

sphere are easily fixed. Its parameters are characterized by the strike azimuth: 0° and 270°; 17° and 287°; 35° and 305°; 45° and 315°; 62° and 332°; 77° and 347°, less fixed fault systems with strike azimuth intermediate relatively with azimuth mentioned above. So, only in Precambrian there took place six large-scale tectonic activations of the Earth, regardless of much smaller — activations phases.

**Earthquakes** present as a oscillations of the Earth surface, caused by abrupt energy release in rather localized tectonosphere zones called sources. Talking about the forces nature caused the earthquakes famous American geologist Bruce Bolt said: the same forces geological or tectonic creating mountains, rift valley, ridges and deep-water trays, the same forces are the primary reason of the earthquakes. The nature of these global forces is not so clear [Bolt, 1981]. Fully share this opinion we can state, that the source of the forces caused the earthquake origin is the mentioned above global stress field occurred in the Earth tectonosphere as a result of its rotation regime variations.

The distinctive features of modern earthquakes from ancient tectonic activations are: its much less

energy intensity; corresponding between origination sources and ancient fault structures; and also — much higher frequency of the earthquakes appearance argued about that the preparation before the earthquakes need much less time. All features mentioned above can be explained by that the modern tectonosphere is less homogeneous relatively with Precambrian tectonosphere. Earlier tectonic activations of the Earth caused the appearance of the weak areas with lower strength ( $<10^7$  Pa). These areas are the zones of Precambrian different scale faults. This feature allows scientists to use it as an additional criterion for the earthquake prognosis.

Based on the possibility to calculate the global stress fields and all study features of earthquakes demonstration our university together with the UkrNIMI NAN Ukraine (Donetsk, Ukraine) are going to make research dedicated to creation of rational forecasting earthquake technique, included relational to its dynamic phenomena in mines, catastrophic consequences of which cause grand losses for mining industry of Donbass. Authors will be glad for collaboration.

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## 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. It belongs to a thrust zone that includes several 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-

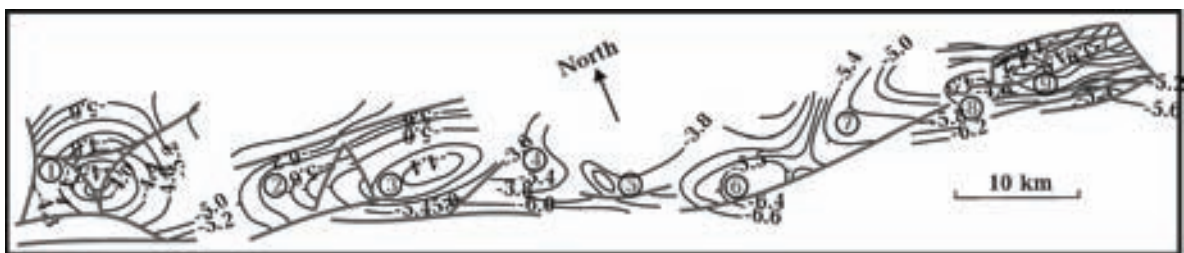


Fig. 1. Schematic map showing the structure and location of the (1) Pivnichno-Volvenkivska, (2) Zakhidno-Spivakivska, (3) Spivakivske, (4) Snizhkiivska, (5) Kamyanska, (6) Svyatogirska, (7) Torska, (8) Zakhidno-Drobyshivska and (9) Drobyshivske productive fields and prospective areas within an extensive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

