PETROLEUM POTENTIAL OF SILURIAN NON-STRUCTURAL TRAPS IN LITHUANIA

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Silurian deposits occur widely in Lithuania and compose the great part of the sedimentary cover. Thickness of the most stratigraptically complete successions reaches 144 m in Eastern Lithuania and it exceeds 1120 m in Lithuanian waters. In the offshore and Western parts of Lithuania occur terrigenous and in Middle and Eastern Lithuania also and various carbonate formations.

In respect of petroleum potential these formations are of a different importance: some of them are important in terms of source rocks, another compose a seal, the others are prone to consist reservoir rocks and form various genesis' traps (Fig. 1). Results of these formations' investigations are generalised in a number of publications [1-41, etc.].

Clayey formations of the middle part of the Llandover (up to 24 m thick) and the Wenlock - the Lower Ludlow (up to 330 m thick) sequences that were deposited in depressions under anaerobic conditions, spread over the Baltic palaeosyneclise and are distinct in respect of source rocks [4, 6, 22, 26, 30, 35, 37, 40, 41, etc.].

The seal is made up from the upper part of the Llandover (up to 53 thick) and the Ludlow upper part - the Pridolian (up to 476 m) clayey formations that formed in offshore and offshore - transition environments and they widely spread over the whole Baltic palaeosyneclise and the Byelorussian-Lithuanian palaeoanteclise. The gypserous clayey dolomitic marl formation (the Širvinta suite) that is up to 17 m thick was deposited in supratidal plain (sabkha) environment and occurs locally in marginal regions of the palaeosyneclise and palaeoanteclise. [6, 26, 27, 30].

The Lower Silurian upper parts' and Upper Silurian lower parts' heterogenetic carbonate formations that appear in the eastern marginal domain area of the Baltic palaeosyneclise are important in respect of reservoir rocks [2, 6, 11, 16, 20, 23, 27, 29, etc.]. Three independent stratigraphic levels are determined according to reservoir rocks composition, genesis and location. Cavernous epigenetic dolomites abundant in faunas remnants have the best reservoir properties within the Gėluva-Dubysa horizons. The rocks exhibit open porosity (o.p.) up to 17.6%, gas permeability (g.p.) up to 1282 mD. Such dolomites were found in the Sutkai eastern paleoflexures' zone. They are considered to be reservoir rocks of the various classes (VIII-I). In the Sutkai western palaeoflexures' zone within the Pagėgiai horizon the crinoidea's (o.p. up to 12 %, g.p. up to 15 mD) and oolitic-oncolitic (o.p. up to 17.3 %, g.p. up to 12.8 mD) limestone exhibits the best reservoir properties out of the carbonate rocks.

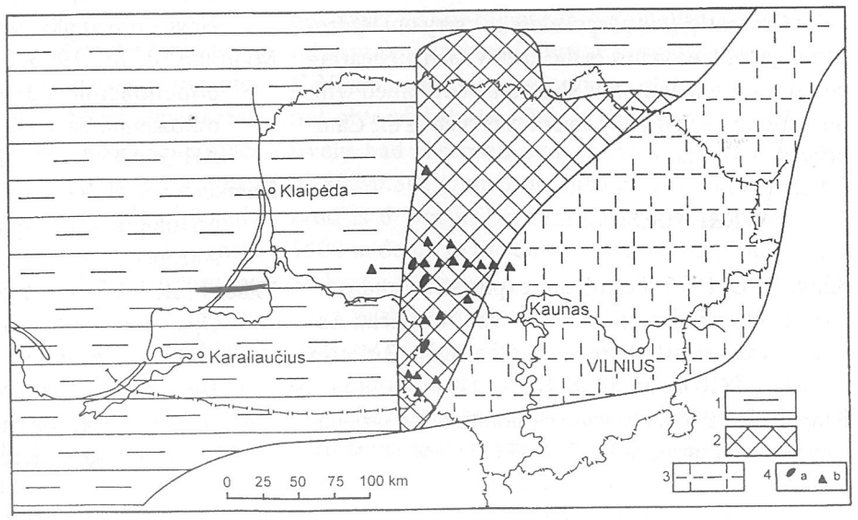

Fig. 1. Location map of the Silurian oil bearing complex formations in Lithuania: 1 - spread of formations that are prone to contain source rocks and seals; 2 - spread of formations that are prone to contain source rocks, reservoir rocks, seals and non-structural traps; 3 - spread of formations that are prone to contain seals, reservoir rocks and non-structural traps; 4a - oil fields; 4b - oil shows on core.

