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Kambala Prospect - An Application of 3D Geomodelling and Inversion to Hydrocarbon Exploration in the Black Sea Basin

O.P. Petrovskyy* (Ivano-Frankivsk National Technical University of O), O.A. Kitchka (DC "Naukanaftogaz"), T.O. Fedchenko (Ivano-Frankivsk National Technical University of O) & V.V. Gladun (National Joint Stock Company "Naftogaz of Ukraine")

SUMMARY

The approach of integration seismic, well and gravity data into one 3D geodensity model proved to be an effective tool during exploration process within NW Black Sea. Interpretation results gave new insight into deep structure and main tectonic elements of the Black Sea offshore Ukraine, its slope and toe revealing trends.
Delineated deepwater prospect could correspond with higher probability to a submarine Neocomian canyon and fan incised into Jurassic bedrock. Taking into account that the Black Sea basin is characterized by lack of reservoir rocks this type of exploration play may represent a top priority exploration target that could host a sizeable hydrocarbon field.

Introduction

High cost for offshore drilling and especially deepwater one put decreasing of exploration risk to the highest priority. For rather immature petroleum provinces like the Black Sea it is typical to deal with regional seismic, rare 3D seismic and scarce well data. This makes revealing of hydrocarbon plays in the complex sedimentary and tectonic environment quite a challengeable task. Recently several drilled dry deepwater wells offshore Turkey has proved the complexity of the problem. Nevertheless, new gas discoveries offshore Romania and Turkey (Domino-1, Ioana-1, Eugenia-1, Istranca-1 wells) still keep this region as one of the most promising in Europe. In this situation the necessity to supplement seismic with additional geophysical data is quite obvious. Multidisciplinary approach have gained general recognition on today most commonly meaning integration with EM methods and building of 3D unified Earth models. However, other geophysical information carried by gravity and magnetic data is not widely used in exploration process.

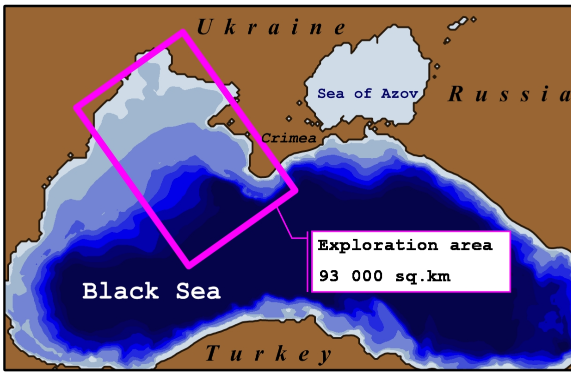

Figure 1 Exploration area.

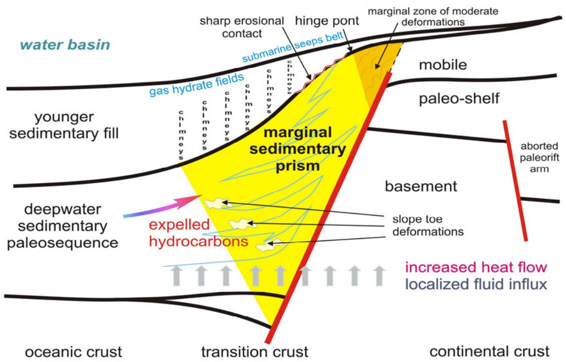

Figure 2 *Marginal sedimentary prism as a promising exploration play.*

This study illustrates general principles and results of 3D geophysical Earth Model for the Black Sea northwestern shelf and adjacent deepwater sector in the Ukrainian economic zone (Fig.1). This model is based on seismic and well data and application of geologically constrained gravity inversion. Compiled 3D density model is interpreted in terms of reservoir properties proved to be a powerful tool to reveal new prospects particularly beyond the hinge of continental shelf within the marginal sedimentary prism (Fig. 2) and to guide exploration activity.