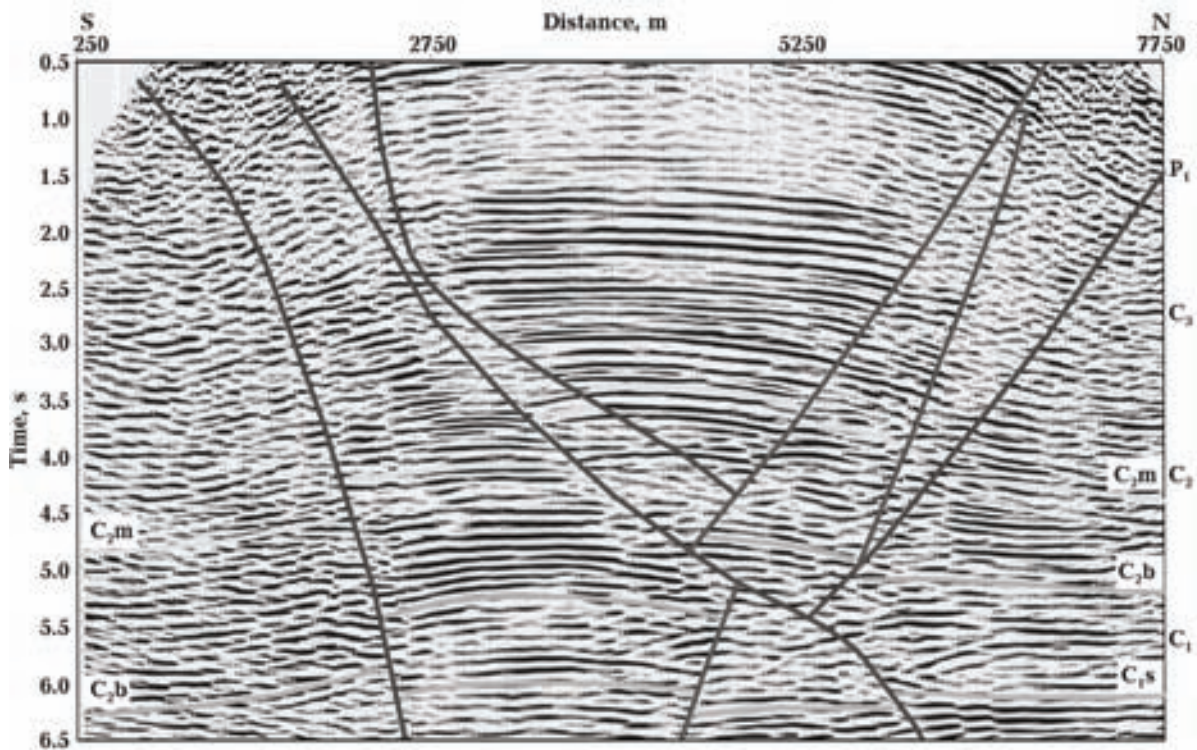


Fig. 2. Typical seismic section passing across the complex horst-anticlinal structure with jump-up thrust faults on the left flank and compensative jump-up faults on the right flank.

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 fur-

ther 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 velocity variations in the thrust environment, we switch the processing sequence to depth processing. This is the only way to minimize the pitfalls of interpreting structures from time sections and obtain geologic 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 velocities and velocity gradient estimation deduced from well data allow the conversion of a time macro model into an initial depth model through map-migration techniques. This initial model is then refined iteratively in order to make it geologically and geophysically consistent using GeoDepth software. Interpreters and structural geologists are closely involved 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 hydrocarbon traps within the zone of interest due to better positioning structural elements and better imaging faults. Since some traps in the area are controlled by faults, it is therefore essential to improve

