High-quality seismic imaging and interpretation of prospective features in a thrust zone of onshore Ukraine

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Introduction. For many years, the Dnieper-Donets Basin (DDB) in Ukraine has attracted extensive exploration activities. In this mature petroleum-bearing sedimentary basin, significant efforts are made to searching for and exploration of hydrocarbon traps in a variety of complex-structure land environments. Geophysicists face, to name a few, overburdens of intense lateral structure variations and large velocity contrasts [Tiapkina et al., 2006], settings of complex salt tectonics [Tiapkina et al., 2008], and highly folded and faulted thrust zones. Interpretation of seismic data in these complex environments is quite a challenge. The objective of this study is to demonstrate, with examples from a thrust zone, which comprises several productive fields and prospective areas, how integration of high-quality depth processing with seismic structure and attribute interpretation can improve reservoir characterization and well planning.

Geological setting of the study area. The area of interest for this study is located in the south-eastern part of the DDB adjacent to the Donets Basin. belongs to a thrust zone that includes se-veral producing fields and prospective areas (Fig. 1). All these brachyanticlines adjoin the main compound thrust fault, which trends NW—SE in the western part and W—E in the eastern part. The geological section of the territory is composed of Paleozoic, Mesozoic and Cenozoic sedimentary rocks. In the Spivakivske field, commercial quantities of hydrocarbons are produced from prolific Bashkirian and Early-Permian reservoirs, whereas in the Drobyshivske field, several wells encountered significant amounts of hydrocarbons in Bashkirian, Moscovian and Gzelian predominantly sandstone reservoirs and proved economic. In some wells, these reservoirs are fractured, which is confirmed by core analysis and mud loss during drilling.

The complex tectonic setting of the region suggests that the Paleozoic rock mass was underwent a compressive stress regime in the course of the Main Cimmerian phase of the Hercynian tectoge-

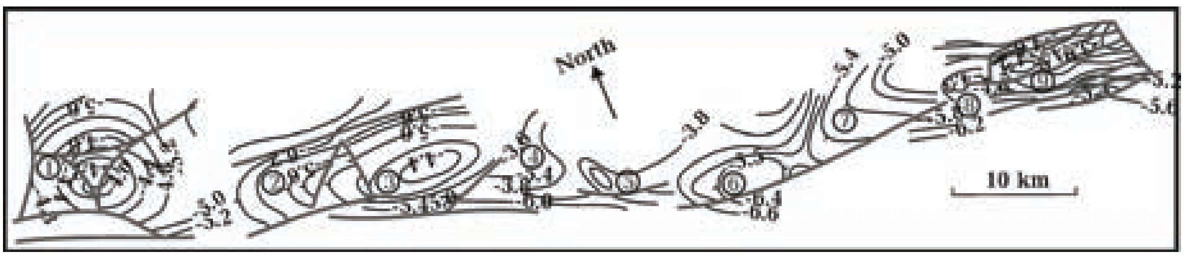


Fig. 1. Schematic map showing the structure and location of the (1) Pivnichno-Volvenkivska, (2) Zakhidno-Spivakivska, (3) Spivakivske, (4) Snizhkivska, (5) Kamyanska, (6) Svyatogirska, (7) Torska, (8) Zakhidno-Drobyshivska and (9) Drobyshivske productive fields and prospective areas within an extensive thrust zone of the south-eastern part of DDB (Ukraine).

