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# PRIORITY OBJECTS FOR GAS EXPLORATION WITHIN DONBAS

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# ПЕРШОЧЕРГОВІ ОБ'ЄКТИ ДЛЯ ПОШУКІВ ГАЗУ В МЕЖАХ ДОНБАСУ

**Purpose.** Presence of gas in the whole section of coal-bearing rocks in the Donetsk basin and results of successful surface degasification of the rocks suggest the possibility of producing methane from tight surrounding rocks within the regional structural and tectonic units. The purpose of the work is to identify priority objects for rapid establishment of commercial gas production within the Donetsk basin based on the analysis of geological features of its structure and results of the latest works conducted to study this problem.

**Methodology.** Drilling and testing of the well has been carried out. The paper is based on the analysis of the new field studies within the Donbas. The data have been studied and analyzed regarding the drilling and completion of wells aimed at production of methane from the coal-bearing rocks.

**Findings.** We have drawn preliminary conclusions about the possibility of methane production from tight coal-bearing rocks within regional structural-tectonic units of the Donetsk basin. The most efficient methods to ramp up production of hydrocarbon gases within the territory have been determined.

**Originality.** For the first time we have published the preliminary analysis of the results of the most recent exploration works aimed on the evaluation of the possibility of industrial methane production from coal surrounding sandy rocks. We have substantiated the expediency of new exploration works within the territory.

**Practical value.** The issue of rapid increase of hydrocarbons production is critical for Ukraine. Use of methane reserves containing in coal deposits of the Donbas is an alternative way to solve this problem. The historical geological data available allows us to determine quickly and reliably the most prospective locations for further exploration.

**Keywords:** *Donetsk basin, Donbas, hydrocarbon gas, methane, coal deposits, tight reservoirs*

**Introduction.** The Donetsk Basin ("Donbas") is one of the world's most thoroughly explored coal mining regions. The Ukrainian coal resource is ranked as one of the largest in the world. Ukraine's proved coal reserves make 3.8% of the global total, making Ukraine the seventh largest reserve in the world. However, because of high gas content, Ukraine's coalbed methane resource is the fourth largest in the world by some estimates. Located in Europe's backyard, this enormous and well known resource could form the core of a long-life national resource.

Rising prices of Russian gas have also increased the relevance of this resource. The nation should find that with these elevated prices, unconventional gas production should be developed.

Ukrainian coal production is 80 million tonnes per year, making the country the world's 11th largest producer [1]. This coal resource and surrounding rock formations are also very rich in methane, which tragically leads to the deaths of 300 to 400 miners every year. It is recommended to put this massive gas resource to use through unconventional gas exploitation.

Geological institutes of the Soviet era thoroughly explored the Donbas in the 1950s and 1960s drilling tens of thousands of coreholes to ascertain the size of the coal resource in place. A great deal is known about the size and potential of the Donetsk Basin coal gas resource significantly reducing exploration risk.

Ukrainian coal production has stabilized after a period of major decline. Many deep uneconomic mines have been closed. Some of these mines continue to vent large amounts of methane into the atmosphere. Even though coal production has declined by 100 million tons per year since the collapse of the Soviet Union, substantial operations continue in this high gas content basin. These decommissioned mines and continuing operations have attracted the interest of the United States Environmental Protection Agency (EPA) because of the environmental impact of their greenhouse gas emissions. Much of the English language information currently available on the Donetsk basin is due to the efforts of the EPA to see this resource put to use.

Despite the decline in Donetsk coal mining, the area still vents annually more than 70 billion cubic feet of gas per year into the atmosphere [2].

**Geological history of the Donbas.** The Donetsk Basin is an area of approximately 60,000 square kilometers. It was largely formed in the Carboniferous era. It contains more than 300 coal seams, some buried as deep as 1,800 meters, only 130 of the seams have a thickness over 0.45 meters. The coals range in rank from sub-bituminous to anthracite.

The Donbas has been formed in a continuous sedimentary rift between the Ukrainian Shield to the South West and the Voronezh Massif to the North East. This rifting began in the mid-late Devonian period and the extension of this rift includes the Prypyat marshes to the North-West in Belorussia, the Dnieper-Donets basin, the Donbas and the Karpinsky Swell in the South-East.