The technique and its application

Interpretation process includes construction of heterogeneous 3D density model based on the inverse problem solution for gravity data in combination with seismic and well log data, and other geological information (Petrovskyy O.P., 2005). Geological and geophysical information sets used for building of initial 3D model of the NW Black Sea and included into gravity inversion procedure were as following:

- 3D structural model based on 2D seismic data for surfaces of Neogene, Paleogene and Cretaceous sedimentary sequences down to the Pre-Cretaceous basement. The assumption of different crust types (oceanic crust is envisaged for the Western Black Sea sub-basin) implicates different crust thicknesses, rocks composition and Moho interface densities;
- 3D density voxel model based on petrophysical data from onshore and offshore wells plus seismic velocities envelops;
- Additional geological information was applied in the form of geological constraints on final model parameters, confidence criteria regarding initial data and optimal parameters of inversion procedure;
- Gravity data (Bouguer anomalies). Spacing of gravity data observation points varies from 200 meters on coastal strip and internal shelf to 2.5 kilometers within deepwater territory.

Inversion results

3D model embraces rock domain 250x372 km laterally and 70 km in depth. Inverse problem includes 23,250 equations for mesh of 32,550 thousands of cells (unknown) of 3D density model (Fig. 3) . Inversion of gravity and geological and geophysical data is aimed to adjust densities of the mantle masses and form of Moho boundary, properties of the basement rocks as well as sedimentary rock properties. The inversion produces unique 3D density Earth model (Fig. 4) with standard deviation of gravity misfit 1.3 mGl (Fig. 5).

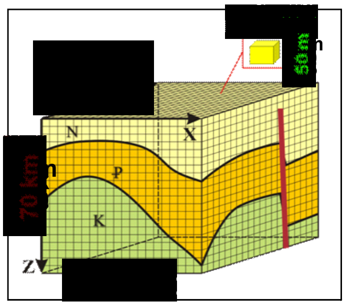

Figure 3 *Parameters of 3D model approximation.*

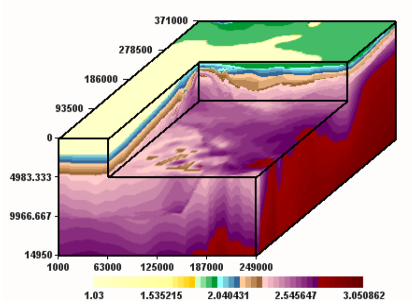

Figure 4 *Resulting 3D density model.*

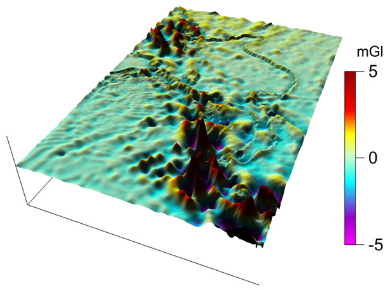

Figure 5 *Gravity misfit.*

Results

First stage of resulting 3D model analysis and interpretation was aimed to delineate tectonic features. This was provided by analysis of basement density properties. Next stage was focused onto recognition and mapping of low density anomalies within Cretaceous and Cenozoic sedimentary cover.

Reflection of known eight gas fields within the internal Black Sea shelf in obtained 3D density model as local low density zones proved validity of the model and allowed to perform further evaluation of other low density anomalies to delineate new prospective plays confined to petroleum-prone Cenozoic and Cretaceous sediments. New prospects of different play types were identified within external shelf, its hinge and deepwater area (Petrovskyy et al. 2011). Some of the prospects were recognized on seismic images by seismostratigraphic analysis as well.

Deepwater prospects

Among the most interesting prospects is one located within the continental slope (Fig. 6). This sedimentary body with rather large area of approximately 2000 sq.km has very peculiar form of spade with thin neck going upward the slope that bear quite clear geological meaning. This particular form apparently speaks about subsurface existence of submarine paleofan composed by clastic turbidite material of lower density comparing to surrounding host rocks ("Kambala" or Flatfish prospect, located within Skifska license area Fig. 7). Theoretical model of such a body typical for slope and toe sedimentary environment is well-known and such prospects have top priority importance for deepwater exploration in many offshore basins (Posamentier and Walker, 2006). Another interpretation can explain this anomaly as prograding deltaic complex. Analyzing the geodensity map for the pre-Cretaceous rocks of the Black Sea northwestern shelf it can be supposed that sedimentary fill of the paleo-canyon (or alluvial channel) and the fan (or deltaic complex) is not Jurassic or older but early Cretaceous in age, mainly Neocomian, Barremian-Valanginian. An idealized model of the sedimentary body interpreted as turbidite fan is shown on Fig. 8.

