

## Exploration history and hydrocarbon potential of Ukraine. Can it contribute to the energy future?

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### Summary

As the biggest European country, Ukraine includes three petroleum provinces with about 500 hydrocarbon fields discovered over a 150-year exploration history. Even though the largest fields are considered to be approximately 80% depleted, Ukraine ranks second in Europe in terms of proven remaining natural gas reserves (32 Tcf) and fourth in terms of oil reserves (635 Mbl). Moreover, the latest research shows that these reserves (onshore and offshore) can be significantly increased by producing numerous previously undeveloped productive horizons even in brownfields, and just applying the modern approaches in exploration and state-of-the-art technologies used worldwide. Therefore, the hydrocarbon reserves of Ukraine can satisfy not only domestic needs in oil and gas but partially become a source of energy for Europe in the coming decades. The abstract reveals the peculiarities of the hydrocarbon potential of each Ukrainian petroleum province.

### Introduction

Ukraine has three main hydrocarbon productive regions, which despite their long exploration history are still prolific and promising: the Dnieper-Donets Basin (east), the Carpathian Basin (west), and the northern part of the Black Sea Basin including its onshore part, the Crimea peninsula (south). Two other basins, the Volyn-Podilia Basin (west) and the Pre-Dobrogea Basin (southwest), are less produced and studied. Oil and gas exploration has mainly focused on conventional resources, whereas unconventional resources have been under study since 2011.

Ukraine is ranked second in Europe after Norway in terms of proven remaining natural gas reserves (32 Tcf) with annual production of 716 Bcf and fourth in terms of oil reserves (635 Mbl) with annual production of 12.5 Mbl. The peak of production in the country reached in the 1970s when the annual gas production was nearly four times more and oil nine times more than it is now.

Recent research indicates that Ukraine still has considerable conventional hydrocarbon resources including numerous new prospects, underexplored reservoirs, and reservoirs at brownfields, which, in terms of the production methods used in Ukraine, are hard to recover or non-recoverable. However, due to the latest technologies, it is feasible to extract significant amounts of residual hydrocarbons at a fair cost.

### Western petroleum province – the Carpathians and the Volyn-Podilia Basin

The Ukrainian Carpathians, the oldest petroleum province in the world, extends from NW to SE and involves the Carpathian Foredeep zone – the main producer of gas, and the Outer Carpathians – the main producer of oil. The Outer Carpathians is a flysch belt made up of a stack of nappes and thrust sheets. Their two main nappes (Boryslav-Pokuttia and Skyba) represent a complex set of superimposed thrust-sheets, composed of Cretaceous to Miocene flysch succession overlain by molasse. The Carpathian Foredeep is the thick Miocene molasse (up to

5000 m in the south-eastern part) which is underlain by the basement of the East European Craton.

Active exploration in the Carpathians began in the mid-19th century followed by discovery of 115 oil and gas fields. In 1861, one of the world's first oil rigs was constructed there. By 1909, the area was producing 5% of the world's oil, or about 40,000 barrels per day, and had more than 12,000 rigs. Oil and gas industry boomed in the region when the Boryslav oil field (1893) and the Dashava gas field (1920), Europe's largest at the time, were put in commercial production. The majority of discoveries were made by the 1990s, and only a few minor fields have been made in the past 30 years mainly due to a lack of funding in exploration and production.

Almost the whole sedimentary secession of the Carpathian Foredeep and the Outer Carpathians contains numerous productive reservoir horizons in different formations, however, only the uppermost part of the sedimentary basins (up to the depth of about 3 km) has been intensively drilled. Most discoveries have stacked productive horizons, which makes drilling each new well more profitable if one approaches both brownfields and green fields properly in terms of the accurate construction of their geological model and production technology. Previous exploration was mainly focused on anticline traps whose identification was based on legacy seismic data with poor quality issued in the 1960-80ss. Conducting high-resolution seismic surveys is extremely key to the modern understanding of the complex geological structure of the region as a whole, and especially within available fields, as well as for identifying new prospects, including stratigraphic traps. However, even on the basis of available geological and geophysical data the most recent independent studies show that the area possesses around 1 billion barrels of untapped oil potential, remaining recoverable gas reserves can also be substantially increased.

The Volyn-Podolia region (the Lviv Paleozoic Basin) is located in Western Ukraine and it is the south-western margin of the East-European Craton. Only two small gas fields were discovered in the basin in 1960-70ss. The region became attractive for shale gas after exploration activity surged in neighboring Poland in 2008. Based on studied well data the most promising intervals for shale gas exploration in the basin are the Lower Silurian and the Upper Vendian. However, the absolute parameters of their potential are still rather uncertain.