Following the initial rifting, major subsidence began in the Carboniferous Era. Throughout the Carboniferous period the Donetsk basin varied between swampy plains, peat bogs and shallow sea environments. This resulted in interspersed layers of sandstone, mudstone, limestone and coal.

During the Permian Era, the Donbas experienced substantial subsidence. It was during this period of deep Permian burial that the coalification of the Donbas sediments took place. This was the primary coalification event in the basin. Subsequent magmatic intrusions led to pockets of higher maturity coals. During the Permian burial large volumes of volatile organics were generated.

During the coalification process from 60 to over 150 cubic meters of methane is generated per ton of coal [2]. Much of this methane usually escapes into the atmosphere, however, owing to the deep burial of the Donbas the methane was trapped in the coal seams and surrounding rocks.

Following the Permian burial, the Donbas went through a period of rift-inversion.

It is believed that the formation of the Ural Mountains led to this reversal and the compression of the Donbas megablock. Whereas the Dnieper-Donets sedimentary basin remained deeply buried, faulting and pressure forced the uplift, rotation and deformation of the Donbas megablock. The stress of the inversion caused significant gas migration.

Following the inversion, in the Early Cretaceous Period, the South-Eastern portion of the Donetsk basin was exposed and much of the methane content escaped. These coals are characterized by high maturity and lower methane content.

The most common coals in the Donetsk basin are from the Serpukhovian (Mississippian) and Moscovian (Pennsylvanian) period where large amounts of methane present in the Donetsk Basin are trapped through conventional traps, contrasting permeability within the surrounding lithology and adsorbed to the surface of the coal.

The miners of the Donbas have long known of the presence of gas in the overlying lithology. Typical degasification techniques have included drilling boreholes from the mining gallery into the roof of the mined seam in advance of long wall mining. These holes were put on pump and intended to evacuate gas not only from the coal itself but also from the overlying rock which is believed to be gas saturated as well.

This technique has been justified in practice, because typically after the collapse of the roof during long wall mining operations, methane levels in the mining gallery rose and mining was halted.

As it has been stated, during the formation of the Donbas coalbelt, large amounts of methane were generated and expelled from the coals into the surrounding lithology, the subject of methane content in the surrounding sandstone seams overlying the coals and the ability to recover this gas has become very topical.

Several private enterprises have endeavored to determine whether the methane embedded in the surrounding coal seams of the Donbas is mobile and can be extracted economically. This article will endeavour to assess the challenges and likelihood of economic extraction of gas from clastic rocks in the Donbas.

**Resource estimates.** The Donetsk basin contains estimated 231 billion tons of coal reserves, including 170 to 180 billion tons of reserves that are classified as recoverable. To be defined as recoverable, a seam must be located at depths of 500 to 1,800 meters and be greater than 0.3 meters thick. This coal is known to contain a very significant methane resource. The methane resource in place has been estimated by Ukrainian and Western assessments to be potentially as high as 117 trillion cubic meters. According to various Ukrainian assessments, the coal seams that are over 0.3 meters in thickness, and within the depth interval of 500 to 1,800 meters, contain between 1,400 and 2,500 billion cubic meters of adsorbed CBM.

It is unknown how much of this resource is recoverable. The United States Environmental Protection Agency estimates Ukrainian CBM resource potential at between 10 and 12 trillion cubic meters, or approximately the same resource as found in the United States.

Common cut-offs are frequently assessed for theoretically recoverable reserves based on reservoir depth, aggregate seam thickness, gas content, and permeability; other factors include water content, pressure, ash content and coal rank [3]. The relatively high rank and extreme gassiness of the Donetsk coals suggest all these factors are satisfied in almost the entire basin. The primary uncertainty is permeability, as reliable data is not available for this factor and production testing will be required to provide values for this crucial factor.

Ukrainian coal, owing to its relatively high rank, low permeability, and deep paleological burial, has very high gas content; almost all Ukrainian coals would be classified by international standards as ultra-gassy.

