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GEOLOGICAL CONDITIONS OF THE CARPATHIAN REGION AND SPECIFICS OF DRILLING: COMPARISON WITH INTERNATIONAL EXPERIENCE

Kucher Mykhailo Stepanovich
PhD student at the Institute of Engineering Mechanics and Robotics
ORCID ID: 0009-0004-2611-5639
Ivano-Frankivsk National Technical University of Oil and Gas, Ukraine
Scientific supervisor: **Artim Volodymyr Ivanovych**
D., professor,
ORCID ID: 0000-0002-8938-552X
Professor of the Department of Civil Engineering and Energy Efficient Structures
Ivano-Frankivsk National Technical University of Oil and Gas, Ukraine

Abstract. *The article discusses the geological conditions of the Carpathian region, which create numerous challenges for drilling. The main attention is paid to the complex geological structure, unstable rocks, high reservoir pressure and temperature, as well as difficulties in transporting equipment in mountainous terrain. Examples of the application of international experience in similar conditions are given, in particular, in Canada, Norway and the United States, where adaptive drilling technologies such as horizontal drilling, special drilling mixtures and automated control systems are used. The conclusions of the article emphasize the need to introduce innovative technologies to improve the efficiency and safety of drilling operations in the Carpathians.*

Keywords: *Carpathian region, geological conditions, drilling, unstable rocks, tectonic faults, reservoir pressure, international experience, adaptive technologies, horizontal drilling, automated control systems.*

The problem statement in the article is to identify and analyze the unique geological conditions of the Carpathian region, which create significant difficulties for drilling and mining. Due to the complex geological structure, the presence of unstable rocks, high reservoir pressure and temperature, and mountainous terrain, there is a need for special drilling technologies and methods that ensure the stability and safety of wells. The problem also lies in the limited local experience in solving such complex tasks, which emphasizes the need to apply international experience and the latest technologies for efficient drilling in the Carpathians.

Introduction

The Carpathian Mountains are not only an important natural and cultural region, but also the object of significant scientific and economic research in the field of geology and natural resource extraction. Given the complexity of the geological structure of this mountain range, special attention should be paid to drilling technologies used in such difficult conditions. The mountainous conditions of the

Carpathians require a specific approach to drilling, as well as constant monitoring of seismic activity and geophysical changes in the underground layers. In addition, a comparison with international practices can help in selecting the most efficient and safe drilling methods for Ukraine.

The article discusses the geological conditions of the Carpathian region, the specifics of drilling in these conditions, as well as opportunities for comparison with drilling in similar mountainous areas of the world, such as the Alps, Appalachia and Norway.