The geo-density slice conformal to the bottom of the Cretaceous sequence depicts another anomaly of similar form to the east of the first one that may point out onto existence of system of canyons and fans along the strike of the basin paleo-margin. It is worth to mention that the Neocomian alluvial systems we studied in the field are known in the Crimea (Gorbenko, 2011) where their sands are quarried in several places, see Fig. 9.

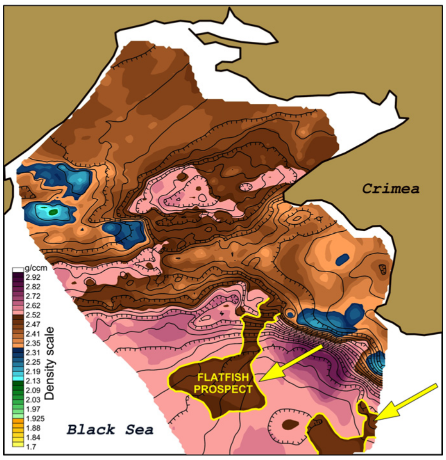

Figure 6 *Low-density anomalies in pre-Cretaceous rocks, northwestern shelf and slope (paleo-fans are indicated by yellow arrows).*

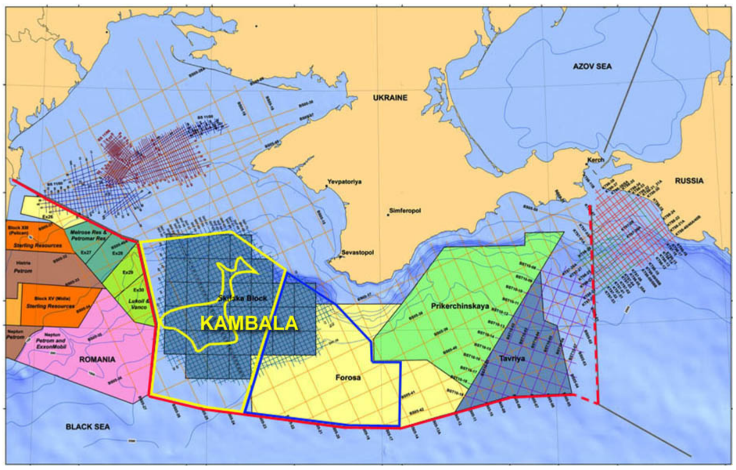

Figure 7 *Location of the Kambala prospect within Skifska licence areaq on the).*

Tentative exploration program for the Kambala prospect and exploration risks

Total area of the mapped lower density deepwater fan body is 2,745 sq.km, and most promising sweetspot area is of 2,000 sq.km. Filling the elevated western part of the trap with gas till modeled GWC at depth – 8,500 m the gas-saturated reservoir will be of 660 sq.km. If to try to satisfy P50 conditions the natural gas reserves in place could be as much as 2.1 Tcm. To minimize the exploration risk it is planned, after conducting and processing of 3D seismic and detailed gravity surveyings, to split the drilling program onto two phases (see exploration targets and position of wells on Fig. 10). During first one is to strike the Miocene and Maykop reservoirs and than continue drilling with directional boring along the deepwater fan tail trying to penetrate its reservoir rocks and discover satellite gas pool sealed by normal fault plane. Depending of the results delivered by the pilot well to decide whether to drill ultradeep well to the main target or not.

