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New 3D seismic data uncover inspiring exploration potential for oil and gas offshore the Dobrogea Foredeep, Ukraine

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More than forty promising structures were identified and characterized in the Dolphin 01—10 E&P special-permits area of NJSC Naftogaz of Ukraine within the Inner zone of the northwestern Black Sea shelf based on the latest 3D seismic data processing and analysis of geological and geophysical information. The geological model of the study area was refined and detailed, and the main components of geological risk for prospective oil-and-gas bearing complexes were assessed to form a portfolio of hydrocarbon play-based exploration prospects along with its ranking and due decision-making.

Key words: Black Sea, E&P special permits, 3D seismics, geological interpretation, hydrocarbon leads, play-based exploration.

Introduction. Play-based exploration, which includes the assessment of probabilities for essential petroleum system components (charge, trap, reservoir, seal) and integration with basin analysis, is crucial for modern oil and gas exploration in regions with limited geological study. More than thirty promising structures were identified and characterized in the Dolphin 01-10 E&P special-permits area of NJSC Naftogaz of Ukraine within the Inner zone of the northwestern Black Sea shelf based on the latest 3D seismic data processing and analysis of geological and geophysical information.

3D Seismic data acquisition, processing, and interpretation. The northwestern shelf of the Black Sea mega-basin is the main gas production area within the Southern oil and gas region of Ukraine. This region offers Ukraine great opportunities for hydrocarbon prospecting and in the unexplored area. In 2021, PGS Exploration ASA, under a contract with NJSC Naftogaz of Ukraine, conducted high-resolution and 3D seismic acquisition coupled with detailed bathymetric mapping in a shallow water area of 5000 km^2 in the Inner northwestern shelf of the Black Sea [Tauvers et al., 2022].

This study delineated in detail three prominent thrusted basement steps forming the Krylov sub-basin (the Dniester, Alibey, and Tendra basement steps) and the Vylkove mini-basin, surrounded by Kiliya, Shatskyi, Lebedinyi, and Zmiinyi Island horsts of crystalline basement and filled with seismically translucent south-dipping seismic sequences segmented by inherited normal faults (Fig. 1).

Seismic data treatment included state of the art depth processing techniques, namely full-waveform inversion, Kirchhoff pre-stack depth migration, and separated wave field imaging. It was a milestone in the exploration of the region [Tegnander et al., 2024]. Several types of seismic facies of the acoustic basement characterize the deep subsurface of the study area. Tentatively, the acoustic basement includes Neoarchean, Paleoproterozoic, and Neoproterozoic blocks within the Dolphin special permits on the Inner shelf.

Some important geological discoveries were made due to the processing and interpretation of the 3D marine seismic data. One is a previously unknown reflection horizon, which we call the main unconformity (the VI seismic horizon). This horizon is a bright seismic boundary with a distinct 'carved' topography associated with the base of the sedimentary cover occurring with Eo-Cimmerian angular unconformity on a heterogeneous and heterochronous acoustic basement. It is clearly traced over most of the study area [Kitchka et al., 2024].

As a result, the new 3D data was correlated with the 3D seismic cube for the Odeske-Bezymenne gas fields area and onshore 2D seismic and deep well data (in the Dobrogea Foredeep) through the coastal «mute» zone ~10 km wide where no seismic data is available. Structural relationships and elements of petroleum systems were transposed to the adjacent offshore domain, where potential traps were identified in an eroded carbonate platform of the Middle(?) to Late Paleozoic age. Integrating these data yielded a balanced 2D geological model illustrating the

