An Integrated 3D Seismic Analysis and Potential Fields Inversion Reveal a TBR Analog for the Dnieper-Donets basin

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Introduction

Searching for oil and gas in the Lower Carboniferous Carbonate Platform of Dnieper-Donets basin (DDB) is facing with particular problems caused by lack of specific knowledge about the morphology and origin of carbonate reservoirs. Employing of standard models for anticline and even biohermal traps gave few hydrocarbon discoveries while exploring the carbonate platform of Tournaisian – Early Visean age. Bogatoyka gas condensate field, which is located in the south-central part of the DDB suits well for a case study to feature its carbonate reservoir heterogeneity and origin.

Exploration and well-testing data and our integrated interpretation of seismic and gravity data have revealed rather quaint character of well production distribution over the field characterizing presence of some dry development and exploitation wells inside the productivity contour. To solve this problem two special software packages were applied, namely an Computer-based System for Integrated Numerical Interpretation of Spatial Data (GCIS, Geophysical Complex Interpretation System STF, "BIPEKS Ltd.", Petrovsky A.P. et al, 2003) and Spectral Data Correlations Analysis (COSCAD, Moscow State Geoexploration University, Nikitin A.A, 1979) that produced a 3D seismic and density model allowing us:

- to outline in the productive carbonate section several spatially correlated anomalous zones of seismic record characteristic of rocks with lower seismic impedance and density values;
- to demonstrate that productive wells are localized on the periphery of those anomalies and dry wells are often locate inside or near their central parts;
- to visualize a stratified character of anomalously high productive pay zones on the periphery of low permeable core ones, which both form a joint geological body of single origin.

The issue of an adequate geological and geophysical model was solved in favor of carbonate (limestones-dolostones) oil and gas reservoirs of hydrothermal origin like the Trenton-Black River ones first described in the Appalachian basin (Pyron A. et al, 2002). This solution has come from comparison of geophysical and production well data on Bogatoyka field with structure and lithological varieties of Lower Carboniferous carbonates observed and studied in natural outcrops and flux dolomites quarries on the south of the Donets Folbelt (Kitchka A.A. et al., 2003). This allowed tracing of stratigraphy and lateral changing of modeled object and making ground truth verification of seismic attributive analysis data.

Bogatoyka gas condensate field

Exploration activity on Bogatoyka prospect started in 1955 and the gas condensate field was discovered there in 1976. To present time within the field it was drilled 30 exploration and development wells. Only 7 from them are commercially productive.

Geophysical exploration

Bogatoyka gas condensate field is covered with 3D seismics on the territory of 200 sq.km (by NADRA Group) with 720-channel INPUT/OUTPUT-2 station. After processing and interpretation of the acquired data using different software packages of Paradigm Geophysical (Focus, Seis, and Voxel Geo) it was produced a migrated data cube with 20x40 m bin size. In

addition, this area was covered with standard magnetometric (of 1:50000 scale) и gravity (scales 1:25000 – 1:50000) surveys.

To compile 3D model of rock density concerted with seismic and gravity data it was made next standard steps:

1. Building of initial structural 3D model that includes 24 structural surfaces, where seven of them were compiled upon 3D seismic data, 15 intermediate ones were generated using well data, and finally, the surface of the crystalline basement top (all of the upon 100x100 m grid).
2. Assigning density properties (derived from well core studies of the field and beyond) to the strata of 3D model.
3. Computation and visualization of initial 3D model to trace continuous changes of density properties through the cell grid of 100x100x50 m.

As an specific improvement to the standard approach it was applied the procedures targeted on optimal matching of density parameters distribution that is based on an original solution (GCIS) for inverse linear problem of gravimetry (Petrovsky A.P., 2005) and to evaluate seismic heterogeneity of productive carbonate reservoir rocks by applying of technique (COSCAD) to compute a time-spatial dispersion of seismic energy in a window of variable form (Nikitin A.A, 1979). This solution of inverse gravity problem has required to solve the system of equations for 20672 points of observed gravity field and was realized for 10 hours using computation cluster combining 12 computing devices and allow building of heterogeneous density 3D model (3307520 cells) agreed with the gravity field (standard deviation is 0.0067 *mGl*), and available seismic and well data (Figure 1).

