Reliability of Reservoir Forecast in One of the West Siberia Fields*

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Abstract

The presence of oil and gas pools associated with non-anticline structures in West Siberian basin initiated exclusive state-of-art reservoir characterization technologies for exploitation and development of new oil and gas fields. The paper shows the reliability analysis of reservoir and net pay thicknesses determination in Jurassic-2 (J2) formation, by comparing of the well log interpretation results in new drilled wells with thickness map from geostatistical stochastic inversion. Conformability of the prediction results demonstrates that the estimation of reservoir properties in clastics formations based on geostatistical partial stack inversion is very reliable and results are confirmed by newly drilled wells. The results can be successfully used for planning future production wells.

Introduction

One of the reliable and accurate seismic tools for reservoir properties prediction is based on inversion technology. Different inversion technology enables to integrate different data to achieve reasonable geological interpretation. Based on deterministic and geostatistical inversions results and dynamic analysis of seismic 3D data, the reservoir distribution forecast and sweet spots for further field development were identified for Jurassic (J2) formation. After new wells were drilled, we have assessed the reservoir properties confirmability.

Conditions for the Geostatistical Partial Stack Inversion

The unique forecast confirmability was obtained despite a number of features that complicate the process of making a forecast and undermine the belief in getting adequate results based on the inversion.

1. The main challenge to predict reservoir thickness is that the target interval includes two independent productive units, each of which has its own area of distribution area. The boundary between them corresponds to a local change of the depositional environment.

2. Low contrast of lithotypes in clastic formations. Formation J2 is a part of Tyumen suite. Lithological heterogeneity is a feature of the lower reservoir, which is composed of sandstone and sandy shale rocks interbedded with coal. Frequent interbedding, incisions and slide traces, noticeable in the core, as well as a large number of coal beds indicates continental geological setting. The structure of the formation J2 is featured by extreme heterogeneity in the distribution of permeable rocks both vertically and lateral, its thickness varies from 13 m to 43 m. In different wells reservoir location and Net-to-Gross ratio varies significantly. Such heterogeneity is partly connected with coal interbedding, though they, for the most part, tend to locate in the lower part of the formation J2. Such a lithological heterogeneity complicates prediction of reservoir properties and requires a detailed, in-depth study. A very complex lithology of the formation reflected a significant difference in its elastic properties. Reservoirs are permeable sandstones and siltstones. Net thicknesses in the study ranged from 1.8 m to 19 m according to well data, net pay thickness, respectively, from 0.6 m to 8.4 m, in some wells permeable rocks are virtually absent. The percentage of lithology type "lithotypes" (ratio in the sample) in J2 formation is the following: oil-bearing reservoir - 11%, water-saturated reservoir - 9%, non-reservoir - 80%. Figure 1 shows lithotypes distribution in a field of elastic parameters. We have chosen P-Impedance, Vp/Vs, Density parameterization. Unfortunately, water-bearing reservoir and non-reservoir lithotypes are characterized by a wide overlapping zone.
3. The presence of shear velocity in only one well in a field, which makes difficult elastic properties modelling.

Rock physics modelling was accomplished in seven wells of the field. As shear velocity was acquired in a single production well, only density and compressional velocity were modelled in the other wells. Besides, due to the limited information about the properties of water-saturated intervals, e.g. formation J2 is mainly productive, fluid substitution from oil to brine was carried out in some wells of the license area. The main purpose for rock physics modelling is to analyze the possibility to separate pay reservoirs using seismic data.

Elastic properties modeling were done to solve the following tasks:

- Good-quality wavelet estimation for reliable well tie.
- Evaluation of the fluid substitution effects and rock lithological composition changes on elastic properties.

Forecast distribution oil-and water-bearing reservoir can be done only with the two elastic parameters. In this case, these are P-Impedance and Vp/Vs. Therefore have been made deterministic and geostatistical inversions based on partial seismic stacks. General principles of deterministic and geostatistical inversions are described in the article written by Filippova and Kozhenkov (2011).

