OIL POTENTIAL PROSPECTIVITY OF THE ORDOVICIAN CARBONATE COMPLEX IN LITHUANIA

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LITHOLOGY, THICKNESS, BEDDING

The Ordovician oil-bearing complex onshore and offshore Lithuania is composed from terrigenous - carbonate formation (Лашков, 1987) that is associated with the Caledonian maximum transgression stage. The formation is composed from heterogenetic shallow marine deposits such as limestone, marl, argillite, domerite and dolomite that were forming on a Eastern European platform's margin. Formation thickness ranges from 50-60 m in Middle Lithuania up to 200 m in North-West Lithuania (Fig. 1). Within Lithuanian waters it is 75 m in the southern part and 130 m in the northern part. Lithological composition's and deposits thickness' changes are related to the basin bottom differenciation that, furthermore, is a result of various tectonic movements and eustatic changes. The most complete stratigraphicaly and more shaly successions are determined in the Jelgava (Мянниль,1963) and Middle Lithuania (Пашкевичюс, 1958) depressions while in the Lower Nemunas (Лапинскас,-1967) rise as well as on slopes of these depressions the successions are less complete and more carbonaceous. Within the present tectonic structure the oil-bearing Ordovician complex's top on the Baltic syneclise's eastern slope occur at depth of -500 – -700 m, on the syneclise's marginal First and Second steps - at -800 – -1500 m, on the sineclise's foreslope - at -1500 – -1800 m, in the Kuršiai depression's onshore part - down to -1 800 m and in its offshore part - up to -2300 m. The top Ordovician occur at -1400 – -2000 m depth on the Liepoja-Saldus ridge zone*.

