Petroleum and Coal

Article Open Access

Shale Gas in Western Ukraine: Perspectives, Resources, Environmental and Technogenic Risk of Production

Yaroslav Lazaruk[1], *Vasyl Karabyn*[2]*

[1] *Institute of Geology and Geochemistry of Combustible Minerals, Lviv, Ukraine*
[2] *Lviv State University of Life Safety, Lviv, Ukraine*

Received March 31, 2020; Accepted June 22, 2020

Abstract

Geological formation factors of non-convectional gas accumulations on the example of Silurian deposits within the Olesk section of Volyn-Podil oil and gas region in the West of Ukraine are studied, their resources are estimated, prospects for industrial production of shale gas are determined, and potential environmental and technogenic risks due to the development of predicted fields are outlined. The research was carried out on the basis of structural, tectonic, lithological, hydrogeological and own field and laboratory geochemical studies using analogy method of the Silurian base geological and geochemical parameters in Ukraine with the corresponding parameters of the same-age formations in Poland. To assess the resource base of shale gas within the Western Ukraine , gas generation potential of Silurian volume clay rocks and genetic method is defined, the maps of the weighted average of geochemical parameters and thicknesses gas generation deposits allocated to the same type of area calculation with similar rock facies, close catagenetic loss of transformation of organic matter and total thickness gas generator rocks, determined the specific gravity of hydrocarbon generation at the measurement sites and calculated ratios catagenetic losses of organic matter and generating gaseous hydrocarbons. Threats to the impact of shale gas production on environmental and civil security were assessed by studying the regional natural features, its environmental capacity to hydrocarbon pollution, and modern technology for shale gas production by hydraulic fracturing of the layer (fracking). The results of geological studies are compared with the risks to the environmental and technological security in the region and the inexpediency of extracting shale gas from the subsoil of Western Ukraine using modern technologies is justified.

Keywords: *Volyn-Podil oil and gas region of Ukraine; Recoverable hydrocarbon resources; Environmental safety; Civil protection; Emergency.*

1. Introduction

At the end of the last Millennium, mankind discovered a new type of raw material energy – shale gas, which forecast resources are, according to the World Energy Council, for 48 oil and gas basins in 32 countries of the world, reach 1200 trillion barrels [1]. The United States has achieved the most success in industrial development of shale gas deposits [1]. Due to the technology of hydraulic fracturing, they reached the production of gas from clay rocks to 25% of the total in the country, coming in 2009 to the first place in the world for natural gas production.

The US success gave rise to the search for shale gas in Europe. Its largest resources are projected in Poland, France, Norway, and Sweden [2].

Assessment of the resource base of shale gas, as well as any other energy raw materials, is an extremely important task. The results of this assessment can significantly affect the energy, environmental, and security policies of the region's countries. The course for shale gas production will require the development of new, more environmentally friendly gas production technologies, scientific methods for preventing emergencies and ensuring the environmental safety of gas production areas [3-4].

The purpose of the article is to assess the prospects for shale gas production in Ukraine. By the term 'shale gas' we mean practically stationary in natural conditions hydrocarbon gas of pelitomorphic rocks with low capacitance and filtration properties. Due to the small size of pore channels (10-1 microns or less), their matrix permeability is very low (less than 0.01×10^3 microns). Shale gas can only be removed from the rock by an artificial fracturing system, such as hydraulic fracturing.

2. Experimental

The factual basis for evaluating the resource base of shale gas was provided by numerous published and stock materials of exploration institutions in Poland and Ukraine [5-7] and the results of structural, tectonic, lithological, hydrogeological and proprietary field and laboratory geochemical studies. Technical documentation for deep oil and gas wells has been systematized. The estimation of the gas-generating potential of clay rocks in Silurian sediments was carried out using a volume-genetic method based on data for determining the generation of hydrocarbons from organic matter scattered in the rock.

To diagnose parental rocks and determine their productivity, information about the distribution of the concentration of organic matter and its genetic types is used, the number and composition of bitumen and hydrocarbons, the geochemical facies types, data on lithophacial complexes maximum depth, paleotemperature and catagenetic maturity of organic matter.

Maps of weighted average geochemical parameters and thicknesses of gas-generating Silurian deposits are constructed. The same type of counting sites with similar lithophanies, close to the degree of catagenetic transformation of organic matter and the total thickness of gas-generating rocks are identified. Specific densities of hydrocarbon generation at the estimated sites were determined.