Geological characteristics of the Carpathian region

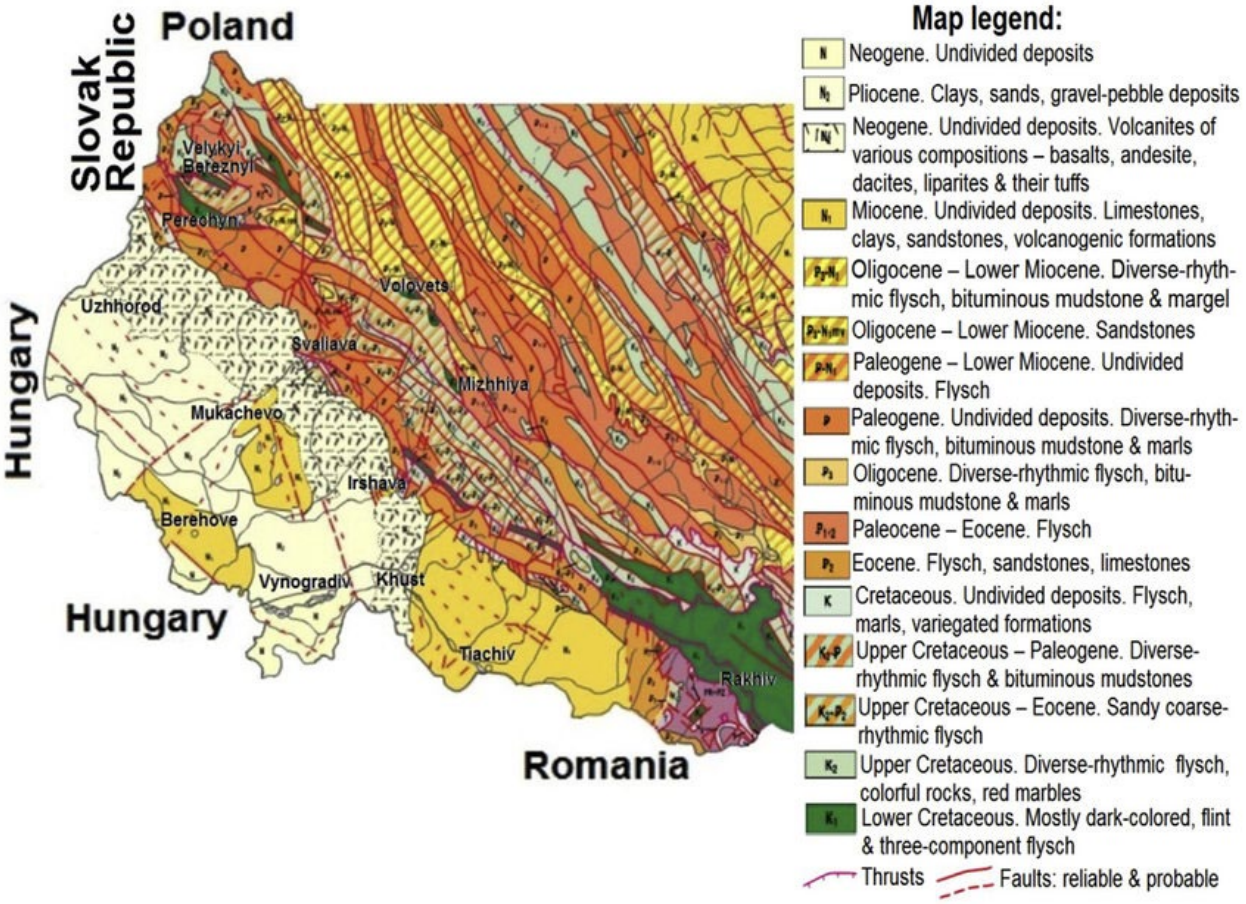

Fig. 1 Ukrainian Carpathians

The Carpathian Mountains are a mountain system that stretches across several countries, including Ukraine, Poland, Slovakia, Romania, and Hungary. The mountain structure of the Carpathians was formed as a result of alpine orogeny, which lasted from the Paleozoic to the Cenozoic. The geological features of the Carpathians make it difficult to drill and extract natural resources in the region.

Structural geology and tectonic processes. The Carpathians are a classic example of tectonic activity zones, where continental and oceanic plates interact as they close, creating numerous faults, folds, thrusts and other complex geological structures. Tectonic processes, in particular, the Alpine process, have formed the Carpathians as a complex geosynclinal massif consisting of various rock types: from limestone, sandstone and clay to metamorphic and igneous rocks. This creates additional difficulties for drilling due to the stratified structure and various types of geological structures.

Mineral resources and their importance for drilling. The Carpathian Mountains are an important region for mineral extraction. Numerous oil and gas fields are located here, in particular in the so-called Carpathian oil and gas basin, which covers western Ukraine. In addition, significant coal deposits have been discovered in the Carpathians, as well as rich mineral water deposits. The geological characterization of these resources is important for planning and conducting drilling operations. In particular, the discovery and development of new oil and gas fields requires taking into account not only the depth of deposits, but also geological features, such as the presence of natural faults, cracks and karst rocks, which can complicate the drilling process.

Soils and groundwater. The soils in the Carpathians are diverse, with both acidic and alkaline soils, which are important for the stability of wells. One of the biggest challenges is groundwater, which is widespread in the Carpathians. It can penetrate drill holes, which complicates operations and requires special sealing methods. There is also a problem with maintaining the groundwater level in the drilling areas, which requires constant monitoring and the use of waterproof materials.

