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Fractured Reservoirs Delination in Carbonates with Duplex Wave Migration Technology Implementation

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SUMMARY

The case study describes a new approach to delineate complex fracturing structures in one of the Timano-Pechera oil fields. The Timano-Pechora basin, located north of the Ural mountains by the Barents and Kara Sea, is a mature petroleum province, and majority of its oil fields produce from naturally fractured and vuggy carbonate reservoirs with complex pore systems. It has been observed that fracturing and vugular zones strongly influence production performance. The application of duplex waves migration allowed to build reliable maps of fracturing zones. It was also shown that the presence of vugular porosity zones has a strong influence on the production behaviors of the wells.

Introduction

Many of Timano-Pechera oil deposits are located in carbonate reservoirs with complex fracturing structure and vugular porosity. The development of such oil reservoirs is sometimes problematic due to the unpredictable behavior of the production wells. The presentation describes one of these complex oil fields. The Silurian carbonate layers with more then 200 meters thickness were accumulated under shallow shelf conditions, however there were almost no signs of primary voids remained. The main void is formed by vugs, but the most productive wells are not always associated with a productive section and in many cases high well yield was associated with the sections with quite dense rocks. The substantial contribution to the oil yield of these wells makes fracturing. And if the reservoir capacity problems can be solved using acoustic inversions, the problem of location of «fracture swarms» (or «sub-seismic faults» or «large-scale fracture») using seismic data is not a trivial task. Nevertheless, several successful projects for delineation of conducting fractured passages were carried out (Khromova et al, 2008, 2011) with "Duplex waves migration" (DWM) technology. Application of DWM technology in this case has also brought new useful seismic information and enabled the identification of large fracturing zones, which accompany the boundaries of thrust planes. The comparison of production data with fracturing zones maps obtained with DWM technology has explained many incomprehensible facts in production wells behavior.

Method and/or Theory

Duplex wave – is a wave that is reflected twice: first time from the sub-horizontal layer, then from a sub-vertical layer (or in the opposite order) and then it reaches the surface and gets recorded. Until quite recently in surface seismic was assumed that the imaging of sub-vertical boundaries was not possible since reflection from those boundaries never reached the surface. The duplex wave properties were studied in works (Kostyukevych A.S. *et al.,* 2001 and 2008, Marmalevsky N.Y. *et al.,* 2005 and 2006,) where it is shown that their energy is strong enough to be used in the exploration of geological targets. The DWM technology is well described in previously mentioned paper (Khromova et al, 2011) and others given in the reference list.

Example

The oil deposits in the studied area were located in the Silurian carbonate layers with the thickness more then 200 meters The adjacent mobile zone of the Ural Hercynian orogeny contributed to the development of the large structural bar formed by several partly overriding planes. The deposits located in different planes have independent levels of water-oil contact (OWC). However the water inflows registered in some wells contradicted accepted and proved levels of OWC, which caused geologists to invent invisible by seismic tectonic barriers for explanation of these contradictions. Very irregular well productivity could not be explained by reservoir rock porosity and permeability: some wells in more dense rocks had better yields then the wells in high porosity layers.

After analyzing of all available geological and seismic information all wells in the area were divided into four groups:
1) high capacity and high production
2) high capacity and low production
3) low capacity and high production
4) low capacity and low production.
The above classification was established by the combination of presence/absence of vugs and fracturing (Figure 1).

	Fractures are present	Fractures are absent
	High capacity and high production wells	High capacity and low production wells
Vuggs are absent	Low capacity and high production wells	Low capacity and low production wells

Figure 1: *Classification of wells.*

The complex of exploration methods for fracturing examination was applied to many wells in the study area. And the comparison with production logging tool (PLT) data demonstrated that not always the maximum inflow was associated with high porosity and vugular intervals. Moreover, the maximum inflow intervals in many cases were omitted during interpretation of borehole imaging log data.