The coefficients of organic matter catagenetic losses and generation of gaseous hydrocarbons were taken into account, which were determined by the Geochemistry laboratory specialists of the Ukrainian State Geological Survey Institute under the direction of IB Hubych, using laboratory pyrolysis modeling of kerogen and obtained data comparison with the results of bituminous core studies.

Specific densities of hydrocarbon generation at the estimated sites are determined by the formula:

$$D = O \cdot K_{k.L} \cdot T \cdot d \cdot K_a$$

where D is the density of gaseous hydrocarbons generation, thousand tons/km^2; O is the content of organic matter in gas-generating rocks,%; $K_{k.L.}$-coefficient that restores catagenetic losses of organic matter,%; T-thickness of clay rocks, km; d-density of rocks, t/km^3; K_a-coefficient of hydrocarbon accumulation,%.

The geological method of analogies, general scientific methods of comparison, induction, and synthesis in the process of generalizing the actual materials and formulating conclusions are used.

3. Results and discussion

Over the past decade, oil and gas companies, such as Exxon Mobil, Marathon Oil, Talisman Energy, and Chevron, have been evaluating the resource base and exploring opportunities for shale gas production in Poland. Geological and geophysical research was carried out on the territory of about a hundred concessions (plots) given to domestic and foreign companies. 56 wells were drilled, 24 of them were fracked, but only a few wells managed to get gas inflows. The best result was achieved by Lane Energy Poland (controlled by Conoco Phillips), which received 8 thousand m^3 of gas from a depth of km^3 per day from a test well near the town of Lembork in Northern Poland. The results of exploratory drilling for shale gas were not as optimistic as at the beginning in 2008, when according to the Polish Geological Institute (PIG), 5.3 trillion m^3 of shale gas was evaluated in the Poland subsoil. According to the results of geological exploration, this figure has decreased tenfold – 346-768 billion m^3. The estimation of the gas resource base in the black shale layers of Poland by various researchers has changed over time within the limits of 1,0-1.4-3,0 trillion m^3 (2009), 5.3 trillion m^3 (2011), 346-768 billion m^3 (03.2012), 38 billion m^3 (07.2012), showing a steady downward trend [2].

For shale gas production in Poland, it was planned to drill about 100 wells every year for three years. The cost of each of them reaches 10-15 million dollars. In order for shale gas production to reach 6 billion m^3 per year, it was necessary to invest 11 billion dollars by 2025, and then to maintain production at the level of 6.5 billion m^3 per year until 2035 spend $ 1.5 billion annually. Therefore, the cost of shale gas production was predicted to be quite high – at the level of $ 300 per 1000 m^3. The resource base reduction and the economic impracticability of shale gas production led to search operations curtailment and the exit of foreign companies from Polish territories.

The geological aspects of Polish shale gas look like this. Silurian complex has perspectives (a small part of Landover, mainly Wenlock layer and the lower part of Ludlow layer), represented by a monotonous layer graptolite shale in the Baltic and Lublin basins. It lies at 2000-4500 m depths. Gas saturated thickness of the Landover deposits varies between 20-40 m, Wenlock varies from 100 m in the South-Eastern part of the Lublin region to 1000 m in the Western part of the Baltic basin. The perspective complex is covered by a two-kilometer clay layer with carbonate rock layers of the upper part of the Ludlow and Przhidolsk layers (Fig. 1).