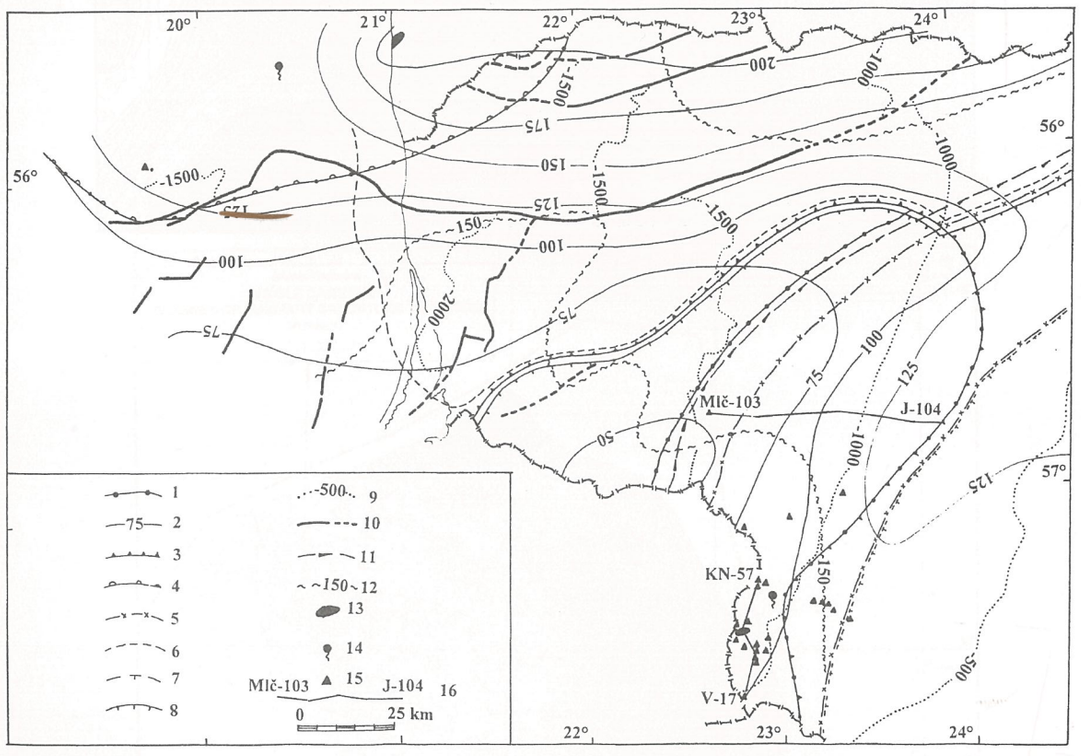

Fig. 1. Map of the petroleum potential criteria's of the Ordovician carbonate complex: 1 – a limit of the oil and dissloved gas reserves' calculation region in the Upper Ordovician Porkuni horizon; 2 – the izopachs of the oil bearing complex (m); 3 – limits of both the Lower Nemunas rise and to this structure related stratigraphic hiatus of Upper Ordovician; 4 – contours of Porkuni horizon's bars and shoals on the north-western slope of the Jelgava depression; 5 – spread limits of the Upper Ordovician Nabala and Pirgu horizons' organogenic-detrital limestone facies and Pirgu horizon's bioherms; 6 – the western and south-eastern limits of the Upper Ordovician Pirgu horizon's aphanitic limestone occurrence; 7 – the western limit of the spread of the Upper Ordovician Pirgu horizon's detrital-micritic and particularly fine crystalline limestone facies with possible bioherms; 8 – the western limit of the spread of the Middle Ordovician Uhaku-Kukruze horizons' organogenic-detrital limestone facies; 9 – depth contour lines (m) of the oil bearing complex's top; 10 – key faults; 11 – the eastern contour of the organic (C_{org}) rich Mossen and Fjacka argillites' occurrence; 12 – the izopachs of the Lower Silurian seal; 13 – an oil field; 14 – oil flow in a well; 15 – oil shows on core; 16 – lines of the geological and facial-palaeographic crossections.

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RESERVOIRS, POTENTIAL RESERVOIRS AND OIL OCCURENCES

In Ordovician the heterogenetic carbonate sequences in the Porkuni, Pirgu, Nabala and Uhaku-Kukruze horizons serve as reservoirs and potential reservoirs (Fig. 2, 3).

Foreshore facies of shallow marine shelf appear to be reservoirs and potential reservoirs of the Porkuni horizon. The facies comprise limestone's conglomerates, gravelites, sandstones, siltstones and oolitic limestones. Open porosity of the rocks ranges from 1.2 to 20.7 % while gas permeability reaches 36.3 mD. A porous space in the reservoirs are related to primary cement – free room between grains, porous remnants of Bryozoa and Crinoidea fauna or secondary dissolution cavities. Beside the pores, there are also caverns up to 2.5 mm in diameter. The best reservoir properties were observed on the SE slope of the Lower Nemunas rise and on the ESE slope of the Jelgava depression offshore. The obtained oil flow rate was up to 0.312 m^3/d in the Kybartai area. In the rest areas the oil shows were found on core.

Potential reservoir rocks within the Pirgu horizon are organogenic-detrital, micritic-detrital, micritic and particularly fine grained limestone that was deposited in shoreface and offshore -– transition environments as well as aphanitic limestone of offshore environment. Open porosity of the aphanitic limestone ranges from 0.5 to 10.5% with predominating values of 2–3.5%. Gas permeability is less than 0.1 mD and it increases up to 3.9 mD in separate samples. It increases significantly due to fractures. The average fractures density is 60.1 1/m** (well Toliai-2). The average fractures permeability is 1.2 mD, localy up to 17.9 mD (wells in the Plungė area). Thickness of the aphanitic limestone is up to 17–21 m. Organogenic-detrital and micritic-detrital limestone occurs on the collission zone between the Lower Nemunas rise and the Middle Lithuania depression. Open porosity of the limestone ranges from 3.0 to 10.5%, gas permeability is less than 0.1 mD with an exception of the value of 10.32 mD (well K. Naumiestis-57). Pore space there is primary or associated with dissolution processes and spaces within organic remnants. Density of fractures

* Tectonic regioning by K.Sakalauskas, 1996;
** Fractures parameters by G.Vosylius, 1996.