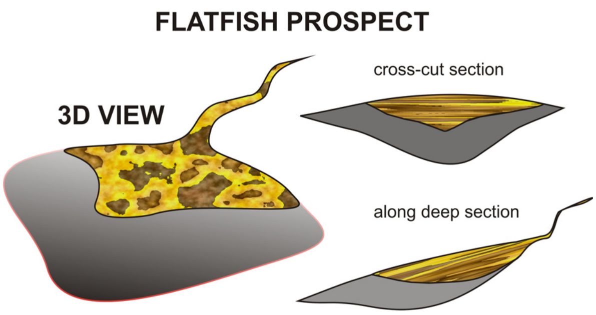

Figure 8 *Sketch outline of the clastic submarine fan on the continental slope of the northwestern shelf.*

Figure 9 *Valanginian alluvial sands and gravels, Zuevsky quarry, the Crimea.*

The main target reservoir of the prospect occurs too deep (7200-9000 m). Stratigraphic age of the rocks responsible for such lower density domain is not known precisely yet. It could be as Upper Albian as Valanginian (this will cause different interpretations for the age of acoustic basement). Tail part of the submarine paleo-fan could be represented as leveed channel as incised canyon filled with younger sediments, typically non-reservoir rocks. Albian and Aptian potential source rocks known onshore do not reveal good parameters as to TOC content as maturity though their deepwater equivalents may be quite good. Promising traps/reservoirs of the complex prospect cannot be tested with one vertical well due to their spatial offsetting. It is also expected that potential deep gas reservoir is overpressured.

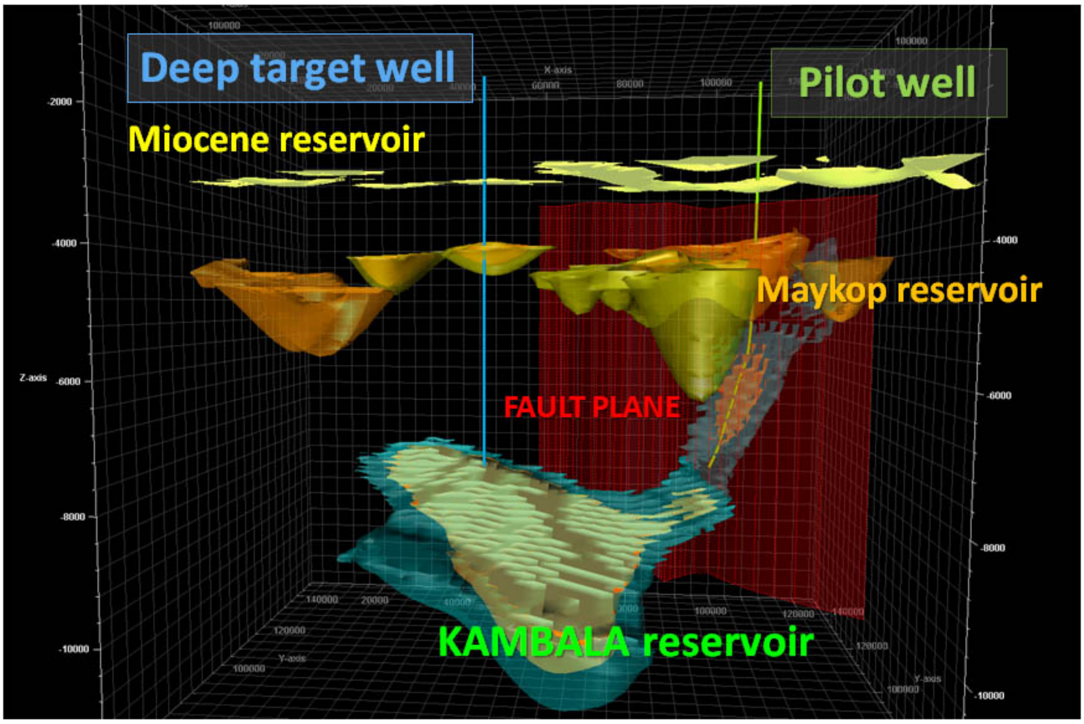

Figure 10 *3D view of reservoir targets and proposed two wells to explore the Kambala prospect.*

Conclusions

The approach of integration seismic, well and gravity data into one 3D geodensity model proved to be an effective tool during exploration process. Interpretation results gave new insight into deep structure and main tectonic elements of the Black Sea offshore Ukraine, its slope and toe revealing trends.
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Acknowledgements

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