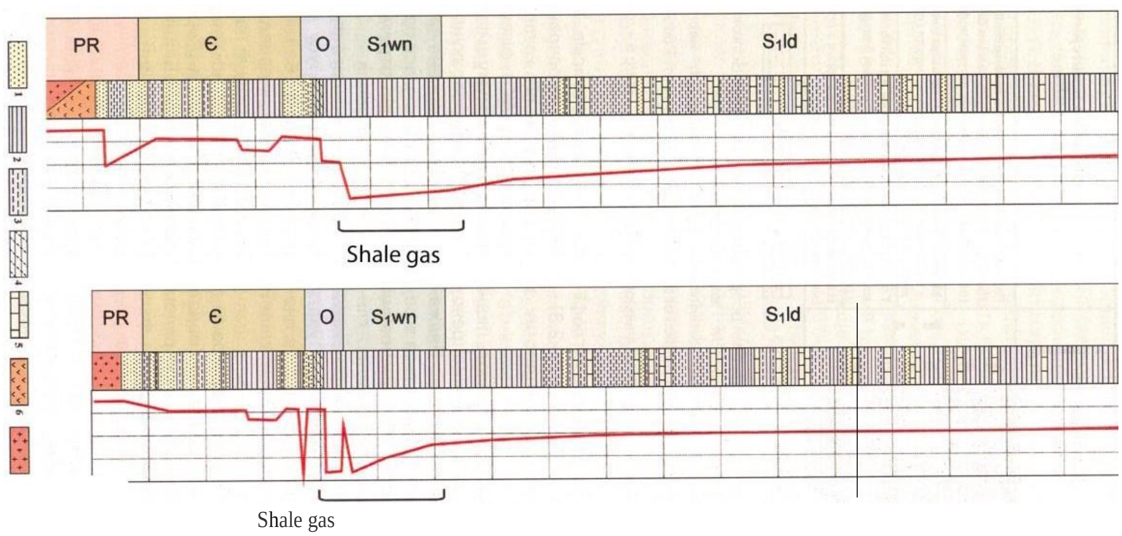

Fig. 1. Simplified lithostratigraphic section of the Lower Paleozoic at the Lublin region (left) and Baltic Basin (right) [5]: 1 – sandstone, 2 – clay, 3 – mudstones, 4 – marl; 5 – limestone; 6 – tuffs; 7 – consolidated rocks, red curve shows the gas saturation of rocks

The organic carbon content in sediments Landover layer in the Western and Central parts of the Baltic basin, as well as in Pidliask basin ranges from 0.5 to 1.3 %, in the Eastern part of the Baltic basin and in the Lublin region it is higher – up to 1-1. 7 % [5]. In the Central parts of the Baltic basin and Pidliask basin rocks of the lower Silurian, the most organic-rich sediments are Landover layer, and in the Eastern part of the Baltic basin and the Lublin region, the highest organic carbon content is confined to the rocks Wenlock layer. The average organic carbon content in them is usually 1-2. 5 %, with the exception of the Pidliask layer, where its amount reaches 6.0 %.

Silurian rocks of the Baltic and Lublin deflections have a high vitrinite reflectivity $R^{o} \geq 2$ (Fig. 2). This indicates their thermal maturity – they are at late catagenesis stages (MK_4-MK_5) and metagenesis (AK_1), which is a necessary condition for generating methane from organic matter.

The South Eastern extension of the Lublin deflexion is the Lviv Paleozoic deflexion on the territory of the Volyn-Podil oil and gas region of Ukraine. Here the thickness of venlaxor and the lower part Ludlow layer is twice less than in Poland and total capacity venlaxor, Ludlow and Przhydolsk layer does not exceed 800 m (Fig. 3). The Silurian complex extends in a South Eastern direction from the Polish border to the Romanian border. The most interesting from the point of view of shale gas is the Olesk section with an area of more than 6300 km^2. (Fig. 4).

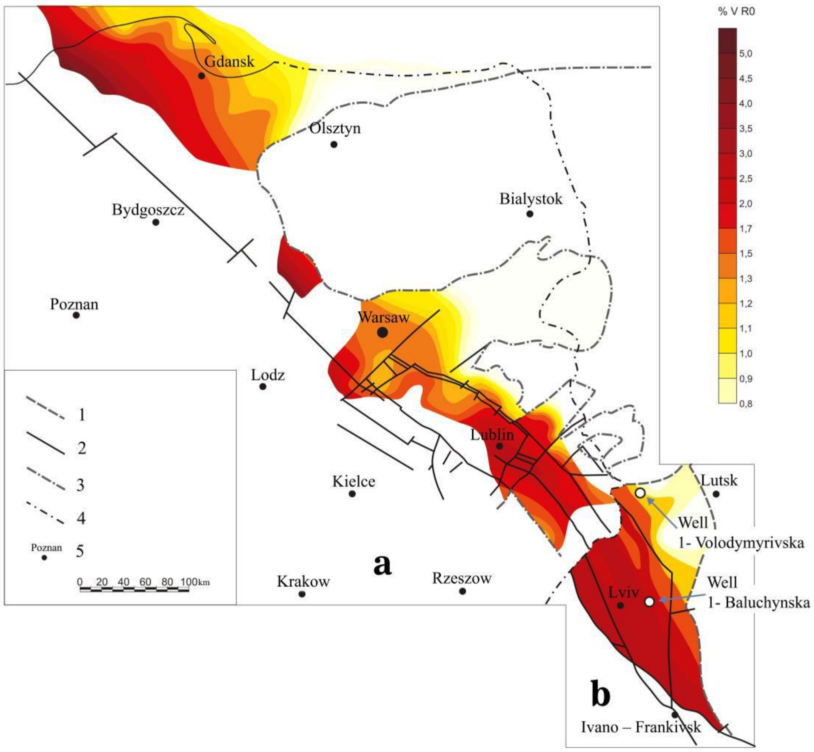

Fig. 2. Reflectivity of vitrinite Silurian rocks: 1 – border of the Lviv Paleozoic deflection, 2 – friction zone, 3 – border of distribution of Silurian deposits in Poland, 4 – state border, 5 – city; a – Lublin region, b– Volyn-Podil region

