿíûõ òðóêòóð êîëëåêòîðû ïîðîâîãî òèïà (Øèëàëüñêîå è Ïîöÿéñêîå íåôòÿíûå ìåñòîðîæäåíèÿ).

Ñ ó÷åòîì òåêòîíè÷åñêîãî ðàçâèòèÿ òåððèòîðèè, ðàñïðîñòðàíåíèÿ ìàòåðèíñêèõ ïîðîä, êîëè÷åñòâà îðãàíè÷åñêîãî âåùåñòâà è ñòåïåíè êàòàãåíåçà, ðàñïðîñòðàíåíèÿ êîëëåêòîðîâ, çàêðûòîñòè íåäð, à òàêæå íà îñíîâàíèè äðóãèõ ðåçóëüòàòîâ ãåîëîãè÷åñêèõ, ãåîõèìè÷åñêèõ è ãåîôèçè÷åñêèõ èññëåäîâàíèé â Çàïàäíîé Ëèòâå âûäåëåíû ïåðñïåêòèâíàÿ, ìàëîïåðñïåêòèâíàÿ è íåïåðñïåêòèâíàÿ çîíû íåôòåíàêîïëåíèÿ.

Ïåðñïåêòèâíàÿ çîíà îõâàòûâàåò âñþ çàïàäíóþ ÷àñòü Ëèòâû: ñ ñåâåðî-âîñòîêà îíà îãðàíè÷åíà èçîëèíèåé „âèòðèíèòà“ Ro = 0,7%, íà þãî-âîñòîêå èçîãèïñîé –1650 ì îïîðíîãî îòðàæàþùåãî ãîðèçîíòà, ïðèáëèçèòåëüíî ñîîòâåòñòâóþùåé èçîãèïñå êðîâëè êåìáðèÿ –1750 ì. Íà äàííîé òåððèòîðèè íàõîäÿòñÿ âñå ê íàñòîÿùåìó âðåìåíè íàéäåííûå ìåñòîðîæäåíèÿ è 13 ïîäãîòîâëåííûõ ê áóðåíèþ ñòðóêòóð (Âåêøíÿéñêàÿ, Ïëåíàêñêàÿ, Øâÿíòàéñêàÿ, Æèãÿéñêàÿ, Þäåéêñêàÿ – (îäíà ïðîáóðåííàÿ â ýòîé ñòðóêòóðå ñêâàæèíà äàëà îòðèöàòåëüíûå ðåçóëüòàòû – Æëèáèíñêàÿ, Ñâèðïëÿéñêàÿ, Óðøóëüñêàÿ, Æÿðó÷ÿéñêàÿ, Ìàæóëÿéñêàÿ, Æâàãèíÿéñêàÿ, Ðàìáèíñêàÿ è îäíà áåç íàçâàíèÿ), à òàêæå äîâîëüíî ìíîãî ñòðóêòóð, âûÿâëåííûõ ïî ñåéñìè÷åñêèì äàííûì. Êðîâëÿ êåìáðèéñêèõ îòëîæåíèé íà ýòîé ïëîùàäè çàëåãàåò íà ãëóáèíå –1750 – –2000 ì. Ñòåïåíü êàòàãåíåçà íåôòåìàòåðèíñêèõ ïîðîä (ïî ïîêàçàòåëþ îòðàæåíèÿ *âèòðèíèòà* Rî) ïðåâûøàåò 0,7%. Ïîðèñòîñòü îòëîæåíèé âåðõíåé ÷àñòè äåéìåíàñêîé ñåðèè èçìåíÿåòñÿ îò <3% íà Òîëÿéñêî-Ëàóãàëÿéñêîì ó÷àñòêå äî 14,5% â Ïàëóêíÿéñêîé ñêâàæèíå. Ñðåäíÿÿ ïîðèñòîñòü ïåñ÷àíèêîâ äåéìåíàñêîé ñåðèè çäåñü íèæå 7%. Êîýôôèöèåíò îêâàðöåâàíèÿ èçìåíÿåòñÿ îò 0 äî 0,7. Ìèíåðàëèçàöèÿ âîäû ñîñòàâëÿåò 140–150 ã/ë è áîëåå, êîýôôèöèåíò ñóëüôàòèçàöèè ($SO_4$/Cl x 100) èçìåíÿåòñÿ â ïðåäåëàõ 0,4–0,6, êîýôôèöèåíò ìåòàìîðôèçàöèè (Na/Cl) – 0,1–1,4.

Íà òåððèòîðèè ñêâàæèí Ðàìó÷ÿé-1, 2 è 3 âûäåëåíà íåïåðñïåêòèâíàÿ äëÿ ïîèñêîâ íåôòè çîíà, êîòîðàÿ, âîçìîæíî, çàíèìàåò è áóëüøóþ ïëîùàäü, íî êåðí ðàñïîëîæåííûõ âáëèçè ñêâàæèí íå áûë èçó÷åí. Ñòåïåíü êàòàãåíåçà îðãàíè÷åñêîãî âåùåñòâà çäåñü î÷åíü âûñîêàÿ, Ro äîñòèãàåò 1,5%, ÷òî ñâèäåòåëüñòâóåò î âûãîðàíèè íåäð. Äëÿ ïîèñêîâ íåôòè â ýòîì ðàéîíå íåîáõîäèìî îñóùåñòâèòü ìîäåëèðîâàíèå è óñòàíîâèòü ãðàíèöû íåïåðñïåêòèâíîé çîíû, çà ïðåäåëàìè êîòîðûõ âîçìîæíû ïëîùàäè, ïåðñïåêòèâíûå äëÿ ïîèñêîâ çàëåæåé íåôòè.