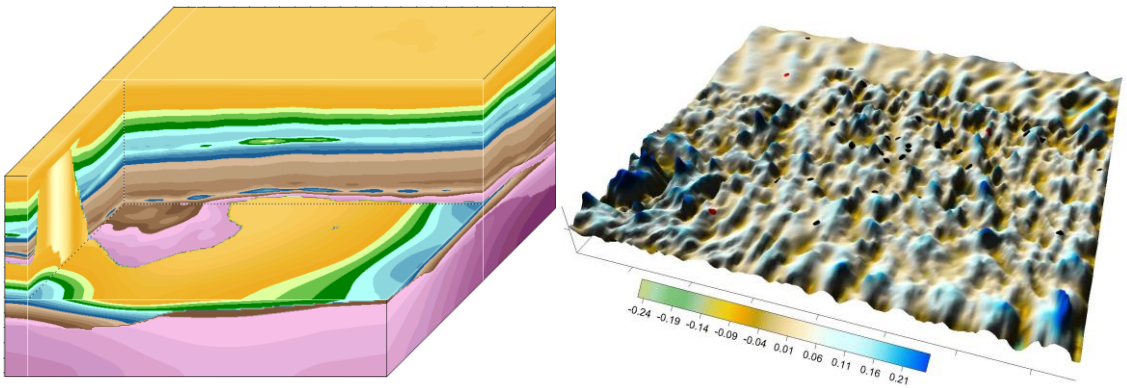

Figure 1. 3D density cube derived from seismic data and residual gravity field map

An analysis of density parameters behavior allow more detail specification of basement internal structure, rock salt distribution under the carbonates and its plug morphology in the southwestern part of the area studied. Within productive sedimentary clastic (2000-3000 m)

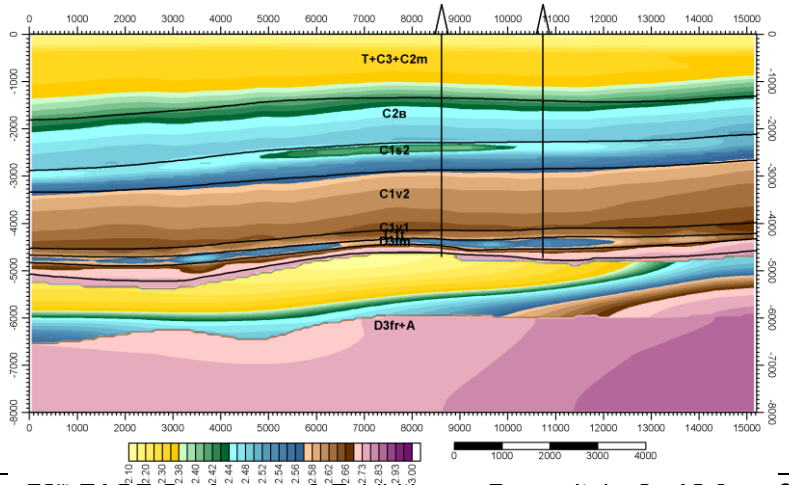

Figure 2. Cross-section of 3D density model through productive well

and carbonate (4000-5000 m) sequences it was recognized zones of decreased density (Figure 2) that is in good coincidence with location of productive wells. Computation of time-spatial dispersion of seismic energy gave us a possibility to visualize seismic heterogeneity of the section expressed by decreased dispersion comparing to the surrounding rocks(Figure 3). These zones coincide with position of pay intervals in the wells.

Model interpretation

It was found high confidence in spatial coincidence of the decreased density zones and decreasing of seismic energy dispersion (Figure 4).

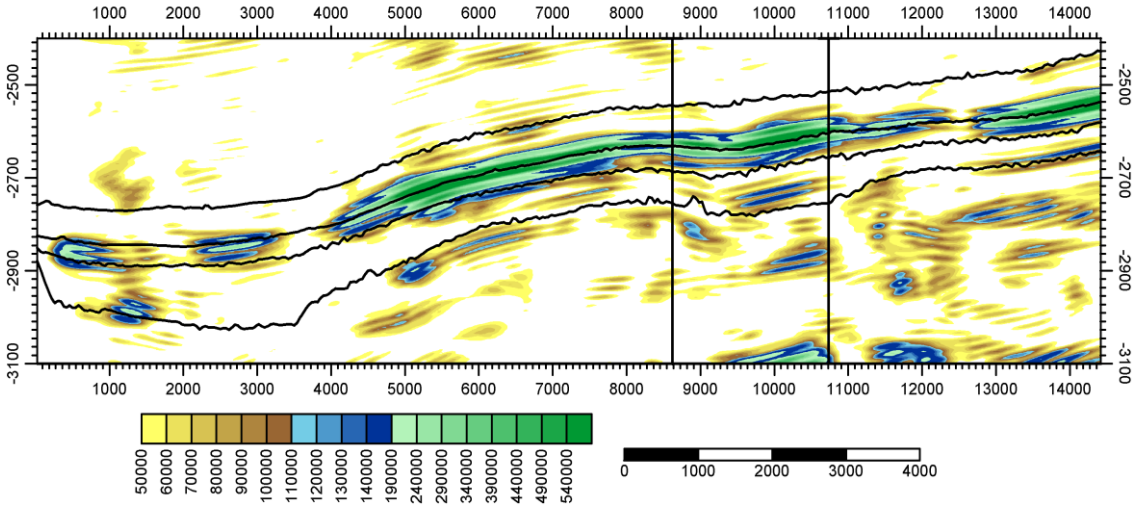

Figure 3. Cross-section 3D spatial dispersion of seismic energy in the carbonates