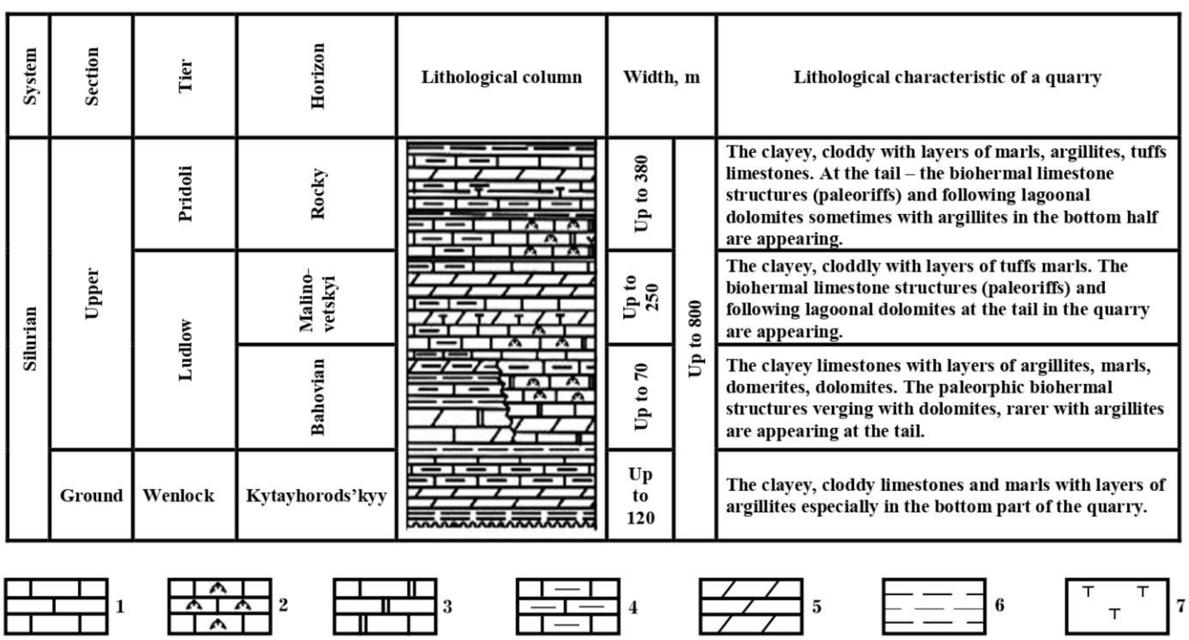

Fig. 3. Combined lithologic and stratigraphic section of the Silurian system of the Volyn-Podil oil and gas region: 1 – limestone, 2 – reef limestone. 3 – dolomitized limestone. 4 – clay limestone. 5 – marl. 6 – mudstones. 7 – tuffs