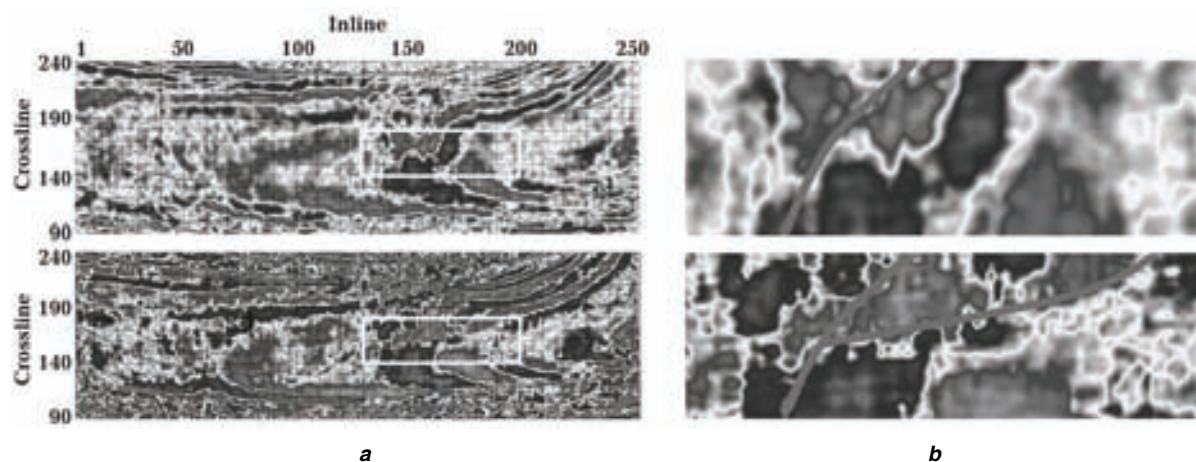


Fig. 3. Time slices extracted from the instantaneous phase attribute show a better interpretability of the structure after PSDM (bottom) than after postSTM (top) — *a*, zoom-in on the time slices from the left demonstrates an improved fault resolution and clarity after PSDM (bottom) as compared with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

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

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.

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## Heat flow pattern and fault structures in Donbas

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A map showing the heat flow pattern at depth in Donbas is based on the data of heat flow measure-

ments in over 5000 boreholes (Fig. 1). An unprecedented degree of detail has been achieved making

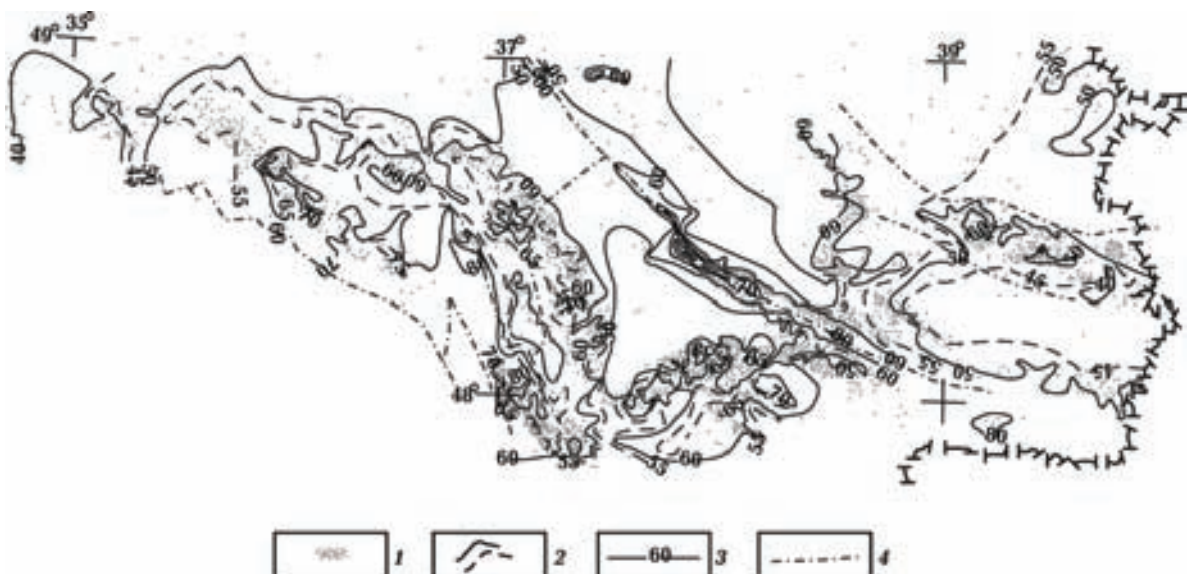


Fig. 1. A map of a heat flow (HF) of Donbas: 1 — points of definition HF; 2 — isolines HF; 3 — values HF (in Mw/m), 4 — fault zone.