Seismic Depth Imaging of Structures with Complex Overburden in Offshore Ukraine*

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Introduction

Of the 96 geologic provinces that contain almost all the world's known petroleum reserves, four lie in whole or part within Ukraine: the Dnieper-Donets, Pannonian, Azov-Kuban, and North Carpathian basins. According to the ranking of the U.S. Geological Survey World Petroleum Assessment 2000, they are 45th, 71st, 81st, and 82nd, respectively, in importance. In such a situation, one may wonder why Ukrainian oil and gas potential does not shine more brightly on the petroleum industry's radar screen? We connect this fact with various reasons, two of which are considered here. First, 2D seismic data acquisition still overwhelmingly predominates over 3D in Ukraine. Even though it is now well established that subsurface models resulting from structural mapping and reservoir quality evaluation with 2D seismic lack the detail provided by the 3D method. Second, basically, seismic data processing in Ukraine is still being performed in the time domain, and prestack depth migration (PSDM) has as yet not become quite commonplace for the Ukrainian seismologist. Meanwhile, in Ukraine, many hydrocarbon resource exploration and development plays in different tectonic settings involve rather thick sedimentary sequences with considerable lateral velocity variations; these in many cases lie above the reservoir or target zones. This gives rise to errors in positioning and shape estimation in seismically imaged deformational or sedimentary structures when using simplified poststack time migration procedures. The magnitude of these distortions is not well appreciated by many Ukrainian interpreters working in areas where the phenomenon occurs. The only way to overcome this shortcoming is to use PSDM much more widely in geologically complex areas with dramatically changing overburden. PSDM, specifically combined with 3D data acquisition, minimizes the pitfalls of interpreting structures from time sections and yields a geologic section better correlated to well depths. The data processing examples from a variety of structural settings in offshore Ukraine detailed here illustrate the improvements in seismic imaging and structural positioning when we stop ignoring lateral overburden velocity heterogeneity and begin to correct for it in depth migration.

Case Study

The territory of interest for this study is located in the northwestern part of the Black Sea's shelf along the marginal edge of the Scyphian platform and covers the prospective Olimpiyska, Komsomolska, Krayova and other areas. The geological section of the territory is composed of sedimentary rocks of Mesozoic and Cenozoic age. Pre-late Miocene regression in this passive-margin rift basin produced a number of deeply incised submarine canyons. They dissect clay rocks of the Oligocene-early Miocene-aged Maikopian Series, which have interval velocities of about 2300 m/s. The valleys are filled with more sandy sediments of Tortonian age with interval velocities of about 2600 m/s. Since these strata with a different velocity represent considerable erosion into the underlayer (300-600m deep), they create difficulties imaging structures below. Here, we present case studies of the mapping of carbonate reservoirs beneath the incised valleys, extensively developed throughout the territory. To demonstrate the potential for achieving improved seismic images through reducing the overburden influence, let us consider the Olimpiyska area.

Two wells have been drilled in this area. The first of them, well 400, produced commercial quantities of hydrocarbons from middle Eocene fractured and cavernous limestone of at a depth of 1950m. Then another well, well 1, penetrated the same limestone at a depth of 1945m, but it turned out to be a dry hole. This was puzzling, given that the well appeared to be drilled on a structural high mapped on the basis of poststack time migration. This structure is clearly visible in Figures 1 and 2, which allow comparison of poststack time migration and PSDM in this area. Figure 1 is a combined line (AA' in Figure 2) passing through wells 1 and 400, with an incised valley, indicated by blue line. Both figures, which show how difference between time structure and true depth structure, clear up the puzzle.

After time-domain processing, it seemed that both wells were drilled within a common anticline, with well 1 being located at the top of the structure. In the poststack time migrated section, we see that the target limestone was mapped at wells 400 and 1 at times of 1880 and 1840ms, respectively. PSDM showed the structure to be two-humped, with both wells located at the tops of the separate anticlines. Furthermore, after PSDM, the seismic depths of the target limestone correlate much better to the above depths in both wells. We consider this an argument for the validity of the structural mapping. What is the difference between the two anticlines?

The southern limb of the left (western) high is deeply dissected by the sand-filled valley indicated in Figure 1. On the one hand, this canyon could erode the impermeable cover of the anticline, initiating a possible leakage of hydrocarbons upward if the carbonate reservoir had been charged before the forming of the incised valley. On the other hand, this canyon could possibly serve as a channel for hydrocarbons migrating updip and past the anticline if this process happened after filling and burial of the valley.

This study has allowed the drilling plan for new exploratory wells in this area to be refined. In examples from other areas of the offshore territory, similar time pull-ups under incised valleys, filled in with sandstones and flanked by slower clays, are also resolved after PSDM.

Conclusions

The results of seismic data reprocessing and reinterpretation demonstrate, in our opinion, that discoveries of large oil and gas fields are still possible in offshore Ukraine with the use of modern technology. We think that future great discoveries may be made in part by PSDM combined with 3D-4C data acquisition and using more sophisticated anisotropic models of strata.