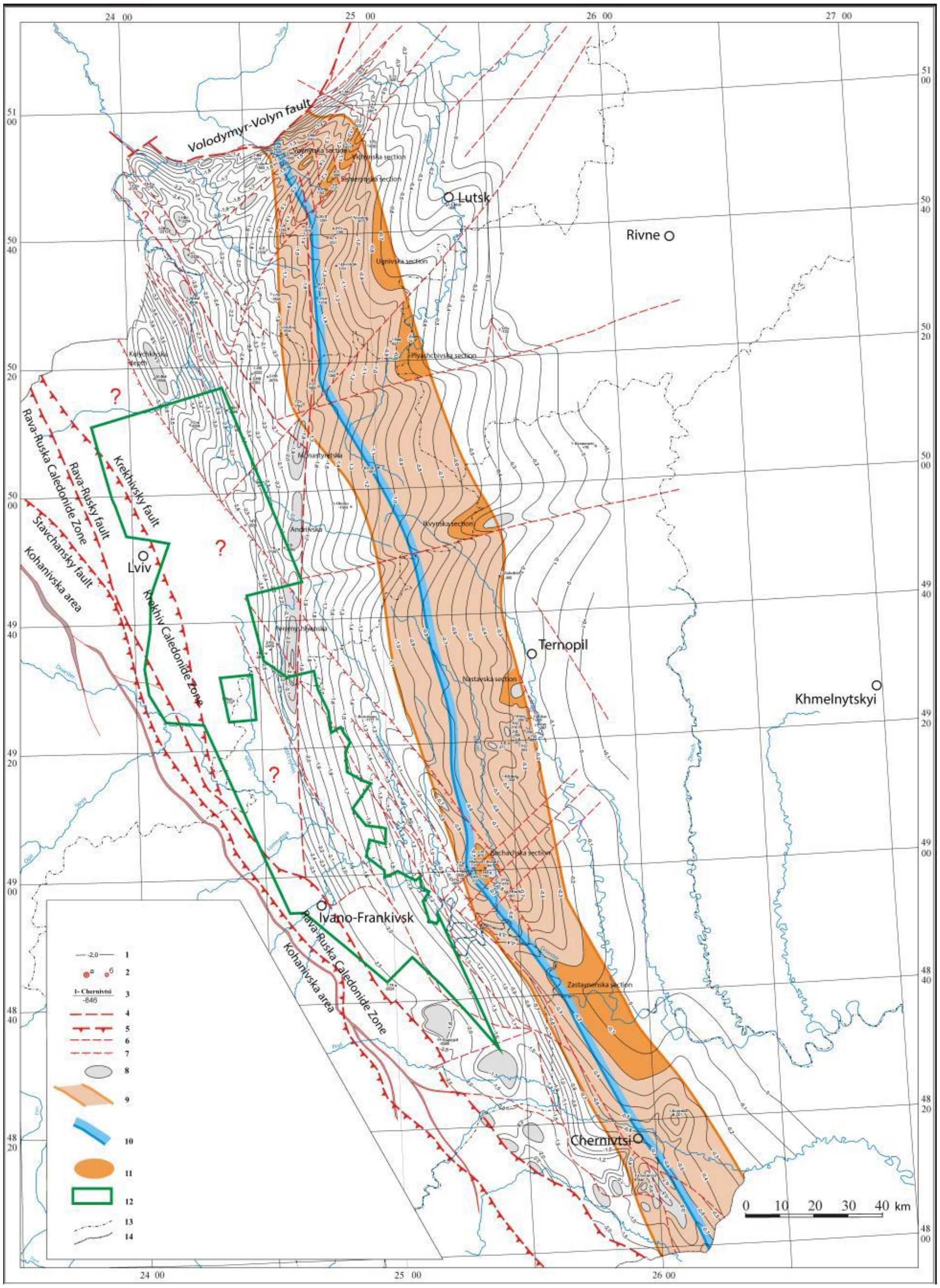

Fig 4. The map of rocks distribution of Silurian period within the Volyn-Podil oil and gas region of Ukraine: 1 – roof isohypses of the malinovetsky horizon of the top Silur (sole of the Skalsky horizon), 2 –wells: deep (a), structural and mapping (b), 3 – name of the well (numerator), horizon roof mark (denominator), 4 – regional break, 5 – regional sliding, 6 – dumping, 7 – sliding, 8 – local positive structure, 9 – strip of distribution of Skalskyi paleoreef, 10 – east edge of a synchronous paleolaguna, 11 –perspective area for formation of hydrocarbons traps in paleoreef, 12 –Olesk area, 13– administrative border of the area, 14 – state border

According to the rocks lithological composition of the mentioned stratigraphic divisions, they differ from the same-age formations of the Polish territory [8-10]. Wenlock deposits of

Volyn-Podil in the lower part is represented by alternation of marls with limestone at the top – a thick layer of lumpy limestones with interbedded shales, marls, dolomites.

On Wenlock formations according to it deposited sediments of Ludlow layer. They are composed of a thick layer of flagged and lumpy limestones with layers of marls, tuffs and bentonite clays. In the North Eastern boundary of Olesk area lower part of the section is composed mainly from laguna, mainly in carbonate sediments. In the South-West direction, that is, in the cross-stretch of the complex, the latter are replaced by slab dolomitized limestones, which in turn gradually turn into lumpy limestones.

Przhydolsk layer deposits are also mostly calcareous. They are made up of lumpy clay limestones with marl layers, mudstones, tuffs, places of lagoon anhydrites and dolomites.

Thus, it makes no sense to talk about the wide distribution of shale rocks of the Silurian Volyn-Podil oil and gas region – we can only talk about separate layers of mudstones, more or less carbonate, the total thickness of which in the Central and North Eastern parts of the Olesk section is 75-80 m, and in the South Western direction increases to 100-120 m.