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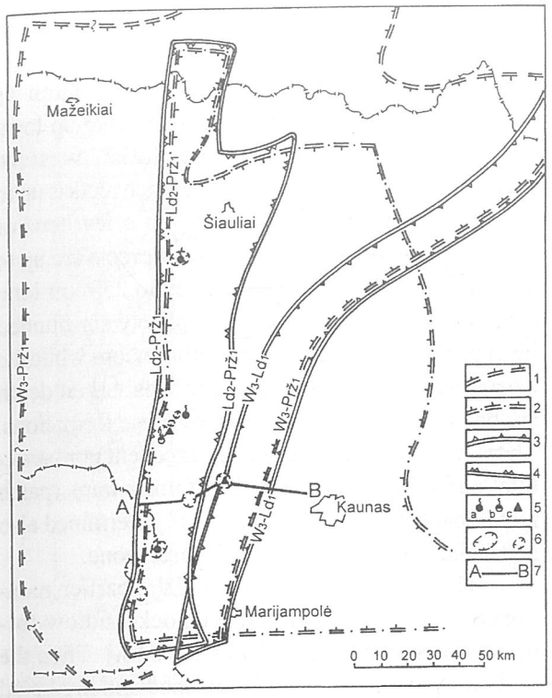

Fig. 2. Location map of the Silurian oil bearing complex' non-structural traps occurrence in Central Lithuania: 1 - Offshore-transition environment's marl and limestone formations of the Gėluva-Minija horizons that occur in patch reefs; 2 - Normal salinity lagoonal environment's dark limestone formations of the Minija horizons that occur in patch reefs; 3 - Shoreface environment's epigenetic dolomite formations of the Gėluva-Dubysa horizons that occur in bars and barrier reefs of the Sutkai eastern palaeoflexures' zone; 4 - Shoreface environment's heterogenetic limestone formations of the Pagėgiai and-Minija horizons that occur in bars, patch and barrier reefs of the Sutkai western palaeoflexures' zone; 5a - oil flow; 5b - oil and water flow; 5c - oil shows on core; 6 - discovered patch reefs; 7 - line of a geological crossection (see Fig. 5).

It is porous reservoir rock, locally mixed type reservoir rock, of the VII-V classes. Stromatopora's (o.p. up to 12.6 %, g.p. up to 2725 mD) and organogenic-debris' (crinoidea's) (o.p. up to 18.2 %, g.p. up to 893 mD) limestone has good reservoir quality within locally distributed heterogenetic reefs of the Minija horizon in the eastern marginal domain of the palaeosyneclise (the eastern margin of the Lithuanian palaeodepression). It is a reservoir rock of porous and mixed type of the VII-I classes.

It has been many different opinions on traps that have favourable conditions to form oil fields as well as on traps' spread. Russian scientists [1, 31-34, etc.] for a long time considered the most favourable traps for oil accumulation to be hypothetical sandy formations that, in their opinion, spread over the southern Lithuania's regions, near the Mazury rise-palaeoexposure. During a period of 1964 - 1970 it was thought [36-39, etc.] that in the north-western regions could exist reefs and palaeoislands that were surrounded by foreshore facies.

In 1964 after more lithofacial studies of the Llandover-Ludlow formation, we proposed a hypothesis that exploration for oil bearing reefs should be carried out within this complex [7.]. In this respect, the most prospective should be the Baltic palaeosyneclise's eastern marginal and Byelorussian-Lithuanian palaeoanteclise's north-western slope's domains. During a period of 1967-1969 lithofacial investigations of the whole Silurian complex were performed by us and it showed that exploration for the reefs should be carried out also within the Pridolian formations in the Baltic palaeosyneclise's eastern marginal domain [2, 3,7-10, 12, 13, 15, 17-19, etc.]. The first small reefs in the Ludlow deposits were discovered in 1967 in the Kybartai area and later, in 1969, also within the Pridolian formations in the Kudirka Naumiestis area. In the latter area an oil bearing reef atoll was identified and it is considered to be the biggest so far found reef in the Baltic Silurian sedimentary basin [24, 25].

Rather insignificant tectonic deformations of Silurian deposits in an occurrence area of possible reservoir rocks and great alteration of lithofacies form favourable conditions for appearance of non-structural and mixed type traps. The previously mentioned three different stratigraphic complexes that contain reservoir rocks are distinctive with their specific conditions for non-structural traps' formation (Fig. 2) [21, 23, 27, 30, etc.].