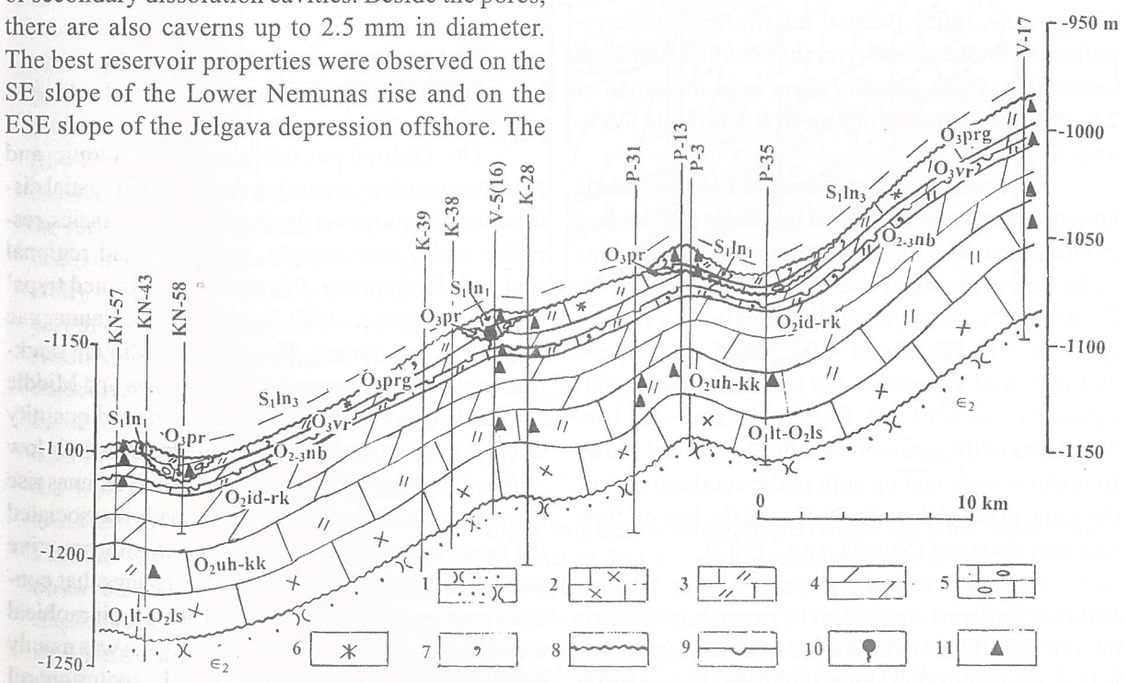

Fig. 2. Geological crossection through the wells Vištytis-17 and K. Naumiestis-57: 1 – quartz sandstone, siltstone, argillite; 2 – red, gray, greenish gray limestone, dolomite, marl, argillite; 3 – organogenic-detrital, micritic-detrital limestone and marl; 4 – marl, argillite, micritic limestone; 5 – debris' limestone; 6 – iron oxides and hydrooxides; 7 – glauconite; 8 – stratigraphic break (hiatus); 9 – short term break in sedimentation; 10 – oil flow; 11 – oil show on core.