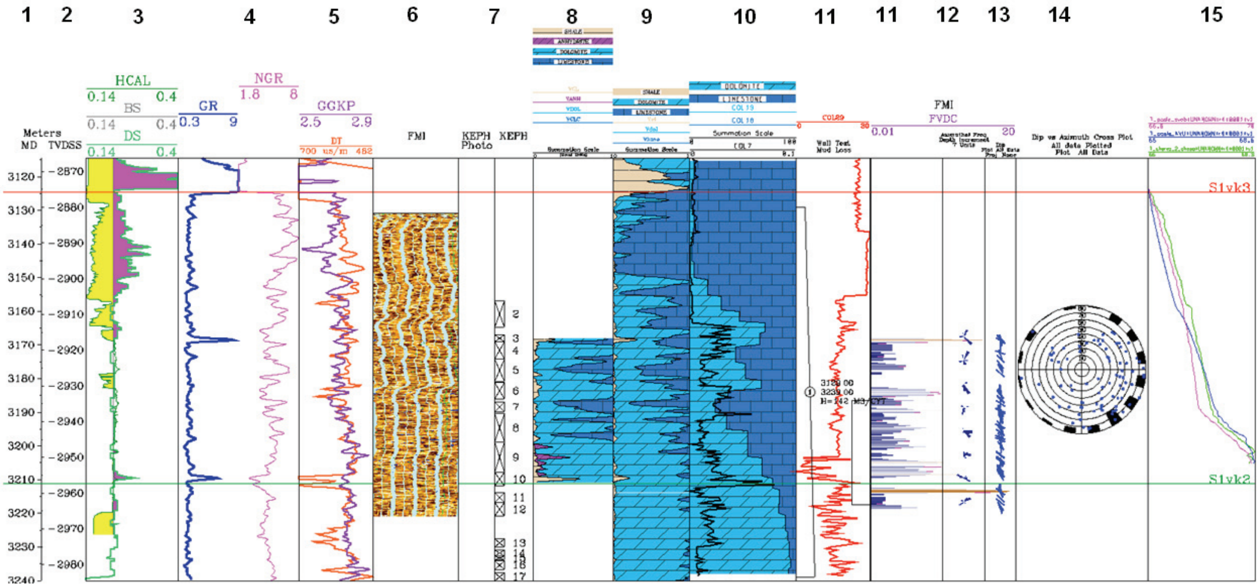

Figure 2: *Well log results from well A. Columns content: 1) MD, 2) TVDSS, 3) Caliper (initial- right, during FMI – left), 4)Gamma-Ray blue & Neitron Log pink, 5) Density violet & Sonic orange, 6) scanning FMI, 7) interval of core, 8) litologic interpretation of Spectral Gamma-Ray,) litologic interpretation of electric logs, 9) litologic interpretation of mud-logging, 10) well test – left & interval of mudloss – right, speed of drilling – red curve, 11) intensity of fracture from FMI, 12) azimuth of fracture from FMI, 13) dip of fracture from FMI, 14)Dip vs Azimuth Crossplot, 15) PLT.*

Duplex waves migration requires assignment of the base surface at the bottom of the target horizon, and the reservoir consists of three thrust planes and autochtone, therefore DWM was applied to each plane and autochtone (Figure 3). This approach helped to describe the areas of productive reservoir above the thrusts.

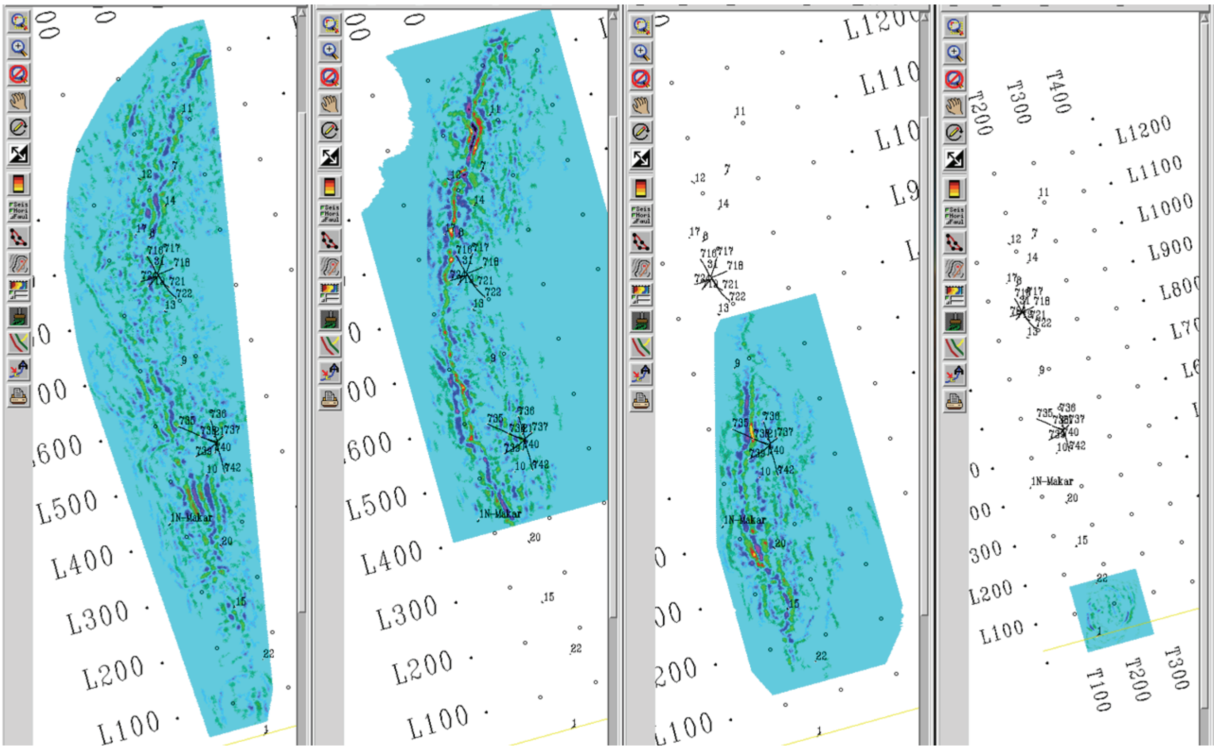

Figure 4. *Amplitude maps of duplex waves separately for four base surfaces: 1) autochtone, 2) north plane, 3) central plane, 4) south plane.*

Nevertheless the complete picture of reservoir tectonic structure can be made using the integrated map (Picture 4-A), obtained by subsequent superposition on the overlaying plane upon underlying surface.