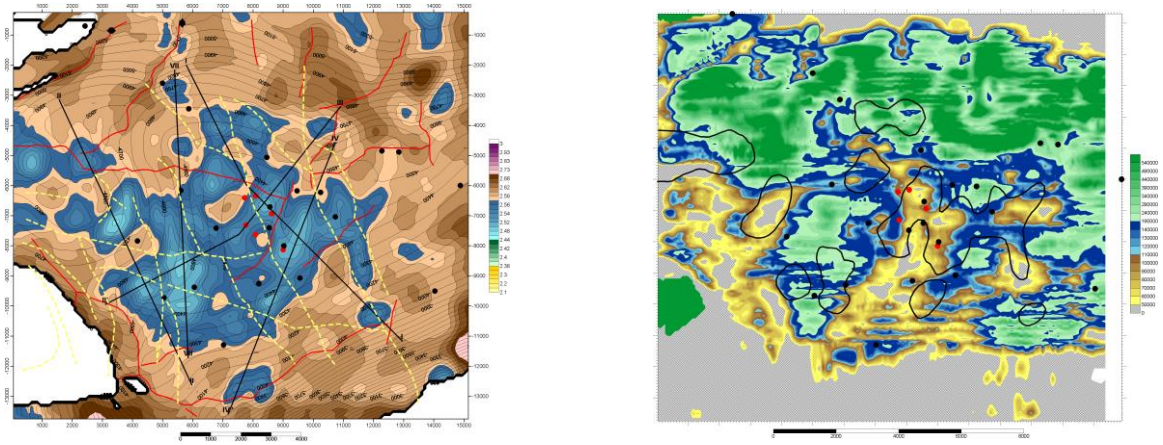

Figure 4. Along beds depth slice of density (left) and time slice of attributive seismic parameters (right) from 3D models in carbonates

Comparison of these zones with available well-testing data (as for commercially productive as non-productive ones) has produced an idea about geological model of the secondary carbonate reservoir in Bogatoyka that similar to TBR, which is known as tectonically-induced hydrothermally transformed carbonates (limestones into dolomites, Figure 5). TBR model explains an absence of production in wells located in the central parts of fractured and leached

reservoir rocks by presence of brecciated clayey karst cones along ascending paths of hydrothermal fluids.

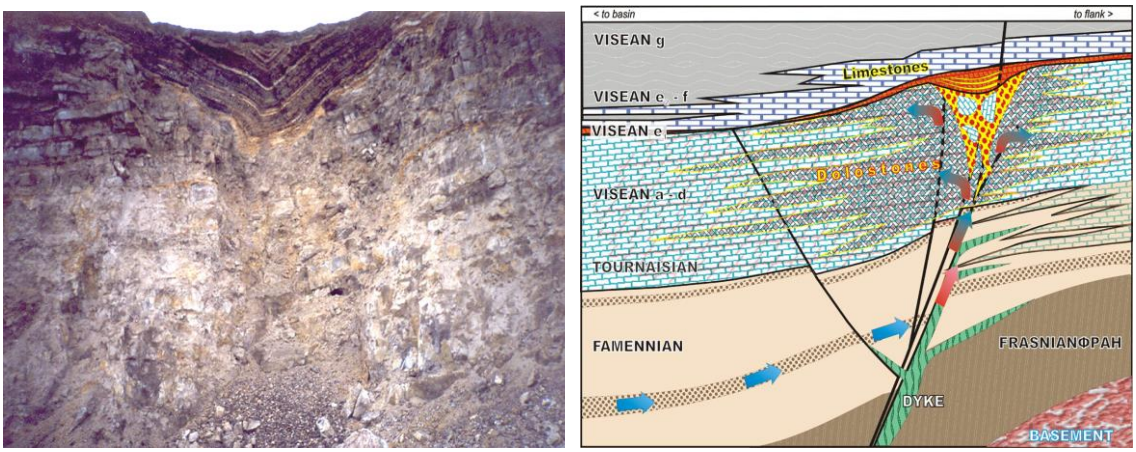

Figure 5. A photo of karst sinkhole upon Visean limestones, Cental quarry, Southern Donbass, and geological model of TBR reservoir origin in Lower Carboniferous Carbonate platform, Bogatoyka gas condensate field, DDB.

Discussion

An integrated 3D model for the carbonate reservoir in Bogatoyka field will stimulate elaboration of new criteria to evaluate prospectivity and productivity of the Lower Carboniferous Carbonate Platform for the entire basin and propose optimal settings to place exploration and developments wells using analogy with TBR. Few wells characterizing central zones (karst sinkholes) require further investigation of their lower permeability. Taking into account that abovementioned carbonate sediments are widespread over DDB the practice gained from this case study will be very useful to explore new small and medium-size oil and gas fields related to tectonically active zones.

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