The varying grades of coal found in the basin have varying gas contents. The gas content of coking coal, lean-coking coal, and lean coal is generally from 20 to 25 cubic meters/ton daf while that of anthracites would be higher, typically in the range of 40 to 45 cubic meters/ton daf. When interpreting these measures it is important to note that the daf measurement of coal is of the dry ash-free weight. Where coals have higher ash and water content, comparable gas content on a volume basis will be lower.

The entire Donetsk Basin is underlain by Middle Carboniferous coal seams. The number of mineable coal seams and coal-bearing beds tends to gradually decrease from the western towards the eastern and northern sections of the basin. The distance between coal seams in this area typically ranges from 20 to 40 meters long.

**Data quality.** The Donbas has been described as one of the most thoroughly explored geological regions in Europe. The EPA has worked with the Soviet era well data and the independent Colorado based Raven Ridge Resources to assess the geological potential of this region. The EPA has

published data values for seam thickness and depth, gas content, moisture content, and porosity and permeability data for the surrounding lithology [4].

The EPA research has, however, approached the Donbas as a coal mine methane (CMM) project rather than a CBM project. The EPA's primary concern involves large amounts of methane vented into the atmosphere by Ukrainian coal mining. For this reason, the data it has collected has focused on existing, producing, mines with large scale methane emissions. Their researched is also geared to recovery of methane from ventilation shafts and in mine degasification boreholes, and not production from virgin seams.

The problem with CMM as opposed to CBM is that it usually has a low caloric value; this is true of gob well gas as well as CMM. The methane communicates with air in the ventilation shafts and mining galleries and as a result often has low methane content. CBM is usually of sales grade owing to the adsorption isotherms of coal, and the relative preference for coal of carbon dioxide.

For this reason, the information reported by the EPA does not contain certain vital production data such as coal seam permeability, precise pressure data and isotherm mapping. This information will have to be obtained either from accessing existing well log data, or obtaining new core samples. An attempt will be made to approach the EPA and obtain the original Raven Ridge Report. However, the EPA's focus on areas of existing mining of high-rank coal means that it is of reduced relevance for prospective CBM exploration.

Contemporary Ukrainian researchers have shown greater interest in the prospects of CBM production. Their work has, however, tended to treat production targeting as a tight-gas phenomenon rather than a CBM prospect. Their focus has been on producing from fissures and conventional traps in the thick Middle Carboniferous section of the Central Donbas, with its large gas accumulations in low permeability country rock formations.

The Donbas undoubtedly contains a large gas resource; however, estimates of this resource should be benchmarked against the quality of the historical data and methodology used in past explorations. As a potential source of free flowing gas, the Donbas represents a large, but low quality gas resource, so errors in methodology or measurement are relevant to any estimates of its size, and very material to an understanding of recoverability.

The main tools available for gas content estimation include core samples for coals, and DSTs for sands, both these techniques had their advantages and disadvantages. The taking of core samples was done in a manner that would meet international standards. Core was removed, but in a hot water bath and methane flashed-off was recorded, finally the sample was crushed and methane recovery was measured. Importantly, rather than independently calculating gas lost during tripping and core removal from the core barrel, a standard coefficient of 30% was added to measured gas contents to account for lost gas. In measuring gas content of sandstones, the techniques used by Soviet researchers did not meet international best practice of the petroleum industry. The gas content of sandstones was reported in cubic meters per ton of rock, which is not consistent with practice in the petroleum industry, where gas content is reported as a percentage of porosity.

The shortcomings in the methodology used, raise significant questions concerning the reliability of estimates of gas contained in the surrounding sandstones. In particular, sometimes the methodology for calculating gas saturation was based on the relative ratio of water and gas coming into the borehole. This is clearly an erroneous methodology as it ignores relative permeability.

Gas content estimates of clastic formation in the Donbas were limited by lack of reliable and meaningful logging tools. The typical logging suite included a caliper log, a resistivity log, and a gamma ray log; a neutron gamma log may have also been included. The standard coal logging suite was intended for lithological correlation and not for estimating gas content in clastics, for this simple reason it lacked a porosity tool to perform gas content assessments.