Ìàëîïåðñïåêòèâíàÿ çîíà óçêîé äóãîé îãèáàåò âûøåîïèñàííóþ ïåðñïåêòèâíóþ çîíó. Íà âîñòîêå åå ãðàíèöà ïðîâîäèòñÿ ïî èçîãèïñå îïîðíîãî îòðà-æàþùåãî ãîðèçîíòà (âåðõíèé îðäîâèê–íèæíèé ëàíäîâåð) –1350 ì. Îðãàíè÷åñêîå âåùåñòâî ìàòåðèíñêèõ ïîðîä íà ýòîé òåððèòîðèè ñîîòâåòñòâóåò òîëüêî ñòåïåíè ñîçðåâàíèÿ «ðàííåé íåôòè», ò. å. âåðîÿòíîñòü ïðîäóöèðîâàíèÿ íåôòè î÷åíü ìàëà, õîòÿ âîçìîæíî ôîðìèðîâàíèå çàëåæåé çà ñ÷åò ïðîöåññîâ ìèãðàöèè. Âñëåäñòâèå áîëåå ìåëêîãî çàëåãàíèÿ êåìáðèéñêèõ îòëîæåíèé êà÷åñòâî êîëëåêòîðîâ çäåñü ëó÷øå. Â þæíîé ÷àñòè ýòîé ïîëîñû ïîðîäû âåðõíåé ÷àñòè Äåéìåíàñêîé ñåðèè äåíóäèðîâàíû, â ñåâåðíîé ÷àñòè èõ ïîðèñòîñòü âûøå 13%, à ïîðèñòîñòü æå ïîðîä íèæíåé ÷àñòè ñåðèè – îò 9 äî 17%. Ñðåäíåå çíà÷åíèå ïîðèñòîñòè ïåñ÷àíèêîâ Äåéìåíàñêîé ñåðèè â ýòîé çîíå îêîëî 10%. Ïåñ÷àíèê – íåîêâàðöîâàííûé. Ïàðàìåòðû ïëàñòîâîé âîäû ýòîé òåððèòîðèè (ìèíåðàëèçàöèÿ, êîýôôèöèåíòû ñóëüôàòèçàöèè è ìåòàìîðôèçàöèè) óêàçûâàþò íà îòíîñèòåëüíî õîðîøóþ çàêðûòîñòü íåäð. Ïåðñïåêòèâíîñòü çîíû ìàëà èç-çà óäàëåííîñòè îò î÷àãîâ íåôòåãåíåðàöèè è îòñóòñòâèÿ „ìåñòíîé êóõíè óãëåâîäîðîäîâ“.

Ê íåïåðñïåêòèâíîé äëÿ ïîèñêîâ íåôòè çîíå â îòëîæåíèÿõ ñðåäíåãî êåìáðèÿ îòíåñåíà âñÿ îñòàëüíàÿ ÷àñòü òåððèòîðèè Ëèòâû, ðàñïîëîæåííàÿ ê âîñòîêó îò ìàëîïåðñïåêòèâíîé çîíû, à òàêæå âûøåíàçâàííàÿ òåððèòîðèÿ, îõâàòûâàþùàÿ ðàéîí ñêâàæèí Ðàìó÷ÿé 1–3.

Íà ñåãîäíÿ ðàçâåäàíû è îöåíåíû ëèøü îêîëî 8 ìëí. ò çàïàñîâ èçâëåêàåìîé íåôòè, ÷òî ïîçâîëÿåò òîëüêî âðåìåííî óâåëè÷èòü äîáû÷ó íåôòè äî 400–500 òûñ. ò â ãîä. Èç íåäð çåìëè óæå äîáûòî îêîëî 4 ìëí. ò íåôòè. Ìàêñèìàëüíàÿ ýôôåêòèâíîñòü ðàáîò â îñâîåííûõ ðàéîíàõ íåôòÿíûõ ìåñòîðîæäåíèé ñ íåáîëüøèìè çàïàñàìè íåôòè îáû÷íî äîñòèãàåòñÿ ïðè ðàçâåäàííûõ 10–20% çàïàñîâ. Ïîýòîìó ýôôåêòèâíîñòü ïîèñêîâûõ ðàáîò íà ñóøå ïîíèçèòñÿ, ïîñêîëüêó óæå äîñòèãíóò ìàêñèìóì îñíîâíûõ îòêðûòèé â çîíå Òåëüøÿéñêîé è Ãàðãæäàéñêîé ñòóïåíåé. Òàêæå ìàëà âåðîÿòíîñòü âûÿâëåíèÿ íà ñóøå êðóïíûõ çàëåæåé, âìåùàþùèõ áîëåå 1,5 ìëí. ò äîáûâàåìîé íåôòè.