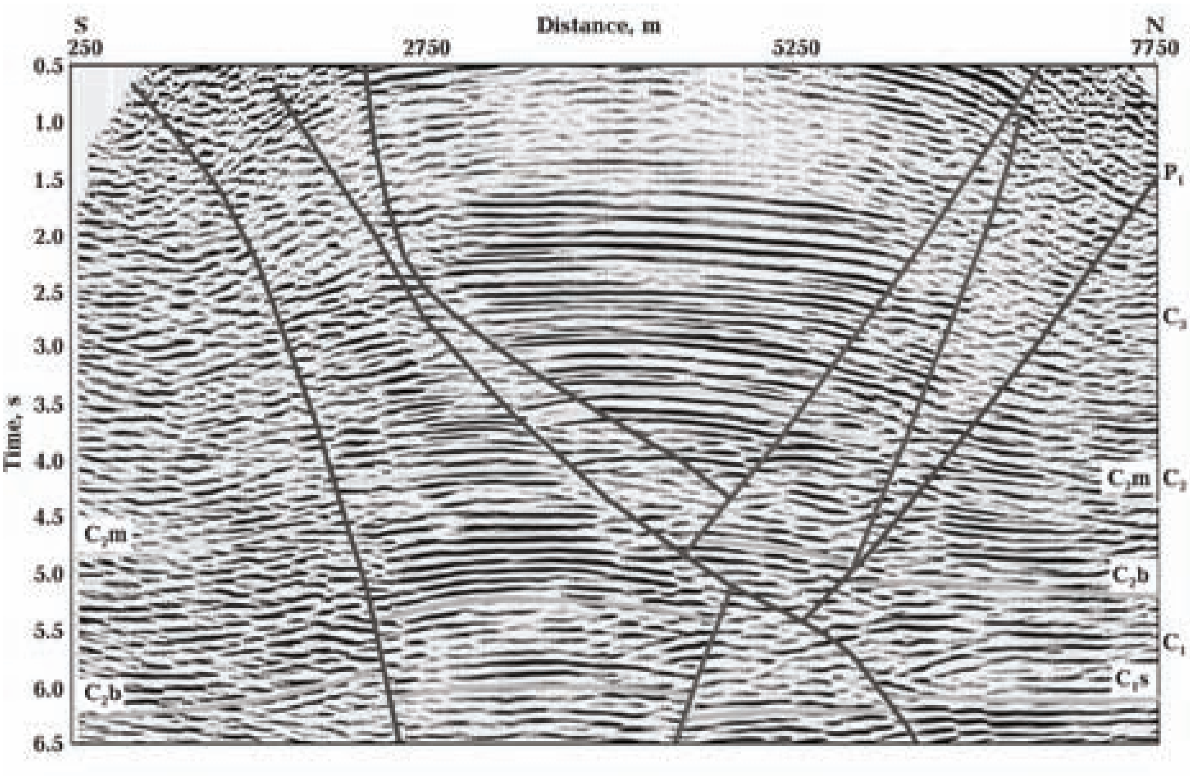
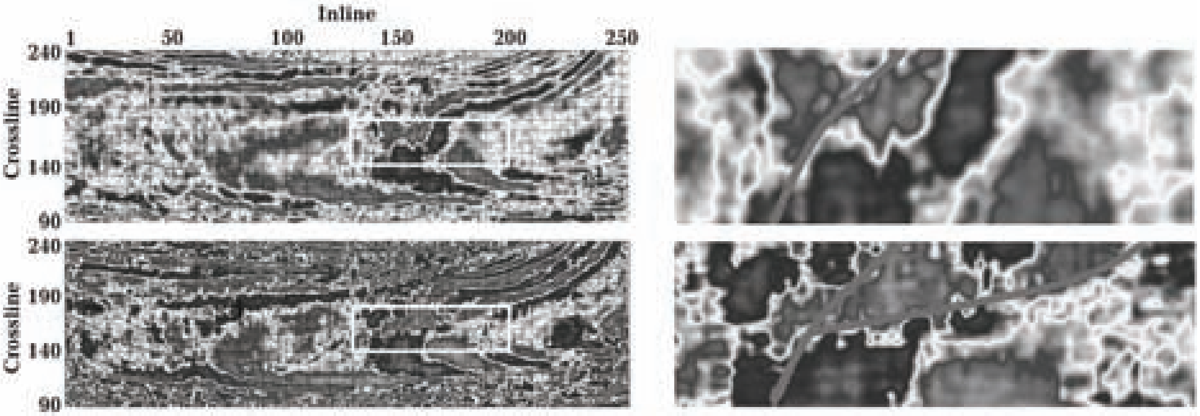