Reservoir rocks of the Gėluva-Dubysa complex are present by cavernous epigenetic dolomite that, furthermore, makes up 2 km wide, up to 28 m thick and more than 120 km long belts of both bars and barrier reefs. Their facial changeability toward beds rising direction and them overlaying clayey seals result in very favourable conditions for non-structural traps' occurrence and where the belts intersect with rises the mixed type traps likely to be located. Two stromatopora's and crinoidea's build-ups up to 15 m thick were discovered within this stratigraphic complex in the Kybartai area. Probably they are patch reefs surrounded and trapped by a marl seal. Such reefs with better reservoir properties may form non-structural traps.

The best reservoir quality of the Pagėgiai horizon is observed in oolitic, oncolitic and organogenic-debris' limestone that composes up to 22 m thick, 6-15 km wide and 250 m long submeridianal strike bars' and barrier reefs' belts in the Sutkai western palaeoflexures' zone. With decreasing burial depth of the beds this rock is being replaced and overlain

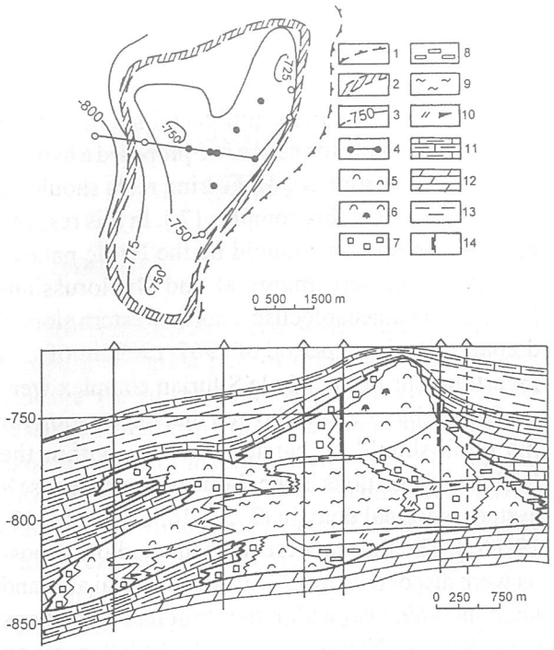

Fig. 3. Minija horizon's Kudirka atoll's geological crossection and structural scheme: 1 - eastern limit of the atoll (according to well data); 2 - limit of the central atoll part (according to seismic data); 3 - contour lines of the atoll top; 4 - crossection line; 5 - stromatopora's limestone; 6 - corrals' and stromotopora's limestone; 7 - organogenic sandstone and gravelite; 8 - clayey organogenic sandstone and gravelite; 9 - micrograined limestone; 10 - dark organogenic limestone; 11 - clayey micrograined limestone; 12 - marl; 13 - argillite; 14 - oil bearing intervals observed on core.

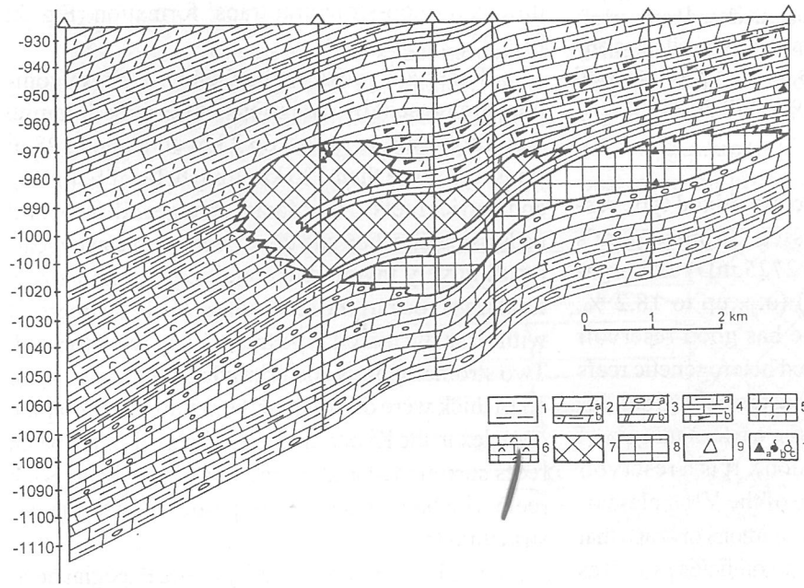

Fig. 4. Geological crossection trough the barrier reefs' formations of the Mituva and Ventspilis suites in the western Bebirva area: 1 - argillite; 2a - marl; 2b - clayey marl; 3a - marl with the limestone noodles; 3b - dolomitic marl; 4a - clayey marl; 4b - limestone abundant in the organic matter; 5 - organogenic detrital limestone; 6 - organogenic debris' limestone; 7 - biolitic and organogenic debris' limestone of barrier reefs; 8- oolitic-oncolitic limestone of bars; 9 - wells; 10a - oil shows on core; 10b - oil flow; 10c - oil and water flow.

by a dolomitic marl seal. Such bedding is prone to form non-structural and mixed type traps.