The content of scattered organic matter in the Paleozoic Volyn-Podil deposits in Ukraine is significantly less than in Poland, and is mainly 0.2-0.7 %, on average 0.4 %. It should be mentioned that in US fields, where shale gas is produced on an industrial scale: Barnett, Marcellus, Woodford, Haynesville, Fayetteville and others, the content of dispersed organic matter reaches 8-10%, but not less than 2-3%.

The depth of Silurian coverage increases from 600 m in the North East of the Olesk section to 3500 m in its South West. In the same direction, the catagenetic maturity of rocks increases from the MK_1 stage to the MK_4 stage. It is somewhat smaller than in the same-age counterparts of Poland, but we can state that catagenetic transformation degree of the Silurian rocks in Ukraine can generate gas.

Direct signs of gas-bearing Silurian deposits were found near the Polish border: a short-term gas inflow of 1.4 thousand m^3/day was obtained from the 1807-1862 m interval of the 1-Volodymyrivska well. Thus, it can be stated that the geological prerequisites for the formation of shale gas accumulations in Silurian deposits in Ukraine are worse than in Poland.

An important parameter for estimating the resource base of shale gas is the values of specific densities of hydrocarbon generation. Within the Volyn-Podil part of Ukraine, specific densities of hydrocarbon generation values vary from 40 thousand tons/km^2 in the Eastern part of the territory to 560 thousand tons/km^2 in its South-West, as we determined in our previous paper [6].

The estimated resources of shale gas in the Silurian column within the Olesk section at about 1 trillion m^3. Its recoverable reserves will be significantly smaller, since not all the rock thickness will be covered by the fracture zone. As a result of hydraulic fracturing, cracks will occur at a distance of up to 200 m around the trunks of individual wells in the cluster. Therefore, only 60-70% of the volume of gas-saturated rocks will be covered by drainage. In addition, not every microscopic gas inclusion will be crossed by a crack, so some of the gas will remain in the rock. Thus, the coefficient of gas extraction from shale rocks will not exceed 15-20% of the total geological resources (similar data were obtained from American shale gas fields), for the Olesk section it will be 150-200 billion m^3. A close estimate of the reserves of shale gas in the Olesk section, namely 100 billion m^3, was given by specialists of the US Department of Energy [11]. About the same figure -158.7 billion m^3 received by the results of their research Krupsky *et al*. [7].

This is a relatively small resource for Ukraine, which can meet the state needs only for 5-6 years. However, there is a significant environmental risk of shale gas production on an industrial scale. Threat factors for the ecological state of the environment due to the production of oil and gas from traditional hydrocarbon deposits in Western Ukraine have been sufficiently studied [12-15]. However, shale gas production has its own characteristics that will significantly affect the environmental safety of the region and increase the risk of emergencies. Gas extraction is possible only by creating a system of artificial cracks using hydraulic fracturing of dense rocks. The drilling of production wells is carried out by a clustering technique. It involves drilling several (usually 16-24) directional wells with a horizontal end from one site. In each of them, it is necessary to carry out multi-stage hydraulic fracturing of the gas-saturated thickness in order to create a system of cracks around the wellbore. To achieve the above-mentioned recovery factor of 15-20%, the cluster area will be about 9 km^2 with 16 directional wells with a horizontal end with an average well face departure of 1500 m from the cluster center. Therefore, 702 clusters of 11232 wells would have to be created on the territory of the Olesk section with an area of 6324 km^2.

On average, 20 thousand m^3 of water is required for hydraulic fracturing of one well. For 11232 wells, it will amount to more than 224 million m^3 of water. Olesk plot is located in the basins of the two largest rivers of Western Ukraine – the Dniester and the Western Bug. Local river flow reaches 226 thousand m^3 per year from an area of 1 km^2. In other words, if all the rivers are dried up, it is theoretically possible to collect 1429 million m^3 of water per year from the Olesk site. Thus, it is necessary to use almost 15% of the annual flow of rivers of the Olesk section for the needs of hydraulic fracturing. Several submerged sulfur pits could be used for water supply, but water extraction from them will lead to a loss of equilibrium of the underground hydrodynamic system and activation of karst processes, which happened earlier during the quarry production of sulfur. Obviously, the mineral water of the Shklo resort, located near the Novoyavorivsk district, will lose its medicinal properties. Of course, some water will be reused for fracking, and drilling will take place for several years, but the scale of ofresh water withdrawal for technical purposes in an under-supplied region is extremely large. The environmental consequences of this are unlikely to be positive.