Deterministic inversion results are often interpreted to get a single model of the environment, regardless of the associated uncertainties. Here the interpretation adopted an approach that is described in paper written by Sams and Saussus (2010), which addressed the probabilistic interpretation of the deterministic inversion result. It should be noted, the uncertainties in lithotypes identifying based on deterministic inversion results related to many factors: the noise of seismic data, seismic resolution, wide overlapping zone of lithotypes distribution in a field of elastic parameters and the use of low-frequency model. Due to the thin oil and water-bearing layers in the target interval J2 (from 0.6 m to 8 m) and the resolution itself the result of a deterministic seismic inversion can't be used for quantitative estimates (for example, the net thickness of the reservoir), as it is an integral character. Thus, the results of deterministic inversion predetermine the necessity to use geostatistical inversion.

For each lithotype, the statistical model was created using the P-Impedance, Vp/Vs, and density data from the petrophysical interpretation and the rock physics modeling. Geostatistical inversion runs on a stratigraphic grid, so, in order to generate a framework for it, it is necessary to have detailed correlations of stratigraphic boundaries in the target intervals and to define the vertical size of a cell. In this case study, the vertical cell size was set to ¼ ms, as this corresponded to the expected size of the thin features of interest within the reservoir layers. Seismic data were presented as partial stacks in the following offset ranges: 0-700 m, 500-1100 m, 900-1600 m, 1400-2000 m, 1800-2500 m, 2300-3000 м with sample rate 2 ms, 350 sq. km. and frequency range 0 – 50 Hz. Highly detailed inversion results due geostatistics and well data, with multiple realizations consistent with the seismic data.

Results

There are 30 realizations that became the result of AVA geostatistical inversion. Forecast net thickness and net pay thickness maps have been obtained as the average of the corresponding thickness maps. A series of QC procedures were performed to check the quality of inversion results:

- Analysis of correlation coefficients between the input seismic data and the synthetics obtained during inversion. All partial stacks were involved in this process;
- Analysis of signal-to-noise ratio maps for each partial stack;
- Analysis of residuals, the difference between the seismic and synthetic data, both in the time and the amplitude-frequency domain.
- good compliance of the inverted elastic parameters in well points and the same parameters obtained from the wells survey;
- Comparison of predictive lithology, porosity, etc. in well points with the results of petrophysical interpretation.

However, data from the newly drilled wells are of better quality and enabled to do the reliability control of 3D reservoir models derived from the seismic inversion. Comparison of net thickness and net pay thickness in layer J2 determined by geostatistical inversion and well log analysis (37 wells) has shown good match. The difference (dHeff) between inversion net thickness (Heff_RM) and true thickness encountered in wells (Heff_well) and determined by log analysis varies from -3.9 m to 4.6 m. The confirmability analysis of determining net thickness done for the formation J2 shows 29 wells have the difference between predicted and actual thickness determined from well log analysis equal to 2.1 meters (Figure 2).

It is less then mean standard deviations calculated from 30 geostatistical inversion realizations (Std_RM) equal 2.3 m. Shallow wells didn't reach the bottom of target interval, therefore, in the analysis of confirmability forecast net thicknesses involved less well than the net pay thicknesses. The difference (dHoil) between inversion net pay thickness (Hoil_RM) and true net pay thickness encountered in wells (Hoil_well) and determined by log analysis varies from -3.1 m to 2.9 m. The confirmability analysis of determining net thickness done for the formation J2 shows 37 wells have the difference between predicted and actual thickness determined from well log analysis equal to 1.7 meters (Figure 3). It is less then mean standard deviations calculated from 30 geostatistical inversion realizations (Std_RM) equal to 2.1 m.

Conclusions

The forecast of the net and net pay thicknesses was applied as a result of deterministic and geostatistical inversions which were performed on the basis of integration of well log interpretation, elastic properties modelling and using facial reconstructions. Confirmability prediction of oil-bearing and water-bearing reservoirs, generated by geostatistical partial stack inversion shows the appropriateness of the geostatistical inversion on the areas of West Siberia.

Acknowledgements

References Cited

Filippova K., A. Kozhenkov, and A. Alabushin, 2011, Seismic inversion techniques: choice and benefits: First Break, v. 29/5, p. 103-114.