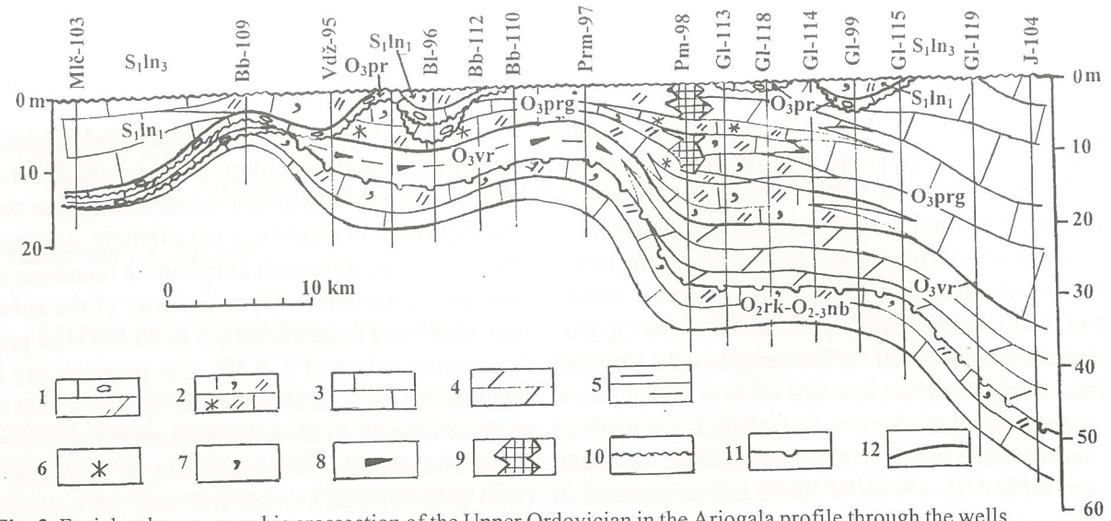

Fig. 3. Facial-palaeogeographic crossection of the Upper Ordovician in the Ariogala profile through the wells Jakšiai-104 and Milaičiai-103: 1 – shallow shelfs foreshore facies – debris limestone, marl; 2 – shallow shelf's shoreface facies – organogenic-detrital, micritic-detrital limestone, marl; 3 – shallow shelf's offshore-transition facies – detrital-micritic, particularly fine crystalline, sometimes detrital limestone, algaes' bioherms; 4 – shallow shelf's offshore facies (aerobic condition) – marl, micritic limestone; 5 – deep shelf offshore facies (anaerobic conditions) – black argillite abundant in C_{org}; 6 – iron oxides and hydrooxides; 7 – glauconite; 8 – increase in C_{org}; 9 – bioherm; 10 – stratigraphic break (hiatus); 11 – short term break in sedimentation; 12 – a limit of the horizons.

is just 7.6 1/m, permeability does not excee values of 0.1 mD. Thicknes of the carbonate complex is from 8 to 13 m. Among the organogenic limestone in the Pamituvys-98 well, a 4.4 m thick bioherm of algaes, corrals and stromatopores were observed. There are caverns up to several cm in diameter that are a result of the corrals and pores dissolution. Algaes' limestone was observed in well Kalvarija-3 (Лапинскас, 1966). Detrital-micritic and fine-crystalline limestone spread over the Middle Lithuanian depression. Open porosity there is in the range of 2.8–7.8, gas permeability up to 0.1 mD, its thickness 8–20 m.

Reservoir and potential reservoir in the Nabala horizon is organogenic-detrital limestone of shoreface environment. The limestone occurs on the SE slope of the Lower Nemunas rise. Its open porosity is from 2.8 to 14.9%; gas permeability usualy does not exceed 0.1 mD, sometimes – 0.13–0.25 mD, once – 20.6 mD (well Vilkaviškis-127).Fractures' permeability there is just 0.13 mD, fracture density – 4.5 1/m. Thickness of the reservoir is about 3–4 m. Oil shows frequently were met on core in the southern part of the zone, in the Vilkaviškis-127 well the low oil flow rate was obtained (Яцына и др., 1987).

Potential reservoir rocks of the Uhaku-Kukruze horizons are present by organogenic-detrital, micritic-detrital, detrital-micritic limestone that was deposited in shoreface and offshore-transition environments. Its occurrence is associated with the Lower Nemunas rise and the Middle Lithuania depression. Open porosity of the limestone is in the range of 1.6–17.6%, gas permeability in less than 0.1 mD, occasionaly reaches 0.58 mD, average fractures density – 9.51 1/m, fractures' permeability is up to 1.3 mD. Thickness of the reservoir is in the range of 5–18 m. Frequent oil shows are associated with pores, sometimes caverns and fractures (wells Vištytis-17, Šakiai-43, the Pajevonys and Kybartai areas, etc.).