Minija horizon's reservoir rocks such as stromotopora's and debris' limestone make up local patch and barrier reefs in the Sutkai western palaeoflexures' zone. Height of the patch reefs is up to 88 m and they occupy an area up to a few tens of square kilometres (Fig. 3). The barrier reefs are up to 43 m high, up to 6 km wide and up to 250 km long (Fig. 4). The patch reefs are completely surrounded by impermeable clayey carbonate formations while the barrier reefs with decreasing their beds' burial depth are being replaced and covered by these formations. These reefs are considered to be excellent non-structural and mixed type traps. The former traps (patch reefs) that are up to 28 m thick were determined also and in the Sutkai eastern paleoflexures' zone.

The regressive sequence of the earlier mentioned bars and reefs in the Wenlock-Ludlow formation was identified as far as 1970 [8.]. Then the first barrier zones were distinguished and predicted within the Jačionys, Mituva, Minija strattons' stratigraphic levels. Later, they were identified and predicted within a few more stratigraphic levels (Fig. 5) [17, 19, 23, 30, etc.].

A first direct evidence of the petroleum potential such as oil shows on core were observed close to the Silurian and Ordovician interface in the Vilnius well in 1949. A number of the shows observed in the Silurian succession increased since 1975 when structural drilling activity became of a wide scale [5, 14, 18]. The most of them were derived in Minijas horizon's limestone in the Baltic palaeosyneclise's eastern marginal domain. The slightly less shows were observed within Pagėgiai horizon's carbonate rocks in the same domain, even less - within Dubysa horizon's carbonate rocks. A new stage of managing this information commenced in 1983 when under our recommendations [10, 14] an oil field was discovered in Silurian reefs in the Kudirka area. A hypothesis that the eastern marginal domain of the Baltic syneclise is prospective for hydrocarbons was proven. So far two oil fields such as the Kudirka and the Šiaurės Bliūdžiai were found in the