After 1980, when much of the exploration of the Donbas had been completed, an acoustic logging tool was included in the suite, this allowed estimating gas content in clastics the most reliably, but even after the introduction of this tool, the reliability of these estimates cannot be assured. Recent wells drilled in the Donbas discovered much lower gas saturation than it was suggested by historical logging tools [5].

**Continuous accumulation.** The reported extensive presence of methane in coal mining operations has led to assumption that there may be ubiquitous quantities of shallow gas of clastic origin in the Donbas.

Recent exploration efforts have suggested these expectations may not be as realistic as thought. The latest shallow tight gas wells drilled in the Krasnoarmeisk area of Donetsk were unable to recover commercial quantities of gas. Two wells drilled within the area by SE "Center of alternative types of fuel" were studied and tested using best international and Ukrainian practises of stimulation, but both wells failed to provide stable gas flow [6].

The KRA-1 well drilled by Karbona Energo LLC encountered limited background gas during the drilling, with mud logging suggesting the presence of some methane. The methane content of mud returns rarely exceeded 1% of mud returns and was typically associated with coal seams rather than clastic reservoirs.

Following the drilling of the well, a logging analysis was made without reliable water salinity data. Based on a series of conceivable water quality numbers, the resistivity in certain clastics was inferred to represent possible pay intervals.

These intervals when perforated and fracture stimulated did not flow gas in commercial quantities. The formations were normally pressured or slightly underpressured and water quality was determined to be much less saline than previously believed. Based on this information, the potential pay zones were reclassified as likely low gas bearing. Although small amounts of gas were recovered from the well, it was most likely semi-irreducible gas from the formation (picture).

The results of these wells suggest that gas saturation in clastics has been exaggerated by historical logging results.

*Pic. Flow test of KRA-1 well*

**Expectation of finding free gas targets.** It is proven that in the Donetsk-Makiivka region free gas is concentrated in the crests of high hinges of monoclines, flexures and hanging-walls of reversed faults. Gas pockets may also be associated with lithologically related permeability contrasts [2].

In the Southern Donbas region and southern part of Krasnoarmeisk region which have the geological origins similar to the Donets-Makiivka region, there are many similarities in the distribution of methane. Gas accumulations are focused in dome structures. High concentrations of methane are also located under fault zones [2].

The results of detailed prospecting within these areas show limited porosity in Carboniferous sandstones (from 2–5 to 9–13 %) and permeability of (0.05–0.1 mD) [2].

The Donetsk Basin offers unique possibilities for the exploitation of low permeability sandstones. The Donetsk coals are interbedded with sandstone layers of varying permeability. These sandstones often contain substantial gas reserves which may suggest communication between the sandstones and the underlying coal beds, or the gas may have migrated to the surrounding lithology during the Permian uplift.

There is some experience with vertical gob wells from the Donetsk Basin. Over 120 boreholes have been drilled to depths of 260–1200m of which over 50 holes were hydraulically stimulated. These gob wells achieved maximum production of 2900 cubic meters per day, higher flow rates of 10,000 cubic meters per day were reported when the well intersected gas bearing sandstones. When overlying formations subsided after long wall mining, gob well production increased to 48,000 cubic meters per day. Cumulative production per gob well has reached 50 to 80 million cubic meters, with a gob well at Yuzhnodonbaska producing over 160 million cubic meters in a five year period [7].

A 1999 study by Montan-Consulting GmbH found that a 200 well degasification project over a 100 km² area could produce 500–700 million cubic meters of gas per year. They estimated the cost of this gobwell project at $60–65 million [8]. This implies per well production of 1400–2000 cubic meters per day at well spacing of 50 hectares per well, and a cost of $300,000 per well.

**Conclusions.** This recent exploration effort would tend to suggest that the existence of a regional ubiquitous shallow gas horizon in the clastics of the Donbas is unlikely. Owing to the great age of the rocks, their reduced permeability, and the considerable amount of uplift and displacement that has occurred subsequent to the main Permian gas generation event; the majority of gas found in tight clastics adjoining coal seams is probably irreducible gas and unlikely to flow in commercial quantities.