TRAPS TYPES AND PETROLEUM PROSPECTIVITY

The Ordovician basin's palaeotectonic and palaeogeographic factors have determined spatial distribution of Ordovician deposits' thickness, facies, reservoir rocks, source rocks, cap rocks and regional seal and, furthermore, this resulted in formed traps' types (Лапинскас, 1967; Лашков, 1968; Лапинскас и др, 1976 and others). The greatest sediment thickness' palaeostructures such as the Jelgava and Middle Lithuania depressions exhibit an increased quantity of clayey facies that, consequently, causes their low propectivity for oil (Fig. 1). The Lower Nemunas rise contains a break in deposition and with it associated the erosive relief. There during the erosion negative structures accommodated shoreface facies that contains reservoir rocks, lithological and stratigraphical traps. Distribution of oil fields in the region was mainly determined of the syneclise's tectonic evolution, oil generation and migration.

Within the present tectonic structure oil fields and oil shows in wells were observed in the eastern part of the syneclise, the First and Second steps as well as in the Liepoja-Saldus ridge.

The Kybartai oil field was discovered in the southern part of the Second step (Fig. 4). It has been investigated by drilling (Клишис и др., 1970). Traps there are of lithological-stratigraphical type and are related to the Porkuni horizon's limestone debris that filled an erosive valley. The oil field is situated in depth's range from -1091 to -1133 m. There two oil-bearing units are separated by the 2.1-3.5 m thick marl's seal. The lower 0.6-2.6 m thick unit is 1.2 km wide and 5.5 km long while the upper 1.3-1.5 m thick unit has been observed only in the western part of the field. The tested oil flow rate does not exceeds 0.312 m^3/d. The estimated oil in place reserves are 0.45 million tones, the recoverable reserves – 0.09 million tones. The Kybartai oil field was not delimited from the eastern side. The similar structure has the Pajevoniai oil field.

Results of these oil fields' geological studies show that Porkuni horizon's sedimentary thickness, stratigraphical completeness and extend are strongly dependant on depth of the erosive valley that is being derived according to the age of underlying beds. In the Kudirkos Naumiestis area the Porkuni horizon's thickness is 0.3 m (the KN-43 well) on the slope of the erosive valley and it underlying rocks are related to the Pirgu horizon. Porkuni horizon's thickness is 5.7 (the KN-58 well), reservoir's – 2.6 m in the deeper part of the valley where the Vormsi horizon underlay this strata. In the Pajevoniai area the Porkuni horizon and the reservoir are respectively 1.7 and 0.95 m thick in the well P-34 while in the well P-33 – 6.2 and 3.2 m thick. Outside erosive valley limits the Porkuni horizon's deposits were not observed. The similar to the mentioned traps may occur in the Lower Nemunas rise, particularly in the eastern its part that borders with the Kalvarija rise. According to this assumption the possible oil reserves were forecasted for the eastern part of the Lower Nemunas rise. Significant incised valleys were not found by drilling in the western part of the Lower Nemunas rise. Moreover, there the local highs with absence of the Porkuni horizon's deposits were not observed. Carbonates there comprise fine debris, are abun-

