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An Integral Geological and Geophysical Modeling Gives an Impetus to Expand Exploration Activity Offshore Ukraine

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SUMMARY

This approach of integral geological and geophysical modeling has been applied to study exploration zones and local prospects in the western (Carpathians) and eastern (Dnieper-Donets basin) petroleum-prone provinces. As known oil-and-gas prospective areas are not confined only to onshore Ukraine and spread out to shelfal and deepwater parts of the Black Sea mega-basin where several gas and gas condensate fields are found to this date. Recently this list was successfully updated with proving of commercial oil productivity for Subbotin field.

Introduction

Last years the practice of oil and gas exploration has faced with some crisis related to essential decreasing of final geological efficiency (impact indicator). While analyzing the reasons of such a crisis it is possible to point out one of the main problems, namely an existed contradiction between modern exploration requirements to regional and local prediction of petroleum potential and interpretation capabilities of applied geological and geophysical techniques. Primarily this crisis affects seismic surveying as the basic exploration tool. As follows from real applications the seismic method is the most effective while solving the task to map subsurface structural peculiarities and fault tectonics that provided by application of detail 2D profiling and spatial 3D acquisition systems. However, to solve that task - even if potential prospective structural leads are successfully outlined – does not mean that main question where enhanced reservoir properties are spatially located in the section and the more so what is the saturation characteristic of a mapped target can be correctly answered.

There is no secret that several decades of seismic surveying development have provided some approaches to solve this important problem. These ones are seismostratigraphy analysis of geological section, prediction of geological structure using an analysis of seismic record dynamic attributes, evaluation of elastic properties of reflected horizons by inversion of seismic record and an amplitude analysis of reflected waves under rather inclined incident angle and so on. Each approach from the above has its advantages that are well described. From other hand, an existed problem of low impact indicator for exploration drilling testifies their limited capabilities. For example, seismostratigraphy plots indicate discontinuities in the wave filed that can be attributed to real discontinuities if the migration is correctly applied. Dynamic characteristics of the wave field that are often applied to analysis like instantaneous phases, frequencies, etc., have only portrayed changes of mathematic characteristic of an analytic signal and they are attributed to real physical properties with so complex set of equations that attempts to substitute it with streamlined statistic correlation (even adjusted using well data) do not give anticipated positive results.

So where is the solution here? Looking back on the development of other geophysical methods such as gravimetric prospecting one can find that similar crisis between geological requirements and interpretation capabilities took place much early, in 70-80's of last century just coinciding with rapid development of seismic tools caused by application to the practice a CDP technique. Since that time the gravimetric method did not stagnated but developed by the researchers pursuing its improvement. Nowadays, the most promising development trend has focused onto geo-density modeling of real geological medium that envisages application of complex multi-parametric models and adequate methods to solve direct and inverse problems of gravimetry and build spatial 3D models. Main obstacle that has been surmounted is a mitigation of essential incorrectness of inverse gravimetric problems and their ambiguity. Understanding and awareness of this problem has resulted in revision of the traditional concept that exploration objectives can be resolved by local application of graviteric method solely. To respond to modern geological challenges it was achieved an increasing of interpretation capabilities for the gravity method by its active transfer to an automated interpretation of gravity data combined with other geological and geophysical information and seismic data first of all. Based on this experience and principles of dialectic system development it is possible to formulate two directions for resolving of information relevance crisis in the interpretation maintenance of seismic exploration and applied geophysics in the whole:

1. Development of new seismic/mathematic models to describe real geological medium and solution of direct and especially inverse kinematical and dynamic problems of exploration seismology within the frame of these models
2. Enhancement of interpretation capabilities for particular methods by application of interpretation workflows based on model parameterization for each method taking into

account how it fit with integral/numerical geologic model of the analyzed medium. Due to its more general character the latter incorporates the first direction so it should be considered as more promising one that can provide transferring of the industry to essentially higher level of performance while extracting geologically valuable information from all available set of original geophysical and geological data. Let us consider the possibilities to apply this approach to hydrocarbon prospecting and exploration in more detail.

Within the whole range of exploration works targeting onto petroleum-prone sections it possible to formulate three main tasks:

1. Regional analysis of hydrocarbon potential aiming to reveal main regional geodynamic regularities of deep structure and understanding of peculiarities of oil and gas formation, migration and accumulation.
2. Local analysis of hydrocarbon potential aiming to outline, localize and describe in detail local prospects confined to regional petroleum-prone suites.
3. Remote geophysical monitoring of oil and gas fields development and geophysical maintenance of subsurface gas storages exploitation, control for reserves recovery and waterflooding of the fields under development.

Solutions of the above tasks have individual peculiarities. Nevertheless, issuing from previously mentioned argumentation their successful solution requires a system application of the integral geological and geophysical modeling. An essence of this principle to solve all three tasks is rooted in the necessity to develop the sequence of concerted integral geological and geophysical macro-models of various scale and micro-models of continuous distribution of physical properties (Petrovskyy O.P. 1997-2006 г.) that produce geophysical fields of minimal deviation from measured ones and best fit to all supplemental set of original geological and geophysical data. Herewith the process of correct defining of model's parameters goes from the general to the special that stimulates their geological consistency.