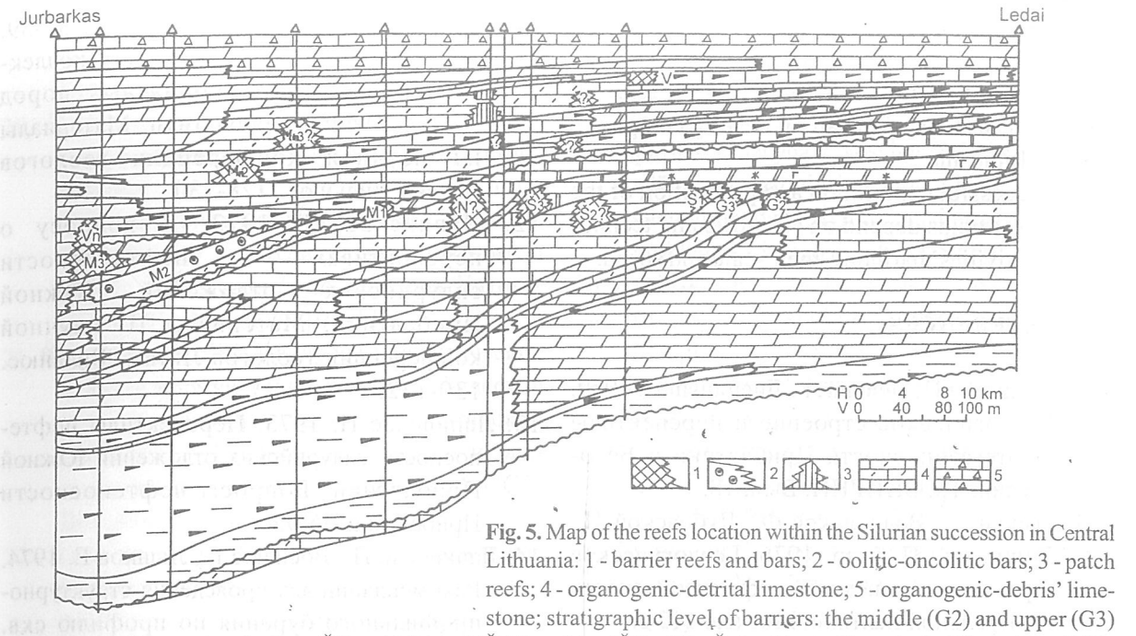

Fig. 5. Map of the reefs location within the Silurian succession in Central Lithuania: 1 - barrier reefs and bars; 2 - oolitic-oncolitic bars; 3 - patch reefs; 4 - organogenic-detrital limestone; 5 - organogenic-debris' limestone; stratigraphic level of barriers: the middle (G2) and upper (G3) parts of the Gėluva suite; the base(Š1), middle part (Š2 ?) and top (Š3) of the Šešupė beds; Nova beds (N); the base(M1), middle part (M2) and top (M3) of the Mituva suite; the Ventspilis suite (Vn); middle part (Mn2) and top (Mn3) of the Minija horizon; Varniai beds (V).

patch reefs.

In order to quantitatively evaluate the oil reserves of the Silurian oil bearing complex it should be taken into account that necessary data to do that is very different for different stratigraphic levels. So far most of the data is obtained for the Pridolian stage Minija horizon's formations. Author together with Mr J.Jacyna in 1996 performed calculations of the predicted geological reserves. The petroleum potential of the rest stratigraphic levels and areas was estimated just qualitatively.

Limits of the calculated Minija horizon's reserves (Fig. 6) were defined on a basis of following criteria: - a western limit conforms with a limit of the known Minija horizon's reefogenic formations' spread; - a southern limit matches the erosive limit of the Jūra horizon's seal; - a northern limit defined according to significant increase of carbonate rocks in the Jūra horizon's seal and where sealing properties of this horizon significantly getting worse; - a south-eastern limit matches the contour line -650.0 of the Minija horizon depth that almost conforms with isolines of both formation water mineralization (80 g/l) and metamorphization (Na/Cl-0.7) that separate moveable and oxidised oil accumulations.

According to obtained data within the calculation area a possible number of patch reefs, an average size of an oil field and a chance of successful discovery, the predicted geological reserves are estimated to be about 100 million tones in Minija horizon's patch reefs that occur in the eastern mar-

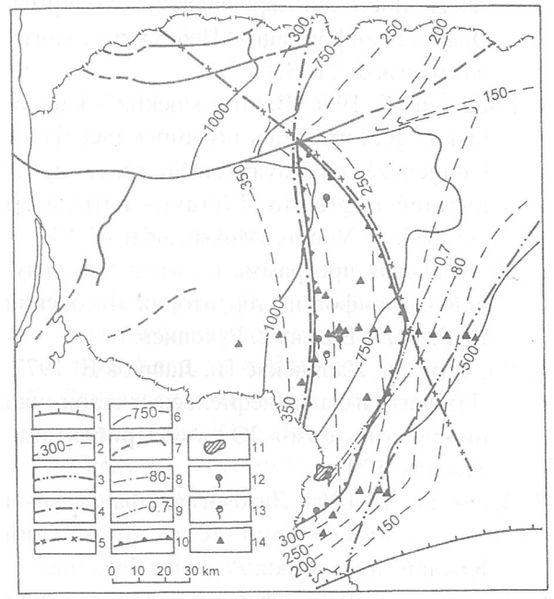

Fig. 6. Diagram of the oil potential criteria of the Silurian oil bearing complex in Lithuania: 1 - a current limit of the Upper Silurian deposits occurrence; 2 - isopachous lines (m) of the Upper Silurian oil bearing complex; 3 - a eastern limit of the Lower Silurian argillites, that are abundant in the organic matter, occurrence; 4 - a western limit of the discovered Upper Silurian reefs distribution; 5 - a eastern limit of the Jūra horizon carbonaceous-clayey seal's facial changes; 6 - depth contour lines (m) of the top of the Minija oil bearing horizon; 7 - key faults; 8 - Upper Silurian formation water mineralization contour lines (g/l); 9 - water metamorphization coefficient (Na/Cl) contour lines; 10 - limits of the region for that calculations of predicted oil reserves within Minija horizon were performed; 11 - oil fields; 12 - oil flow; 13 - oil and water flow; 14 - oil shows on core.

ginal domain of the Baltic syneclise. Average density of the reserves is 26 thousand tones/km^2. The dissolved gas and oil ratio is 2.26 m^3/t. These reserves are the greatest out of the all oil bearing complexes onshore Lithuania.

Successful exploration and production of the Silurian oil fields depend on scientific and technological activities' harmony, their scale and speed.

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