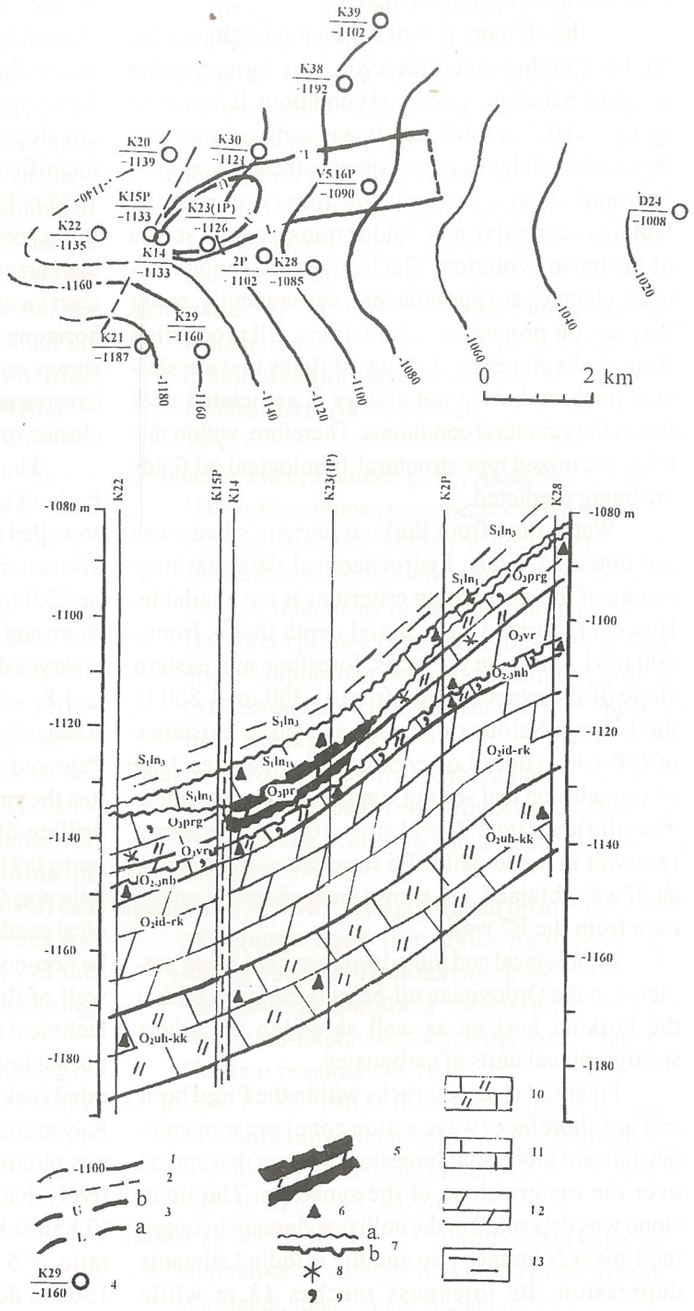

Fig. 4. Structural map and geological crossection of the Porkuni horizon in Kybartai oil field: 1 – depth contour line (m, bellow sea level) of the top Porkuni horizon; 2 – a zone of tectonic fracturing; 3 – spread limits of the oil field's lower (L) (a) and upper (U) (b) beds; 4 – a well: a number in numerator means a well number, a number in denominator – depth of the top Porkuni horizon; 5 – oil bearing beds; 6 – oil shows on core; 7 – stratigraphic hiatus (a) and short term break (b) in sedimentation; 8 – iron oxides and hydrooxides; 9 – glauconite; 10 – organogenic-detrital, micritic-detrital limestone; 11 – aphanitic, detrital-micritic limestone; 12 – marl; 13 – argillite.

dant in very fine grained quartz and sparry admixture, cemented with micro-crystalline cement that does not exhibit marks of dissolution or recrystallization. This area is regarded as a low prospective for hydrocarbons domain and the forecasted reserves have not been estimated there.

In the offshore part of the Liepoja-Saldus ridge the Porkuni horizons' reservoir was formed under different palaeogeographical conditions.It is present by up to 10.5 m thick debris and oolitic limestone facies of the Jelgava depression southeastern slope's bars and shoals. It was being formed during the Kuldiga regressive and Saldus transgressive stages of the basin evolution. The lateral facial and thickness' changes are possible that, consequently, result in reservoir properties' alternations. Oil production from the explored by drilling oil fields that are situated onshore Latvia not always is associated with favorable structural conditions. Therefore, within this ridge the mixed type structural-lithological oil fields are being predicted.

Water flow from Porkuni horizon's beds was not obtained. Thus, hydrochemical data that may be one of the exploration criterions is not available. However, horizon's top burial depth that is from -800 to -1 800 m on the steps, foreslope and eastern slope of the syneclise and from -1 300 to -1 800 in the Liepoja-Saldus ridge zone as well as existence of 150-180 m thick Lower Silurian regional seal lead to a conclusion that sealing conditions are quite good. The oil flow rate 2.7 m^3/d from 700 m deep laying reservoir in the so-called E6 structure on the Latvian shelf was obtained. Oil shows were observed on the core from the E7 well.