Seismic activity. One of the most important characteristics of the Carpathians is their seismic activity. The Carpathians belong to the areas with increased seismic activity, which creates risks not only for infrastructure construction but also for drilling. The need to take seismic risks into account increases when drilling at significant depths, which requires additional safety measures and special technical solutions for the stability of wells and equipment.

Specifics of drilling in the Carpathians

Fig. 2 Drilling rig

The drilling process in the Carpathians is complex and requires taking into account special geological conditions, such as high seismic activity, groundwater and complex tectonic structures.

Technical difficulties of drilling. Drilling in the Carpathians requires the use of specialized methods due to the variability of geological layers, the presence of natural faults and high costs of maintaining technical equipment. Such conditions are characterized by drilling to great depths, where conventional methods may be ineffective. Often, special drilling rigs with reinforced materials and technical solutions are used for drilling, which allow working in such conditions.

Use of modern technologies. An important aspect is the use of the latest technologies for drilling in such difficult conditions. Among them are technologies related to the automation of drilling processes, the use of specialized materials for sealing and protecting wells, as well as constant monitoring through geophysical tools to detect changes in geological layers and identify potential problems.

Groundwater management. Groundwater availability is another important factor that complicates drilling in the Carpathians. To combat this problem, various

methods of drainage are used, as well as special sealing materials to reduce water leakage into the well. The use of the latest sealing methods helps to avoid erosion of well walls and maintain their stability throughout the entire period of operation.

International experience and comparison with other regions

Comparison with other mountainous regions of the world can provide useful lessons for improving drilling technologies in the Carpathians. Other countries with similar geological conditions demonstrate a variety of approaches to solving these problems.

Norway and Sweden.

Norway and Sweden have similarly challenging mountainous terrain with a high level of seismic activity, which poses numerous challenges for drilling. However, thanks to the introduction of high-tech drilling rigs that automate most operations, as well as specialized drilling materials, both countries have been able to reduce drilling costs and improve safety. The use of geophysical and geochemical monitoring systems allows for early detection of anomalies, which helps to avoid accidents.

USA (Appalachia)

The Appalachian region in the United States is an important example for comparison with the Carpathians. It also has difficult geological conditions, in particular, due to significant tectonic movements and high seismic activity. In the United States, hydraulic fracturing (fracking) methods are actively used to extract oil and gas resources from hard-to-reach formations. These methods can be adapted to the conditions of the Carpathians to increase production.

Switzerland and the Alps

The Alps also face similar drilling challenges, including a high level of seismic activity. To ensure the stability of drilling rigs and reduce environmental risks, Switzerland uses drilling technologies that provide for maximum sealing of wells and constant monitoring of geophysical parameters.

Prospects for drilling development in the Carpathians

The development of drilling in the Carpathians depends on the introduction of the latest technologies and improved safety standards. However, it is important not only to

adapt international technologies, but also to take into account the specifics of Ukrainian geological conditions to achieve optimal results.

Table. 1 - Comparison of International Drilling Experience in Mountainous Regions

Country	Methods and technologies	Challenges	Achievements
United States of Americ	Rotary and percussion systems	Deep drilling in difficult geological conditions	High-quality results and efficiency
Canada	Nanotechnology for strengthening materials	Extreme climatic conditions	Increasing sustainability and durability
Norway	High-tech drilling platforms	High mountains and harsh weather conditions	Stability of the drilling process
Japan	Vibration and noise reduction technologies	Densely populated mountainous areas	Reducing environmental impact
Ukraine	Optimization of drilling tool geometry	High risk of cave-ins and landslides	Increased safety and efficiency of operations

Conclusions. The Carpathian region is challenging for drilling due to its geological, seismic and environmental conditions. However, modern technologies and international experience can significantly improve drilling efficiency and reduce environmental and technical risks. Important aspects include automation of processes, use of new materials for well stability, and continuous monitoring of geophysical parameters for safety.

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Kucher M.

Scientific adviser: Artym V.