Further exploration should be oriented towards small size conventional traps. The presence of small structural localized traps within the Donbas remains an interesting possibility for gas exploration, but care must be given to ensuring that the structures are coeval with gas migration events as the presence of a structural feature and gas, does not necessarily mean that the gas will have filled the reservoir in sufficient quantities to be free flowing.

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Пілотний проект: особливості випробування комплексу методів вивчення та видобутку метану вугільних родовищ Донбасу / К.В. Автономов, Б.І. Лелик, С.Г. Храпкін [та ін. ] // Геолог України. – 2009 – № 3. – С. 74–82.

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Присутність газу в усьому розрізі вугленосних порід Донецького басейну та результати досить успішної поверхневої дегазації даної товщі порід сприяли формуванню припущення щодо можливості видобутку метану з щільних вуглевміщуючих порід у межах регіональних структурно-тектонічних одиниць.

**Мета.** Визначення першочергових об'єктів для швидкого налагодження промислового видобутку газу в межах Донецького басейну, виходячи з аналізу геологічних особливостей його будови та результатів останніх робіт, спрямованих на вивчення цієї проблеми.

**Методика.** Проведені роботи з буріння та випробування свердловини. Робота основана на аналізі нових даних польових досліджень у межах Донбасу. Вивчені й проаналізовані дані буріння та освоєння свердловин, орієнтованих на видобуток метану з вугленосної товщі.

**Результати.** Надані попередні дані щодо можливості видобутку метану з щільних вуглевміщуючих порід у межах регіональних структурно-тектонічних одиниць території Донецького басейну. Визначений найбільш раціональний та пріоритетний шлях до нарощення видобутку вуглеводневих газів на території досліджень.

**Наукова новизна.** Уперше представлені дані останніх геологорозвідувальних робіт, спрямованих на оцінку можливості промислового видобутку метану вугільних родовищ із вміщуючих піщаних порід, наведено попередній аналіз результатів цих робіт. Обґрунтована доцільність проведення нових геологорозвідувальних робіт на території.

**Практична значимість.** Наявні геолого-геофізичні дані минулих років дозволяють швидко та достовірно визначити найбільш перспективні об'єкти для проведення подальших робіт.

**Ключові слова:** *Донецький басейн, вуглеводневий газ, метан, вугільні родовища, щільні колектори*

Присутствие газа во всем разрезе угленосных пород Донецкого бассейна и результаты достаточно успешной поверхностной дегазации данной толщи пород обусловили формирование предположения о возможности добычи метана из плотных углевмещающих пород в границах региональных структурно-тектонических единиц.

**Цель.** Определение первоочередных объектов для быстрого налаживания промышленной добычи газа в пределах Донецкого бассейна исходя из анализа геологических особенностей его строения и результатов последних работ, ориентированных на изучение данной проблемы.

**Методика.** Проведены работы по бурению и испытанию скважины. Работа основана на анализе новых данных полевых исследований в границах Донбасса. Изучены и проанализированы данные бурения и освоения скважин, ориентированных на добычу метана из угленосной толщи.

**Результаты.** Представлены предварительные данные касательно возможности добычи метана из плотных углевмещающих пород в границах региональных структурно-тектонических единиц Донецкого бассейна. Определен наиболее рациональный и приоритетный путь к наращиванию добычи углеводородных газов на территории исследований.

**Научная новизна.** Впервые представлены данные последних геологоразведочных работ, ориентированных на оценку возможности промышленной добычи метана угольных месторождений из вмещающих песчанистых пород, приведен предварительный анализ результатов этих работ. Обоснована целесообразность проведения новых геологоразведочных работ на территории.

**Практическая значимость.** Имеющиеся геолого-геофизические данные прошлых лет позволяют быстро и достоверно определить наиболее перспективные объекты для проведения дальнейших работ.

**Ключевые слова:** *Донецкий бассейн, углеводородный газ, метан, угольные месторождения, плотные коллекторы*

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