Lithological and mixed type traps are being predicted in the Ordovician oil-bearing complex within the Porkuni horizon as well as within the others stratigraphical units of carbonates.

Potential reservoir rocks within the Pirgu horizon are shoreface (wave action zone) organogenic-detrital and biohermal limestone's facies that spread over the eastern slope of the syneclise. The limestone was deposited in the collision domain between the Lower Nemunas rise and the Middle Lithuania depression. Its thickness reaches 18 m while bioherms are up to 4.4 m thick. Aphanitic limestone occurs on the Telšiai, Akmenė, Mažeikiai steps and in the onshore part of the Kuršiai depression. Marls replace the limestone facies within Lithuanian waters and the southwestern part of the country. The limestone is from 18 up to 21 m thick in North Lithuania. Lithological traps may occur in zones of intense fracturing and dissolution.

On the eastern slope of the syneclise the Pirgu horizon comprises shallow marine micro-crystalline and very fine grained limestone's up to 20 m thick facies that localy consist of remnants of single and colonial corrals (Ульст и др., 1982).

Reservoir rocks and potential reservoir rocks of the Nabala and Uhaku-Kukruze horizons are present by detrital limestone facies that were deposited in the shallow shelf's wave action zone. These facies spread over the First, Second steps and eastern slope of the syneclise. Lithological traps were identified in the Vilkaviškis-27 well (Яцына и др., 1987). This trap occured due to better reservoir rocks' properties in the oil field compare them with the surrounding rocks. Oil shows have been often seen on cores from the Nabala and Uhaku-Kukruze horizons in other areas and wells. Commonly, the shows on the core are related to pores, sometimes caverns and occasionally fractures that lead to a conclusion on lithological traps existence.

The predicted oil reserves were calculated for Porkuni horizon's deposits using analogy method's so-called resources density (thousand tones in square kilometer) way. These reserves are considered to be 25.9 million tones that is 15.3 million tones onshore and 10.6 million tones offshore Lithuania. The reserves density within an onshore prospective area is 1.8, offshore - 4.35 thousand tones/km^2. As a standard for the onshore reserves calculations the Pajevoniai and Kybartai areas were chosen where just the small Kybartai oil field was discovered after drilling of 22 wells. The greatest oil flow rate was up to 0.315 m^3/d, the oil self-flow out of the borehole was 0.016 m^3/d. Therefore, under current technical conditions the exploitation of this oil field would be non-commercial. Oil saturated rocks in the P-13 well of the Pajevoniai area were not tested due to technical reasons while in the P-3 well oil flow was not achieved due to poor reservoir quality. Oil saturated rocks of the Porkuni and Pirgu horizons in the K.Naumiestis area were tested and the oil flow was not obtained there. This is associated with relatively bad reservoir properties, high oil density (0.856-0.865 g/cm^3) and the low gas/oil ratio. The ratio is 6 1/m in Porkuni horizon's deposits at -1500 m depth in the Gusev oil field that is located 30 km to the west.

Within the continental shelf of Lithuania just small oil fields can be predicted according to results of exploration activity onshore Latvia and because the reservoir thinners and reservoir properties getting worse to the south of the E6-1 and E7-1 wells (Laškovas, 1994) in Latvian waters. However, these oil fields under recent technological conditions will not have a commercial value.

No oil fields were discovered within the Pirgu, Nabala and Uhaku-Kukruze horizons despite of many oil shows on core were observed there. Formations there were tested during drilling (wells Kybartai-39, K.Naumiestis-43, Vilkaviškis-135, Pilviškiai-140, etc.). 4 liters of oil was extracted per 6 days out of the Nabala horizon after the formation's treatment with accids and lowering water level in borehole down to 276 m. Density of oil is 0.877 g/cm^3. Due to above mentioned reasons, the reserves' prediction was not made for these horizons. Two algaes-corrals-stromatopora's bioherms shoud be addmitted that were found within the Pirgu horizon in the Pamituvys-98 well of the Ariogala profile on the II'nd step of the syneclise. They was not tested because oil indications were not met there. Small oil fields were discovered in a such composition bioherms and carbonate mud mound on Gotland island. The oil flow rate there ranged from 40-80 to 507 BOPD (King,1975, 1976, 1978). Not big oil fields may be expected under more favorable geological conditions according to trap types on the SE slope, 1'st and 2'nd steps of the syneclise.