Studying for petroleum potential of the prospecting areas and structures is based on rational set of geological and geophysical data. Hence, for regional analysis it should be based on seismic and gravimetric (of 1:200000-1:100000 scale), aeromagnetic (of 1:100000-50000 scale), atmo-geochemical and field geophysical data, and regional petrophysical dependencies for the wave velocity and formation density parameters as well. Local analysis can be fulfilled on the basis of seismic, gravimetric (of 1:50000-1:25000 scale), geochemical, field geophysical and field data, and petrophysical dependencies for velocity and density parameters in different geotectonic zones. Remote geophysical control is the most complex and critical stage for detail study of internal structure and condition of the target medium. For this there should be available 4D seismic and gravimetric (of 1:10000-1:5000 scale), geophysical field and field information retrieved from results of exploration and development drilling, petrophysical dependencies for velocity and density parameters derived from well-bore cores and well-log data.

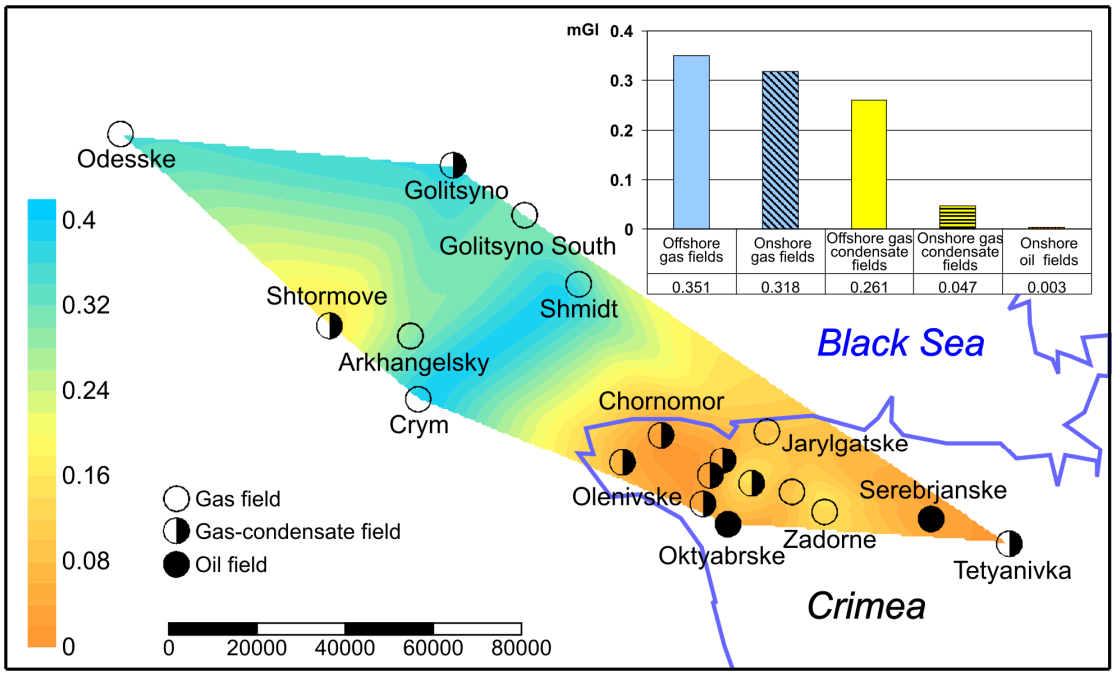
As it seen the main emphasis is made onto profound combining of seismo-gravimetric information. An optimality of such a package is stipulated by difference in physical principles these methods employ that provides independency in estimating of values for the parameters of physical geosection. And what is important in this case is known relationships between prospectivity of certain rock sequence and its degree of compaction and porosity, respectively. Thus, at other conditions being equal the increasing of porosity or oil-and-gas saturation ratio lead to the decreasing of mean rock density.

All the abovementioned has served as the basis for thematic geological and mathematical substantiation to develop and apply «Technology of an integral interpretation of geological and geophysical data set to search for oil and gas fields» (Petrovskyy O.P. 2006.), which is implying development of spatial geo-density models concreted with seismic seismostratigraphic, well, magnetometric and gravimetric data to recognize zones of anomalous density behavior within these models and their further interpretation. This is dependent on the geological tasks to be solved for particular geo-environments as follows:

- areas of petroleum-prone suites;
- local zones of enhanced reservoir properties;
- mapped traps to determine distribution and dynamics of hydrocarbon fluids.