Sams, Mark, and Denis Saussus, 2010, Comparison of lithology and net pay uncertainty between deterministic and geostatistical inversion workflows: First Break, v. 28/2, DOI: 10.3997/1365-2397.2010005.
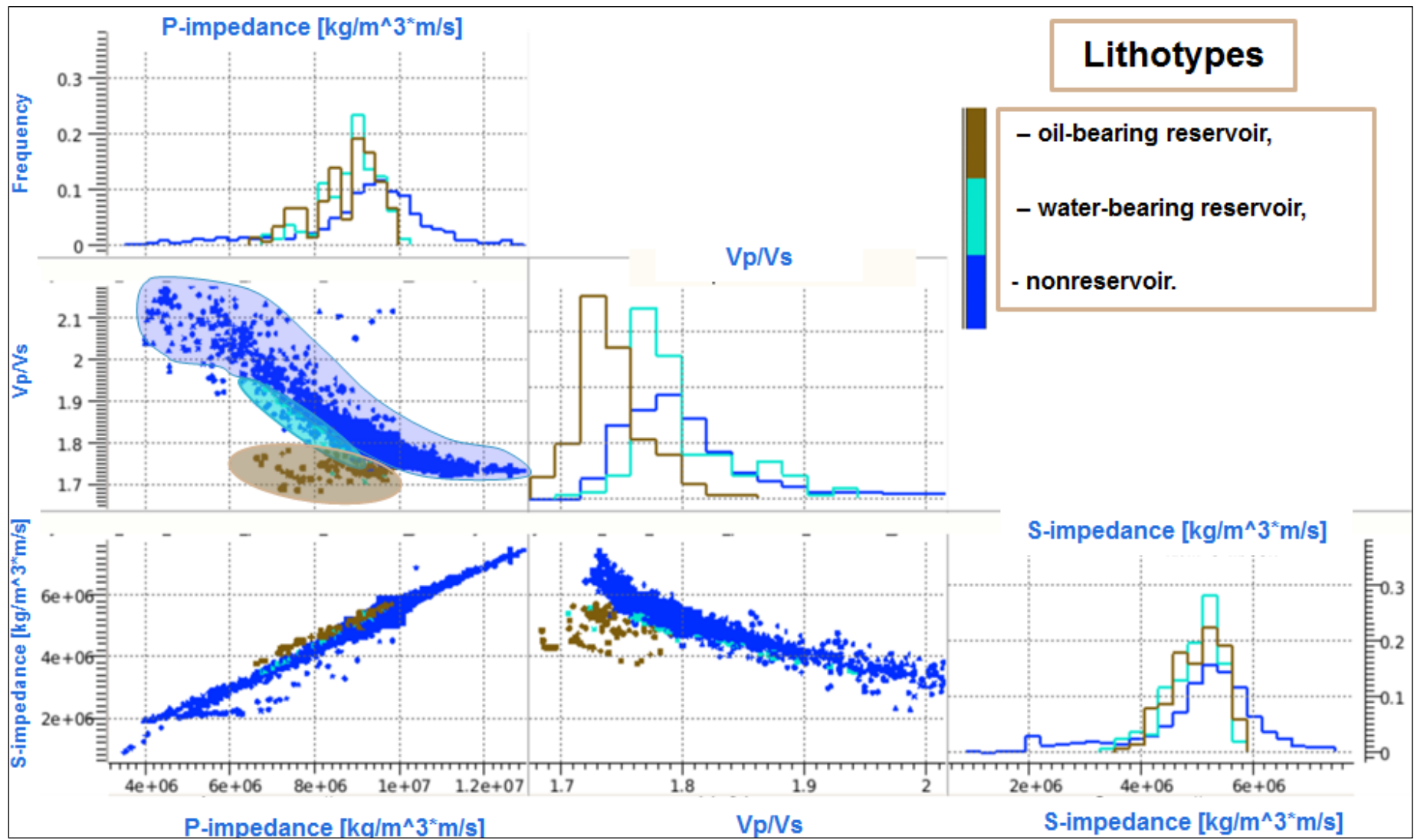
Figure 1. Cross-plots of well log data in geostatistical scale, showing the separation of lithotypes in the field of elastic parameters.