Petroleum indications and oil fields formation in the deposits are related to oil migration from the Cambrian oil bearing complex due to deformations of structural fields during periods of tectonic activity. The many oil shows within tectonic fractures, dissolution pores and caverns in the Ordovician successios' various statigraphic levels above Cambrian oil fields (the Gargždai field in Lithuania, the Krasnobor, Ushakov, Slavinskaya fields in Kaliningrad enclave, the Kudilga field in Latvia) can be seen. Vertical hydrocarbons' migration was going more intensively on the slope and steps of the syneclise where the Ordovician succession getting more carbonaceous.

Currently, it is purposeless to carry out hydrocarbon exploration just in the Ordovician oil bearing complex. Such activities should be combined with oil exploration in the key complexes such as the Cambrian and Silurian.

REFERENCES

King, R. E. 1975. Petroleum exploration and production in Europe in 1974. The American Association of Petroleum Geologist Bulletin (AAPGB), vol. 59, N 10.

King, R. R. 1976. Petroleum exploration and production in Europe in 1975 (AAPGB), vol. 60, N 10.

King, R. E. 1978. Petroleum exploration and production in Europe in 1977 (AAPGB), vol. 62, N 10.

Laškovas J. 1994. Viršutinio ordoviko Porkuni naftingojo horizonto sandara ir kolektoriai Baltijos jūros akvatorijoje. Gelmių geologinio tyrimo, naudojimo ir apsaugos problemos Lietuvoje. Vilnius. 63-64.

Клишис В. И., Сауленас В. В., Сидаравичене Н. В., Стирпейка А. Д., Чехавичюс З. Б. 1970. Геологическое строение и нефтеносность Кибартайской нефтепоисковой площади. Нефтепоисковые критерии Прибалтики и методы их изучения. Тр. ин-та геол., вып. 8. Вильнюс: Минтис. 55-65.

Лапинскас П. П. 1967. Литология и фации верхнеордовикских и нижнесилурийских (лландоверийских) отложений Южной Прибалтики. Автореф. канд. дисс. Вильнюс. 19 с.

Лапинскас П.П., Лашков Е. И., Лашкова Л. 1976. Палеогеографические предпосылки поисков месторождений нефти в неструктурных ловушках кембро-силурийских отложений юго-восточной части Балтийской синеклизы. Палеогеографические исследования с целью прогнозирования месторождений нефти и газа связанных с ловушками неструктурного типа. Москва. 34-35.

Лашков Е. М. 1968. Литостратиграфия, литология и фации ордовикских отложений Южной Прибалтики. Автореф. канд. дисс. Вильнюс. 24 с.

Лашков Е. М. 1987. Субформации ордовика юго-западного края Восточно-Европейской платформы в Прибалтийском регионе. Тектоника, фации и формации запада Восточно-Европейской платформы. Минск: Наука и техника. 96-103.

Мянниль Р. М. 1963. Биостратиграфическое обоснование расчленения ордовикских отложений Западной Латвии. Тр. ин-та геол. АН ЭССР, Т. 13. 41-74.

Пашкевичюс И. Ю. 1958. Стратиграфия и фауна ордовика и силура Южной Прибалтики. Автореф. канд. дисс. Вильнюс. 27 с.

Ульст Р. Ж., Гайлите Л. К., Яковлева В. И. 1982. Ордовик Латвии. Рига: Зинатне. 294 с.

Яцына И. Б., Друнгилас П. Ю., Кадунене Е. Ф., 1987. Геологическое строение и нефтеносность Кудиркской площади (рукопись; фонды геологической службы Литвы). Вильнюс.