The approach proposed has been widely applied to study exploration zones and local prospects in the western (Carpathians) and eastern (Dnieper-Donets basin) petroleum-prone provinces. As known oil-and-gas prospective areas are not confined to offshore Ukraine and spread out to shelfal and deepwater parts of the Black Sea mega-basin where several gas and gas condensate fields are found to this date. Recently this list was successfully updated with proving of commercial oil productivity for Subbotin field.

Taking into account high costs for marine exploration it was conducted the study aiming to improve the quality of prospect mapping (Fig. 1) for the northwestern Black Sea shelf based on formulated principles of an integral geo-modeling to secure its geological and commercial impact factor. This is resulted in building of an integral geo-model of region's deep structure (Fig. 2) and revelation of some structural peculiarities of gas-prone sequences in Golitsyno gas condensate field (Fig. 3).



Figure– 1 Gravity contrast range for oil and gas fields in the Black Sea NW shelf.

The study has shown that known hydrocarbon prospects are corresponding to sizeable gravity anomalies with amplitude as much as 0.4 mGl. It was updated our knowledge about the deep structure of this region thanks to rectification of Moho position and geo-density rock properties above and beneath this boundary, and studied structural peculiarities of the basement rocks and its sedimentary cover as well.

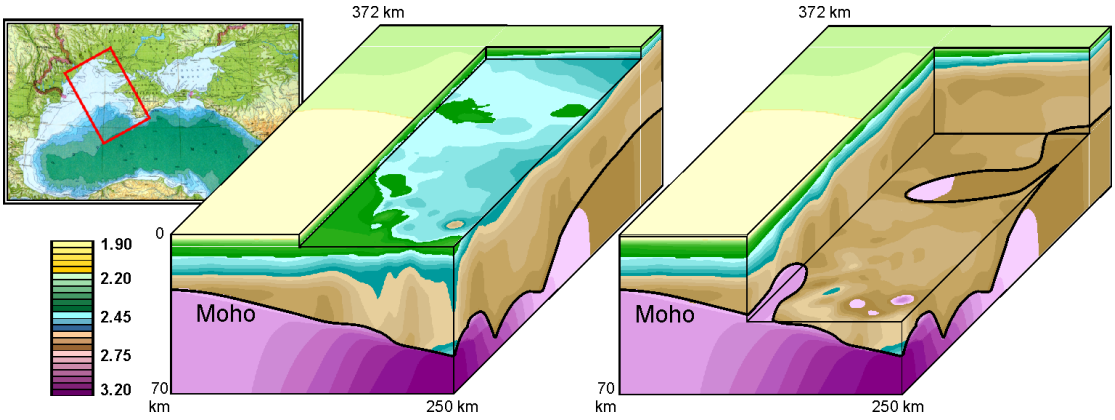


Figure 2 – Integral spatial geo-density model of the Black Sea NW shelf.

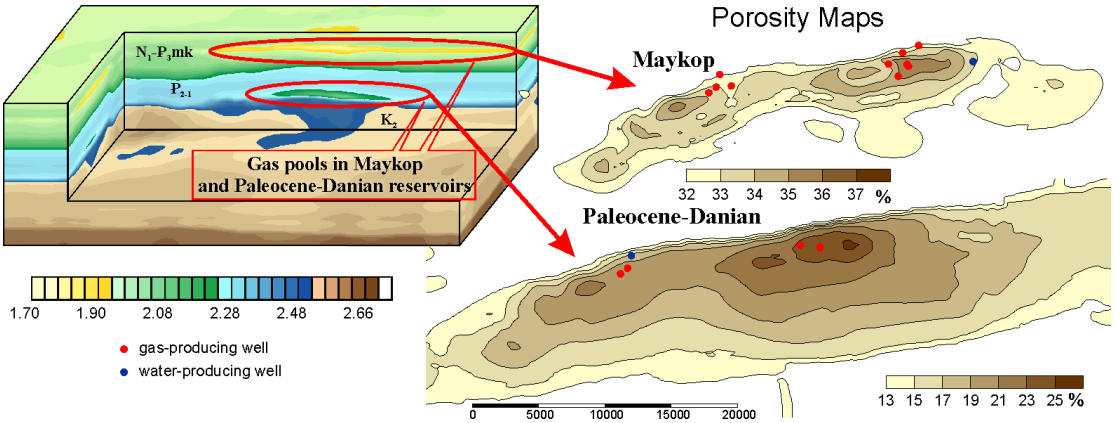


Figure 3 – Integral spatial geo-density model for Golitsyno gas field.

It was delineated dominant trends of density-induced weak zones that control as known as undiscovered oil and gas fields. Within Golitsyno gas condensate filed this study has revealed a heterogeneous structure of productive beds, outlined the domains of enhanced reservoir rock properties, and found location of new promising prospects for exploration drilling.

The geological information obtained within this research program testifies a confident effectiveness of proposed integral geo-modeling to evaluate and rank offshore prospects and attests for essential hydrocarbon potential of the Black Sea basin within its inner shelf, continental margin and slope, including deepwater areas as well.

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