The exploration results of borehole fracturing (core photos, FMI, wide azimuth acoustic, spectral gamma logging, hydrodynamic study) with stratigraphic slices and vertical sections of the duplex waves cubes demonstrated high resemblance. High-output and / or quickly watering out wells were usually located within linear anomalies of duplex waves. Low-output wells are always located outside of the duplex waves linear anomalies. However, there was a group of high production wells located outside of the duplex waves linear anomalies. The careful analysis of well hydrodynamic study results showed the linear pattern of Inflow performance relationship curve, which gave evidence of a matrix reservoir.

Conclusions

The application of duplex waves migration for carbonate reservoir allowed obtaining of reliable map of fracturing zones development and explained numerous contradictive results of exploration of production drilling.

Acknowledgements (Optional)

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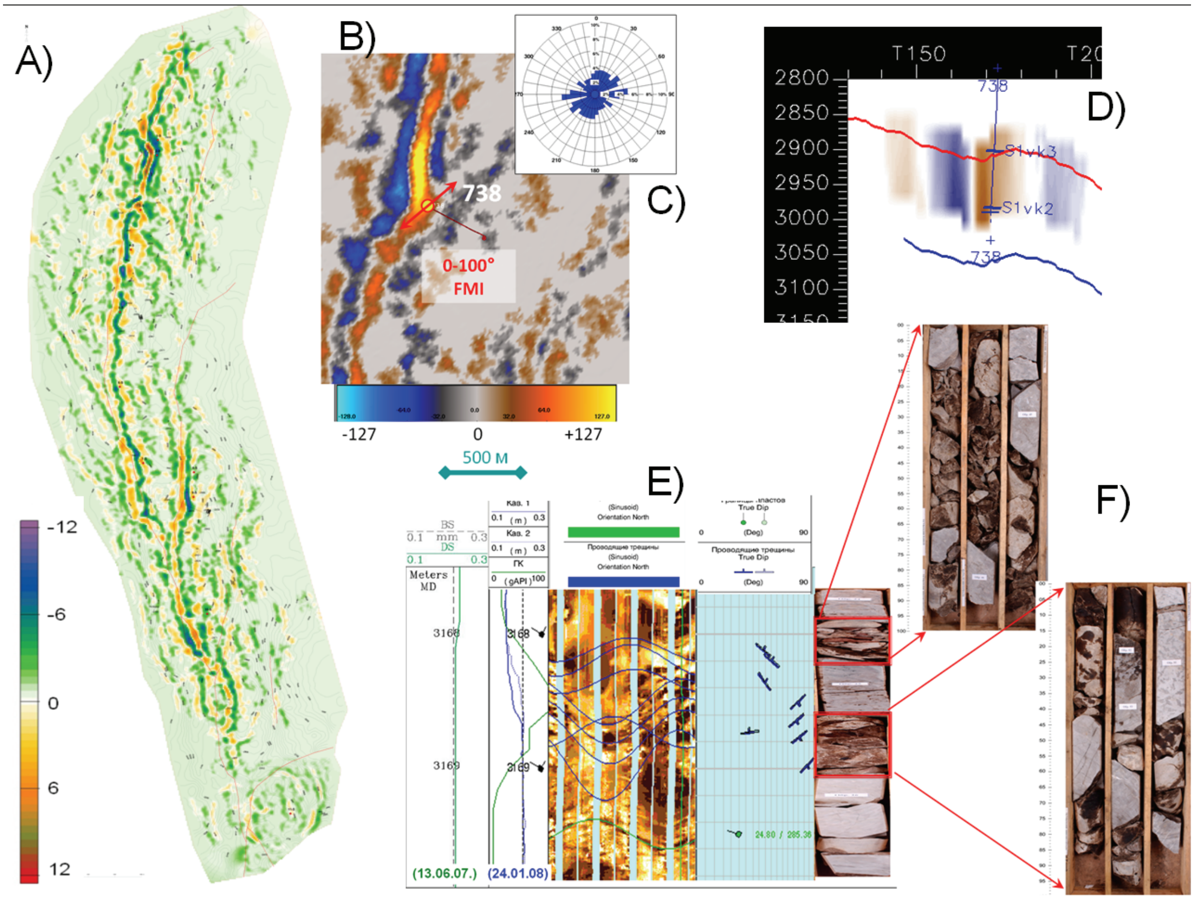

Figure 4. *A) map of duplex waves amplitude for study area, B) map fragment of duplex wave amplitudes in vicinity of 738 well, drilled through the highly fractured section, C) rose-diagramm of fracture from FMI, D) duplex waves depth cube section through 738 well, E) surveying panel FMI of 738 well in the high fracturing interval, F) photos of strongly fragmented core.*

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