Wells	Heff_well, m	Heff_RM, m	dHeff, m	Std_RM, m
A	5.7	6.7	2.4	1.8
B	8.4	10.8	2.4	2.3
F	17.0	20.0	3.0	2.9
H	11.8	14.3	2.4	2.2
I	19.0	15.1	-3.9	1.9
J	13.5	16.4	2.9	2.9
L	15.6	18.7	3.1	2.1
M	12.7	12.5	-0.2	1.5
N	10.9	15.5	4.6	2.0
P	13.3	16.3	3.0	2.7
R	14.3	18.1	3.8	2.1
T	10.5	12.7	2.2	3.3
U	13.4	13.7	0.3	3.8
V	6.4	9.2	2.8	1.8
W	14.0	16.7	2.7	2.3
X	14.6	17.1	2.5	2.6
Y	3.5	4.1	0.6	2.7
Z	6.9	6.9	-0.1	1.9
AA	7.0	7.7	0.7	2.5
BB	1.8	0.6	-1.2	1.5
CC	7.2	4.4	-2.8	1.5
DD	7.4	7.2	-0.3	2.0
FF	4.8	2.6	-2.2	1.6
GG	7.6	10.3	2.7	2.9
HH	8.0	7.2	-0.8	2.6
II	4.0	5.0	1.0	1.7
JJ	3.0	1.5	-1.5	1.8
LL	4.6	5.5	0.9	2.2
MM	13.7	12.3	-1.5	2.7
Min,m/ft	1.8/5.9	0.6/2.0	-3.9/-12.8	1.5/4.9
Max,m/ft	19.0/62.3	20.0/65.6	4.6/15.1	3.8/12.5
Mean,m/ft	9.7/31.8	10.7/35.1	1.0/3.3	2.3/7.5
Std,m/ft			2.1/6.6	

Figure 2. Fragments of net thickness map with comparison of net thickness obtained from simultaneous geostatistical partial stack inversion with data from newly drilled wells.