Each well cluster requires a site of at least 2 hectares, so the total area of withdrawn arable land, meadows, and forests within the Olesk area will be more than 1400 hectares. This should also include the area of pools for storing technical fluids for fracking, roads that will connect clusters, and technical bases for servicing the gas field. Based on the extent of Chevron's use of the territory in Texas for the development of the Barnett shale gas field, about 5,000 hectares of land will be removed from the use of local communities at the Olesk site.

For the development of shale gas fields, millions of tons of cargo will need to be transported with heavy equipment. For the needs of one well, only in water, about a thousand 30-ton machines are needed. Therefore, heavy machinery with water, propane, and chemicals will constantly move along the roads (Fig. 5).

Fig 5. Parking for heavy vehicle. Shale gas area, Texas, USA (photo from Google)

This will cause a significant dust, vibration and noise load on the environment. It will depend not only on vehicles, but also on the hydraulic fracturing process at the well, where dozens of powerful pumps pump fluid into the wells for a long time. And so periodically, since the gas flow rate is steadily decreasing over time and there is a need for new hydraulic fracturing and new wells. American experience shows that the average shale well gives up 60% of its reserves in the first year of operation and another 30% in the second. After that, it becomes unusable and you need to equip the next well. To compare, a well for extracting natural gas from traditional deposits can remain productive for 35-50 years.

Fracking is planned to be carried out in Silurian deposits at depths of 2-4 km. Olesk site was affected by many fractures. And if hydraulic fracturing is carried out near them, there is no guarantee that they will not open up under pressure and technical liquids with chemicals will not reach the chalk aquifers, which are the main sources of water supply for the population.

However, the main environmental policy and problems are the uncertainty of ways to dispose of hydraulic fracturing fluid, which contains a lot of chemicals and is dangerous to the environment. In many existing fields, after hydraulic fracturing, the liquid rises to the earth's surface and is stored in settling tanks.

Fig. 6. Satellite image of the surface, Barnet field, Texas (photo from Google)

It can be seen at Fig.6 that at the Barnett field in Texas, the waste liquid with chemicals is stored in barns until it evaporates naturally. Barns are abandoned to their fate, destroyed, their contents spread on the ground, volatile chemicals fall into the air, and dissolved in the soil. Given the small population density in the state of Texas and the significant deposits of shale gas in the subsurface, perhaps such environmental risks are partially acceptable. But they are absolutely unacceptable within the Western Ukraine, where the distance between settlements does not exceed 2-4 km, and the population density is 70-120 people/km^2.

Scientific research in the field of mining, environmental safety, and civil protection is being carried out at a high rate, and it is possible that in the future technologies for the safe extraction of shale gas will be developed. However, today, given the small resource base of shale gas and high environmental and technological risks, in our opinion, it is premature to develop shale gas fields within the Western Ukraine. Nowadays it is advisable only to start a purposeful study of Silurian shale layers by geological and geophysical methods [16].

4. Conclusions

In the depths of the Volyn-Podil oil and gas region, according to a set of geological and geophysical criteria, it is likely that shale gas deposits are confined primarily to the Silurian deposits. The recoverable resources of shale gas within the Olesk area are estimated at 150-200 billion m^3. Taking into account Ukraine's annual gas consumption at the level of 32 billion m^3, it can be stated that due to the shale gas of the Olesk section, the state is unlikely to gain energy independence in the strategic aspect.

There is a significant environmental risk of shale gas production associated with the hydraulic fracturing use, unsolved problems of water supply sources and disposal of process fluids. It is advisable to continue the shale gas study in the form of separate pilot projects in order to gain experience in prospecting, exploration, deposit development and assessment of the environmental consequences of shale gas production. Hasty decisions on shale gas field industrial development can turn the recreational zone of Western Ukraine into a dangerous technogenic desert.

References

[1] World Energy Resources. 2016. Published by the World Energy Council. 2016: 1028. Retrieved from https://www.worldenergy.org/

[2] Rutkowski M. Gas pojawja sie i znika, czyli krotka historia szacowania zagobow weglowodorodow neekonwencjonalnych w Polsce. [Gas appears and disappears, or a brief history of estimating of unconventional hydrocarbones in Poland]. Przegland Geologiczny. 2013; 61(6): 331-333 (in Polish).

[3] Khorolskyi A, Hrinov V and Kaliushenko O. Network models for finding optimal economic and environmental development strategies. Procedia Environmental Science, Engineering and Management. 2019; 6(3): 463-471.

[4] Khorolskyi A, Hrinov V, Mamaikin O and Demchenko Yu. Models and methods to make decisions while mining production scheduling. Mining of Mineral Deposits. 2019; 13(4): 53-62.