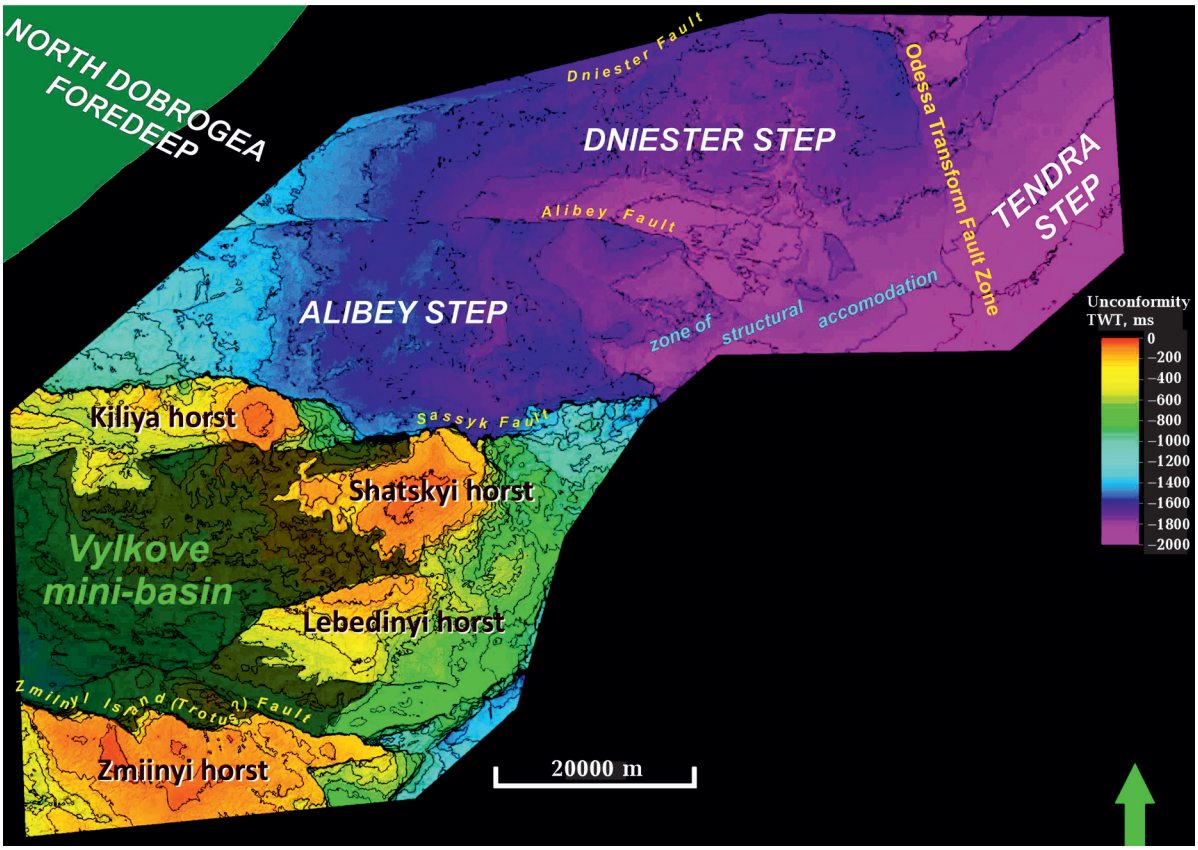

Fig. 1. Tectonic zonation of the area studied upon the reflective horizon VI (acoustic basement) based on 3D seismic data.

structural relationships between the land and marine shelf.

Hydrocarbon plays recognition. Based on the interpretation of the latest 3D seismic data and relying on the industrial «standard» for the identification of oil and gas plays, seven promising hydrocarbon plays within the perimeter of Dolphin 01-10 special permits were identified, namely:

1) weathered and fractured rock formations of the Proterozoic-Early Paleozoic consolidation;

2) anticlinal and faulted anticline traps in the Paleozoic strata. Stratigraphic traps (erosional knobs) associated with angular unconformity in the Paleozoic sediments;

3) anticlinal and stratigraphic traps associated with an angular unconformity in the top of the Valanginian-Jurassic sequences;

4) anticlinal traps in Lower Cretaceous (Neocomian-Albian) pre-rift plus syn-rift sediments and stratigraphic traps (with erosional and facies compartmentalization);

5) anticlinal traps in the Upper Cretaceous-Middle Eocene carbonate platform complex: Reef bodies in the Upper Cretaceous (Campanian-Maastrichtian) sediments and stratigraphic traps associated with stratigraphic disconformities in Paleogene-Cretaceous sequence;

6) Upper Eocene-Oligocene-Lower Miocene (Maikopian) anticlines and lithological and stratigraphic traps;

7) Neogene 4-way closures and lithological traps.