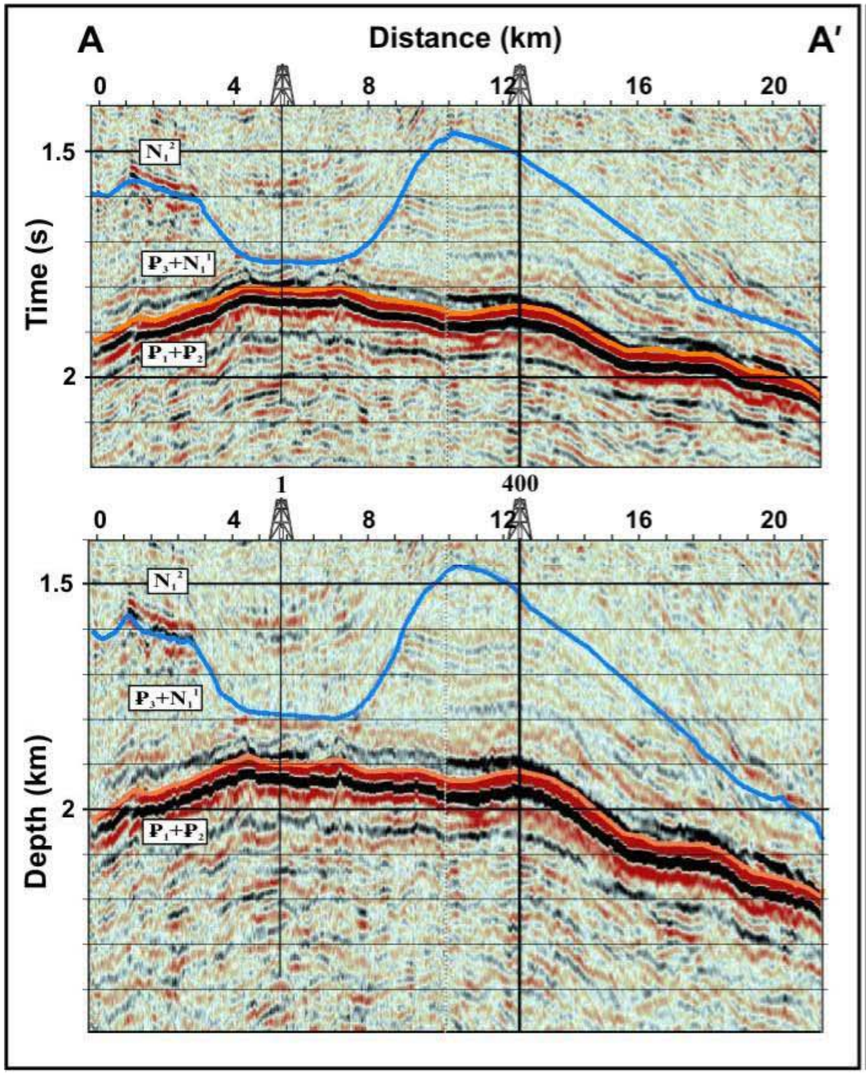

Figure 1. Comparison of poststack time migration (upper) and PSDM (lower).

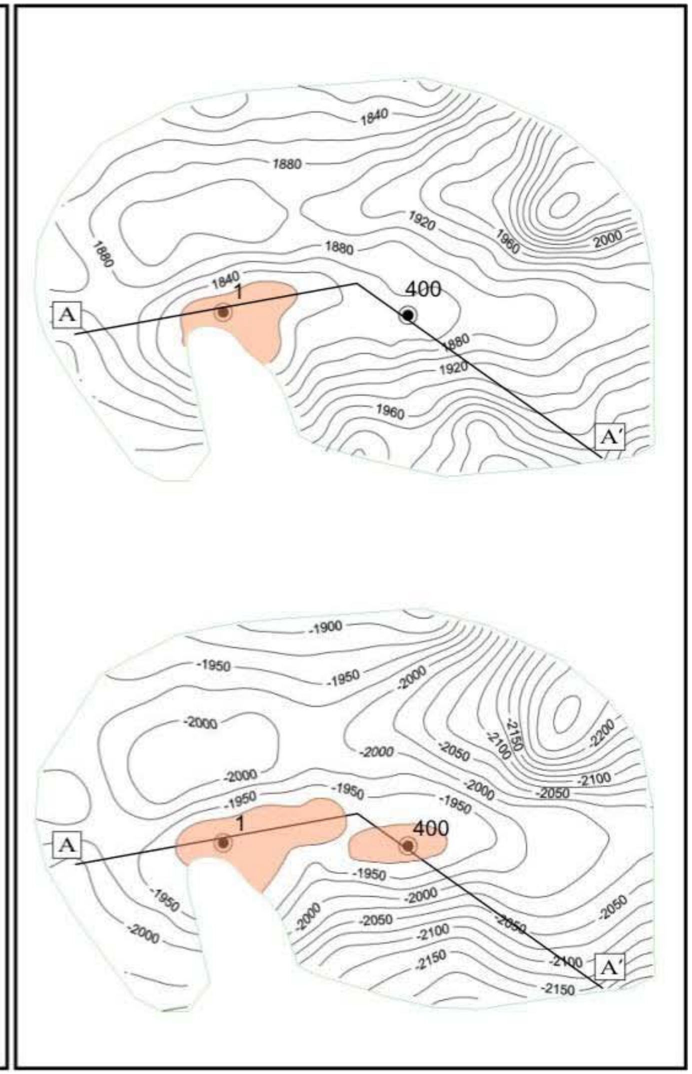

Figure 2. Time (upper) and depth (lower) structure maps at the top of the middle Eocene.