Fig. 2. Typical seismic section passing across the complex horst-anticlinal structure with jump-up thrust faults on the left flank and compensative jump-up faults on the right flank.

nesis in Middle Jurassic. This horizontal stress induced extensive strike-slip faulting and large-amplitude anticlinal uplifting. Then, during on-going compressive deformations, stress was redistributed within the Paleozoic rocks. As a result, in the lower part of the deformed unit, of the Early and Middle Carboniferous (C_1—C_2) age, horizontal stress increased and produced intense compound thrust and jump-up faults. Their planes incline to the northern side of the DDB, where stress was maximal. At the same time, in the upper part of the deformed strata, of the Late Carboniferous (C_3) and Early Permian (P_1) age, stress was released and transformed into tension, specifically on the opposite limbs of the folds. As a result of this local tension regime, the northern flanks of the structures were affected by multiple compensative jump-up faults, dipping southwards to the axial planes of the anticlines. The same forces pushed up the structural crests and formed fault-bounded horst-anticlines. Both types of the controlling faults, with the former being more pronounced, propagate and can readily be identified on seismic images up to the wide-spread pre-Triassic unconformity surface (Fig. 2). They cross and go out in the Lower Carboniferous deposits.

High-quality imaging of prospective features. Before, the study area was investigated by 2D seismic and proved to be productive from several wells. Nevertheless, it can still contain significant amounts of unexplored hydrocarbons. However, the isolated, limited areal extent, intricate geometry, and fault nature of these traps are major exploration and development challenges for 2D seismic. For this reason, a 3D seismic survey was acquired over this geologically complex area with the objective to generate new drilling prospects. In order to make further interpretation more successful, a high-quality objective-oriented depth processing sequence was applied. Before embarking on depth migration, we process any data in time to attenuate noise and enhance signal (see [Tiapkina et al., 2008; Tiapkina et al., 2010] for more details). Then, because of a complex structure of rocks and rapid lateral velo-city variations in the thrust environment, we switch the processing sequence to depth processing. This is the only way to minimize the pitfalls of interpre-ting structures from time sections and obtain geo-logic sections better correlated to well depths.

Depth migration in thrust settings requires an interpretive approach to building a plausible depth-velocity model, the key determinant in successful depth imaging. To this end, we integrate seismic and well data along with structural-geology constraints into the velocity model. We start with selecting several main geologic interfaces with regard to the main velocity contrasts in the area. For each layer, time-migrated picked horizons associated with RMS ve-locities and velocity gradient estimation deduced from well data allow the conversion of a time macro model into an initial depth model through map-mi-gration techniques. This initial model is then refined iteratively in order to make it geologically and geo-physically consistent using GeoDepth software. In-terpreters and structural geologists are closely in-volved in each step of this process to ensure that the velocity models are confident with well data and the known structural regime. Applying the advanced tool enables a more confident delineation of hydro-carbon traps within the zone of interest due to bet-ter positioning structural elements and better imag-ing faults. Since some traps in the area are con-trolled by faults, it is therefore essential to improve fault resolution and clarity and the ability to map events across these faults. Fig. 3, *a* shows that the structural elements after Kirchhoff prestack depth migration (PSDM) are more pronounced than those after Kirchhoff poststack time migration (postSTM). In Fig. 3, *b*, a zoomed portion of the left-hand side, demonstrates that an axial-parallel small-scale fault on the crest of the main domal uplift of the structure can be identified and tracked much more confidently after PSDM than after postSTM



a *b*

Fig. 3. Time slices extracted from the instantaneous phase attribute show a better interpretability of the structure after PSDM (bottom) than after postSTM (top) — *a*, zoom-in on the time slices from the left demonstrates an improved fault resolution and clarity after PSDM (bottom) as compared with those after postSTM (top) — *b*.

The seismic data interpretation workflow utilized and some results of reservoir characterization in this thrust zone are described in [Tiapkina et al., 2010]. The results of reservoir delineation and reservoir description allowed the drilling plans for new exploratory and development wells to be refined.

References

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