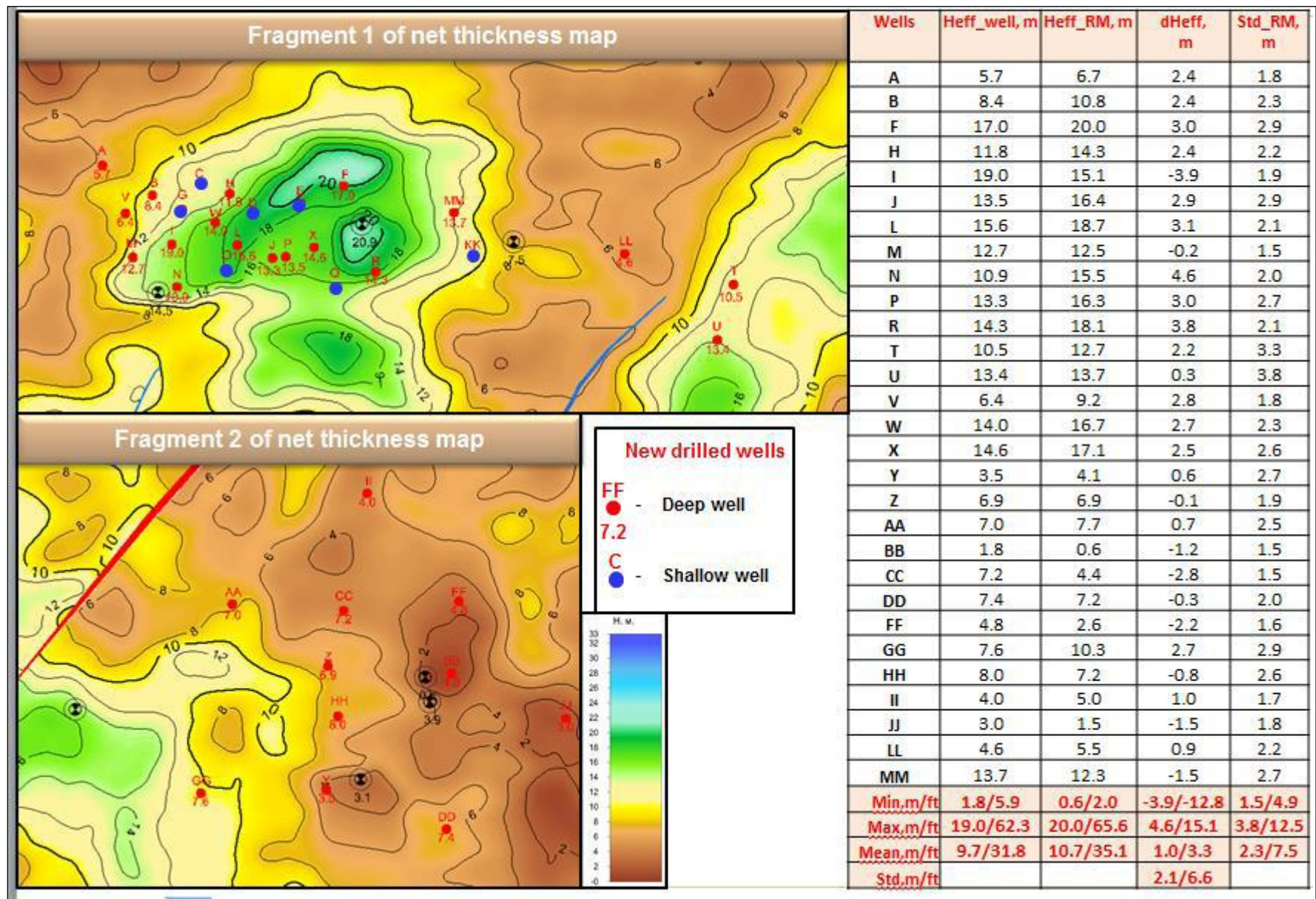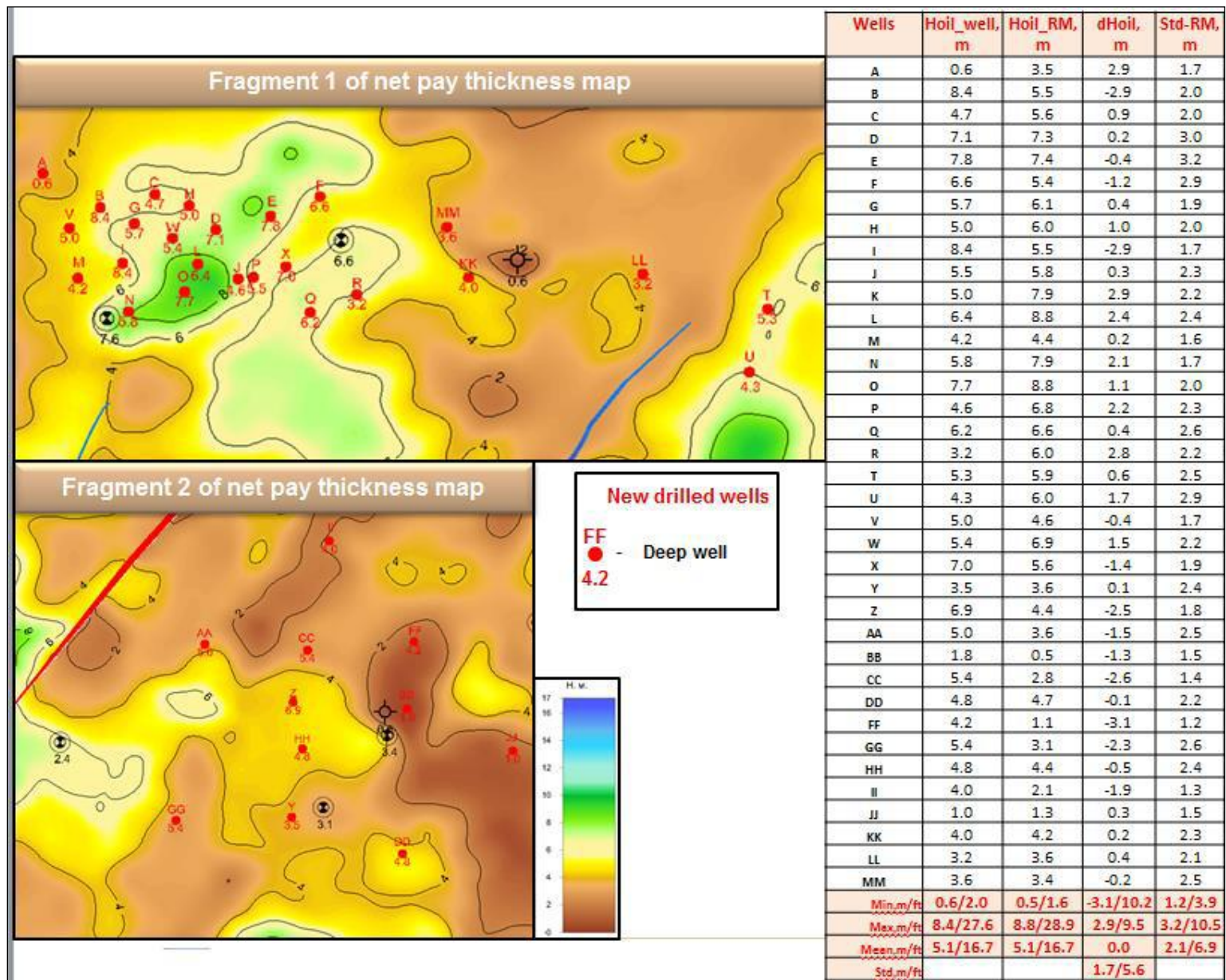| Wells	Hoil_well, m	Hoil_RM, m	dHoil, m	Std-RM, m
A	0.6	3.5	2.9	1.7
B	8.4	5.5	-2.9	2.0
C	4.7	5.6	0.9	2.0
D	7.1	7.3	0.2	3.0
E	7.8	7.4	-0.4	3.2
F	6.6	5.4	-1.2	2.9
G	5.7	6.1	0.4	1.9
H	5.0	6.0	1.0	2.0
I	8.4	5.5	-2.9	1.7
J	5.5	5.8	0.3	2.3
K	5.0	7.9	2.9	2.2
L	6.4	8.8	2.4	2.4
M	4.2	4.4	0.2	1.6
N	5.8	7.9	2.1	1.7
O	7.7	8.8	1.1	2.0
P	4.6	6.8	2.2	2.3
Q	6.2	6.6	0.4	2.6
R	3.2	6.0	2.8	2.2
T	5.3	5.9	0.6	2.5
U	4.3	6.0	1.7	2.9
V	5.0	4.6	-0.4	1.7
W	5.4	6.9	1.5	2.2
X	7.0	5.6	-1.4	1.9
Y	3.5	3.6	0.1	2.4
Z	6.9	4.4	-2.5	1.8
AA	5.0	3.6	-1.5	2.5
BB	1.8	0.5	-1.3	1.5
CC	5.4	2.8	-2.6	1.4
DD	4.8	4.7	-0.1	2.2
FF	4.2	1.1	-3.1	1.2
GG	5.4	3.1	-2.3	2.6
HH	4.8	4.4	-0.5	2.4
II	4.0	2.1	-1.9	1.3
JJ	1.0	1.3	0.3	1.5
KK	4.0	4.2	0.2	2.3
LL	3.2	3.6	0.4	2.1
MM	3.6	3.4	-0.2	2.5
Min,m/ft	0.6/2.0	0.5/1.6	-3.1/10.2	1.2/3.9
Max,m/ft	8.4/27.6	8.8/28.9	2.9/9.5	3.2/10.5
Mean,m/ft	5.1/16.7	5.1/16.7	0.0	2.1/6.9
Std,m/ft			1.7/5.6	

Figure 3. Fragments of net pay thickness map with comparison of net pay thickness obtained from simultaneous geostatistical partial stack inversion with data from newly drilled wells.