[5] Poprawa P. Potencjał wystepowania złóź gazu ziemnego w lupkach dolnego paleozoiku w bałtyckim i lubelsko-podlaskim. [Potential of deposits occurrence of natural gas in the Lower Paleozoic shales in the Baltic and Lublin-Podlasie]. Pszeglad Geologiczny. 2010; 58(3): 226-249 (in Polish).

[6] Lazaruk JG, Hubych IB, Syrota TO, Barchuk VV, Derenevskyj AM, Alexandrova IV and Vyslotska OI. Heokhimichni doslidzhennia ta pidrakhunok zapasiv slantsevoho hazu v mezhakh pivnichno-zakhidnoi chastyny Volyno-Podillia. [Geochemical studies and calculation of shale gas within northwestern part of the Volyn-Podolia]. Mineralni resursy Ukrainy. 2012; 2: 9-12. (in Ukrainian).

[7] Krupski YuZ, Kurovets IM and Chepil PM. Prohnozna otsinka resursiv hazu iz chornykh slantsiv syluru Volyno-Podillia. [Estimate of gas resources of black shales of Silurian Volyn-Podolia]. Netradytsiini dzherela vuhlevodniv v Ukraini:poshuky, rozvidka, perspektyvy: Materialy nauk. konf., Kyiv, 27-29 lystopada 2013. Kyiv.: 30-31. [Alternative sources of hydrocarbons in Ukraine: prospecting, exploration prospects: Proceeding of Scientific Conference, Kyiv, 27-29 November 2013, p. 30-31] (in Ukrainian).

[8] Radkovets N, Rauball J and Iaremchuk I. Silurian black shales of western Ukraine: Petrography and mineralogy. Estonian Journal of Earth Sciences. 2017; 66(3): 161–173.

[9] Radkovets N. The Silurian of southwestern mar gin of the East European Platform (Ukraine, Moldova and Romania): Lithofacies and palaeoenvironments. Geological Quarterly. 2015; 59(1): 105-118.

[10] Kurovets I, Drygant D, Naumko I, Kurovets S and Koltun Y. Geological and physical-chemical characteristics of Lower Paleozoic deposits of Volhyno-Podillya, Western Ukraine. Biuletyn Państwowego Instytutu Geologicznego. 2012; 449: 119—130.

[11] Alternatyvy hazozabezpechennia Ukrainy: skraplenyi pryrodnyi haz (SPH) ta netradytsiinyi haz: (Analitychna dopovid Tsentru Razumkova). [Alternative of gas supply of Ukraine: liquefied natural gas (LNG) and unconventional gas: (Analytical report by Razumkov Centre)]. Natsionalna bezpeka i oborona. 2011; 9: 2-47. (in Ukrainian).

[12] Karabyn V, Popovych V, Shainoha I and Lazaruk Ya. Long-term monitoring of oil contamination of profile-differentiated soils on the site of influence of oil-and-gas wells in the central part of the Boryslav-Pokuttya oil-and-gas bearing area. Pet Coal. 2019; 61(1): 81-89.

[13] Malovanyy M, Masikevych A, Kolotylo M and Yaremchuk V. Analysis of environmental safety of recreational territories of mountain ecosystems and development of technical measures for its stabilization. Eastern-European Journal of Enterprise Technologies. 2019; 10(102): 15-24.

[14] Malovanyy M, Petrushka K and Petrushka I. Improvement of Adsorption-Ion-Exchange Processes for Waste and Mine Water Purification. Chem. Chem. Technol. 2019; 13(3): 372–376.

[15] Rusyn IB, Moroz OM, Karabyn VV and Kulachkovs'ki OR. Biodehradatsiia vuhlevodniv nafty drizhdzhamy rodu Candida. [Biodegradation of oil hydrocarbons by Candida yeast]. Mikrobiolohichnyi zhurnal. 2003; 65(6): 36-42 (in Ukrainian).

[16] Chepil VP. Osoblyvosti provedennia heolohorozviduvalnykh robit na slantsevyi haz Volyno-Podillia na rehionalnii stadii vyvchennia. [Features of conducting of geological exploration on shale gas in Volyno-Podillia at the regional stage of studying]. Mineralni resursy Ukrainy. 2019; 2: 21-24. (in Ukrainian).

To whom correspondence should be addressed: Dr. Vasyl Karabyn, Lviv State University of Life Safety, Lviv 79000, 35, Kleparivska St, Ukraine, E-mail: vasyl.karabyn@gmail.com