### **Eastern petroleum province – the Dnieper-Donets Basin**

The Dnieper-Donetsk basin (DDB) is the principal producer of hydrocarbons in the country accounting for 90 % of all current Ukrainian production from about 250 hydrocarbon discoveries. The DDB, the deepest basin in Europe with up to 19 km of sediment fill, developed as an intracratonic rift system. It is filled with a thick Upper Devonian syn-rift sequence, which was deposited in a shallow-marine environment and contains a significant amount of salt, and is overlain by a post-rift sequence of Carboniferous age and younger.

The first oil discovery in the DDB was made in 1939. Over the 80 years, the exploration activity has been mainly focused on the upper 4-5 km of its part, although some wells drilled up to 6 km. The most production (85%) in the basin is made from gas fields that predominate in the southeastern part of the basin; the oil fields mainly concentrate northwestward. The largest oil and gas accumulations associate with structural traps in Carboniferous-Permian sediments that were formed due to the movements of the Devonian salt. About 20 % of the gas reserves are in the Shebelynka gas field with remaining recoverable reserves of 3.6 Tcf, the largest field in the basin discovered in 1950 and still produced.

The official conventional remaining recoverable reserves of the basin stand for 0.4 Bbl of oil and 27 Tcf of gas. At the same time, the most productive hydrocarbon fields in the DDB are considered to be at the final stage of production. However, preliminary results from our detailed reconsiderations of geological models of randomly selected gas fields indicate that they are underexplored and can contain 20 times more recoverable reserves than officially estimated. This means that numerous brownfields in the DDB require at least a modern approach to re-evaluate their geological model. Additionally, newly obtained results suggest the discovery of large gas accumulations associated with structural traps in the vicinity of salt diapirs and stratigraphic traps that have not been carefully studied with high-resolution seismic.

### **Southern petroleum province – the Black Sea and the Pre-Dobrogea Basin**

The Black Sea (BS) is one of the most promising unexplored areas in Europe. The Ukrainian economic sector covers one-quarter of the whole BS. Exploration activity has been taking in the region for about the last 50 years. Eight gas-condensate commercial fields have been discovered within the Odesa shelf and one oil-gas field (Subbotina) was discovered in 2005 within the Kerch shelf. Hydrocarbon accumulations were also discovered on the Crimean Peninsula and the Azov Sea. The Upper Cretaceous to Lower Miocene sequences contains the principal productive horizons. According to the data from the adjacent area the source rocks are Oligocene and Aptian-Albian mudstones.

A series of inverted anticline structures that originated during Cenozoic compression events and, in most cases, along latitudinal faults, constitute the principal productive traps in the shelves. The official estimates of the remaining reserves in these fields are rather low. Some of the offshore fields are underexplored and our preliminary analysis based on the results of the reinterpretation of geophysical and geological data has shown that there are good chances for increasing their production by up to four times after further exploration work, including exploratory drilling. The Upper Jurassic carbonate, Lower Cretaceous (Albian) sandstones, and Miocene-Pliocene fluvial sediments can be considered potential reservoirs. Numerous undrilled anticlines, potential plays in the existing fields, and traps created by geological punchouts and fluvial channels are examples of prospects.

A very important offshore discovery made in 2005 was the Subbotina Field, located on the Kerch shelf. Our assessment has shown that the recoverable reserves of the field reach some 750 Mbl of oil and about 700 Bcf of gas. The discovery revealed the enormous hydrocarbon potential of the whole Kerch shelf (the Sorokin Trough).

Drilling has not been carried out in the deep water of the Ukrainian BS. However, its enormous potential is provided by numerous look-alike anticlines in the deep-water part of the BS as well as Miocene-Pliocene submarine fans. Furthermore, according to the seismic data, the numerous gas chimneys and bright spots are widely developed within the deep water area which are clear indicators of hydrocarbons. Moreover, the recent discoveries of large gas fields in Turkish (Skarya Gas Field, 25 Tcf) and Romanian (Doina and Ana Gas Fields, 35 Tcf) deep-water sectors in Miocene-Pliocene sands strongly support high hydrocarbon potential of the Ukrainian part of the BS. Our preliminary estimate, based on the interpretation of seismic data and other geological information, shows a high probability of discovering giant and large fields both in the shallow and deep-water parts of the Ukrainian BS, each of which can contain more than 1.7 Tcf of recoverable gas reserves.

The Pre-Dobrogea Basin is a Permian-Triassic paleorift. In the 1980s small oil pools were discovered in Devonian carbonates at the depth of 2-3 km by two fields in Ukraine that have not been produced. The region's oil and gas potential is generally not well studied.

### Unconventional resources

Ukraine is considered to have substantial unconventional gas potential in the form of coalbed methane (150 Tcf) in the main coal mining areas of eastern Ukraine, shale gas (500 Tcf) in the Volyn-Podolia basin and the DDB, and tight gas (140 Tcf) in the DDB. Despite such an optimistic prognosis of unconventional gas potential in the country, these resources are still at the stage of the investigation, since the issues of the generation potential of source rocks, their distribution, organic matter content, degree of its maturity, and dynamics of the hydrocarbon systems are still unknown.

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