The spatial localization of the above-mentioned plays is shown along the model cross section through the Dolphin special permits of the Inner Shelf in Fig. 2.

After analyzing hydrocarbon plays and their segments, it was managed with ranking and geologically derisking of 40 leads (anticline and stratigraphic traps) for the presence of hydrocarbon system elements, eight of which were mapped for the first time within the area based on the processing and

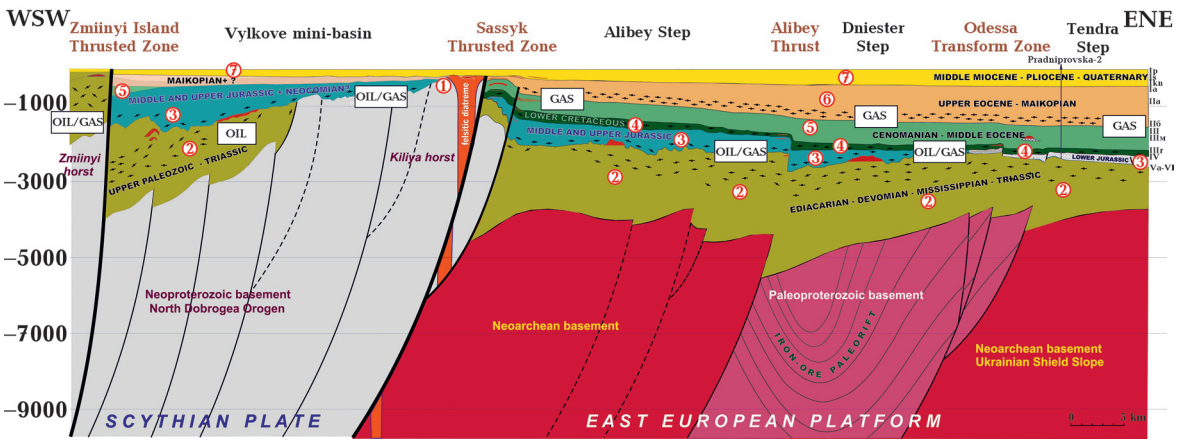

Fig. 2. The main prospective oil and gas plays along the model geological cross-section through the study area.

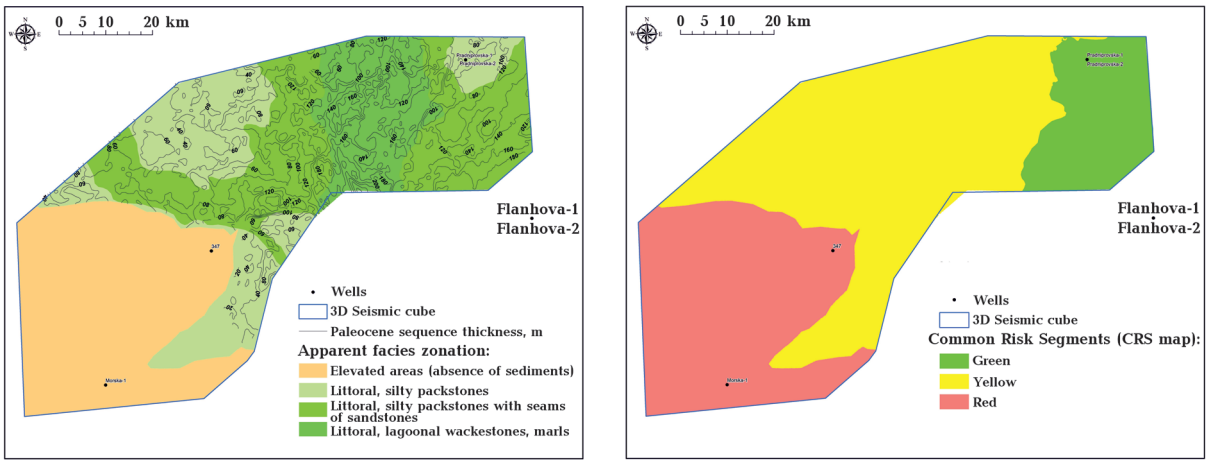

Fig. 3. Seismofacies prediction map and Composite Common Risk Segment map (or «traffic light map») (*a*), both for the Paleocene segment play (*b*).

interpretation of 3D seismic data. As for the classification by seismic waveform, the wave field along the seismic horizon was used to build seismic facies maps. Assuming that the shape of the reflected wave depends on the elastic properties of the acoustic boundary and on the shape of the seismic signal, it is possible to judge the change in these properties.

Geological risk assessment. For each play and its segments, the thermal maturity and seismic facies distribution maps were built applying attribute analysis (by signal shape and the special attribute set) for all reference seismic horizons (Ia, IIa, IIb, III, IIIm, IIIg, IV, V, VI) of the entire sedimentary cover. Derived from those sources, the probability maps of the reservoir and seal quality/presence were compiled, too. To create a spatial model of the thermal maturity of oil and gas host rocks within the work area, we used the dependencies for both the onshore area by the UkrSGPI study (1992) and for the adjacent offshore area, according to Simon Petroleum Technology Ltd (1994).

Based on expert consensus, probability ratios were established for four components (probability of source/migration/fill—trap—reservoir—seal).The composite common risk segment of each of the seven prospective oil-and-gas bearing complexes (plays) was determined. The case for the Paleocene segment of the Krylov sub-basin of the Upper Cretaceous-Middle Eocene play is illustrated

in Fig. 3 (maps of its apparent seismofacies distribution and composite common risk segment).

Conclusions. The area of study, the conjugation zone between the slope of the Precambrian EEP, Paleozoic-Cimmerian Scythian platform, and younger Meso-Cenozoic Black Sea basin, is surprisingly complex in terms of tectonic structure. Thus, it is the most interesting area from the geological point of view despite the relatively moderate hydrocarbon resources. The extension of the North Dobrogea Foredeep into the Black Sea was confirmed, and elements of its petroleum systems were transferred to the adjacent offshore domain, where potential hydrocarbon traps were found in the eroded Paleozoic carbonate platform. The established and traced dependencies made it possible to assess the composite geological risk and prospects for commercial oil and gas potential of the Dolphin special permits in the Inner northwest shelf of the Black Sea and to proceed to assess their resource potential using deterministic and stochastic approaches.

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Новітня 3D сейсміка розкриває позитивні перспективи на нафту і газ на морському продовженні Переддобруджинського прогину, Україна

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На основі обробки даних новітньої 3D сейсморозвідки та аналізу геолого-геофізичної інформації виділено й охарактеризовано понад сорок перспективних структур на спецдозволах Дельфін 01-10 НАК «Нафтогаз України» у межах внутрішньої зони північно-західного шельфу Чорного моря. Уточнено та деталізовано

геологічну модель району робіт, оцінено основні складові геологічного ризику за перспективними нафтогазоносними комплексами для формування портфеля нафтогазопошукових об'єктів, їх ранжування та прийняття управлінських рішень.

Ключові слова: Чорне море, спецдозволи на розвідку і видобування, 3D сейсморозвідка, геологічна інтерпретація, перспективні структури, нафтогазопошукові роботи на основі оцінки нафтогазоперспективних комплексів.