SHORT COMMUNICATION

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An example of practical application of information on fracturing according to the well logging data complex and high-tech methods

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Abstract. In the article the issue of investigation by logging methods of reservoirs with natural fracturing is considered. A special case of revealing the reason for fast watering of productive layers with the help of a logging data complex and high-tech methods, such as: cross-dipole acoustic logging, acoustic scanner, electric micro-imager is considered. Scanners allow us to get an image of the inner surface of the well wall in order to reveal fractures. Measurement of the propagation characteristics of acoustic waves is used to detect fractures. Complex interpretation led to the conclusion that the watering is due to the presence of sub-vertical fractures associated with the underlying aquifers.

Keywords: fracture, microscanner, watering

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There are several approaches to identification and investigation of reservoirs with natural fracturing. Out of these approaches, the following deserve closer attention (Dobrynin et al, 2004):

- lost circulation and growth of ROP during drilling are the main indicators that drilling is going on in a fractured and porous medium;
- fractures and core solution channels provide direct information on the nature of reservoir's porosity. If actual flow rates of a formation are several times higher than those estimated with core data, then we should suspect presence of natural fractures in such a formation not observed on core samples. A low core delivery rate – less than 50% – also presumes presence of a strongly fractured carbonate rock in the core sampling interval;
- logging tools are designed in such a way that their readings are variously affected by different features of a borehole and a section. Well Logging methods based on measurements of acoustic waves propagation characteristics are used for identification of fractures. Caliper logging data, density logging and electrical logging data in certain circumstances may be useful for identification of fracture zones;
- pressure build-up curve analysis;
- vertical fractures in a non-deviated hole may be identified as high-amplitude anomalies intersecting other bedding planes;
- fractures and solution channels are discovered with methods for direct or indirect imaging of borehole walls applying a borehole imager;
- abnormally high production rate is typical of naturally fractured formations;
- a significant growth of a Well's productivity after hydrochloric acid inflow stimulation is a reliable indication of a formation with natural fracturing. Acid treatment is conducted in order to expand fractures and channels;
- due to high permeability of fractures, pressure's horizontal gradient in a fractured formation is generally not high, both near the well and over the entire formation.

Table 1 shows the methods, and their capabilities and limitations in identification of fractures. It is obvious that the most effective instruments for assessment of fractures are acoustic and electrical micro imagers.

The oilfields of TPP "TatRITEKneft" of Nurlat Group showed flooding of productive horizons during development. In order to establish causes of fast flooding, it was decided to apply an extended set of Well Logging methods, including high-tech investigations. Fracture studies in Mid and Lower Carboniferous deposits were conducted in two wells: No. 1426 (crestal) and No. 1429 (flank). Their location is shown on Fig. 1 of a structure map for top Tournaisian stage. The entire completed set of Well Logging methods was analyzed, including electrical micro imager (MCI), cross-dipole acoustic log

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	Core	Electrical Formation Imagers (FMS\FMI\MCI)	Acoustic Borehole Imager	Litho-Density Log	Lamb-Stoneley Wave	Lost Circulation
What is identified?	Local fracture porosity	Mud penetrating fractures	Contrasting acoustic properties	Density of hard mud particles penetrating the fractures	Stoneley wave energy reflected by fractures	Loss of circulation from borehole into formation through fractures
How narrow are the fractures to be identified?	Approximately several micro meters	Approximately several micro meters in case of sufficient conductivity contrast	1 mm	5 mm	1 mm	0.2 mm
Man-made fractures mistaken for natural permeable fractures	Fracture porosity. Man-made fractures.	Fracture porosity. Man-made fractures. Formation damaged while drilling	Fracture porosity. Man-made fractures. Interlayers with high impedance values and part of healed fractures	Fracture porosity. Formation damaged while drilling. Salinity.	Boundaries of cavern	No
Survey depth	Core diameter	10 mm	3 mm	100 mm	Less than 1.8 м	Mud penetration radius is >1 m
Can data from this method be used to establish fracture's dip angle and bedding plane angle?	Yes	Yes	Yes	No	No	No
Mud limitations	No	Only water-based mud	Mud density must be less than 1.68 gr/cm^3	Mud density must be 1.2 gr/cm^3	No	No
Remarks	No core delivery from highly fractured «corrugated zones»	Hard to differentiate fractures with high and low permeability	Hard to differentiate fractures with high and low permeability	No	Fractures clogged with mud's hard particles are often not identified	Provides information on the level of formation damage and requirements to its treatment

Table 1. Brief characteristics of natural fractures investigation methods (according to Mukhamadiev et al, 2014)

(MPAL) and acoustic scanner (CAC) in order to identify fractures which contribute to Well flooding.

Figures 2, 3 show interpreted data from the extended Well Logging set of methods. The second track after depth column on Figure 2 shows Gamma-Ray curve, Caliper Log and Neutron Gamma-Ray Log, Gamma-Gamma Density Log curves; the third track shows Nuclear Magnetic Log; the fourth one – electrical metering; the fifth track shows porosity and oil saturation coefficients; the following columns show fractured intervals identified due to various Well Logging techniques, including anisotropic intervals identified after Cross-Dipole Acoustic Logging (tracks 8-10). The right-hand side of the Figure shows Cement Bond Log data, string contact, Variable Density Log (string bond and rock bond). Identified fractured intervals are confirmed by deterioration of the casing string's cementing quality identified during another acoustic survey in a cased hole (Fig. 2b), as well as by further fast flooding of productive reservoirs.

Well 1426 in the 951.0-1035.0 m interval (Vereiskian-Bashkirian) after electrical micro imager identified 13

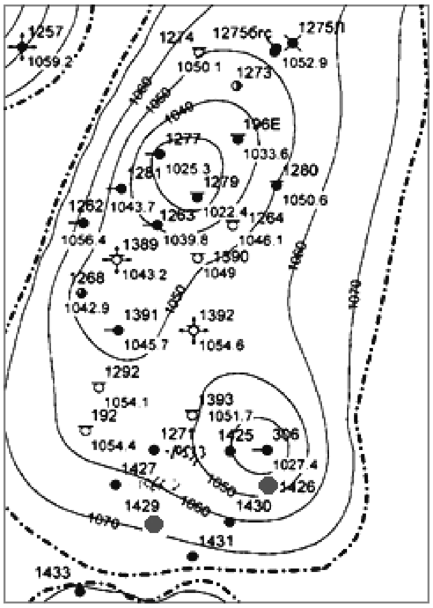


Fig. 1. Structure map for top Tournaisian stage

healed fractures, 8 partially-healed fractures and 3 open fractures. The 1196.5-1295 m interval in total showed 20 healed fractures, 14 partially-healed and 4 conductive fractures. The fracture dip angle was predominantly 45.2-74°.

According to acoustic logging data, in well 1429 five healed fractures were identified in the 1188.6-1222.4 m interval. The fracture dip angles vary within 65.8-71°, the dip azimuth is within 91-115.6° range (south-east being the main dip direction).

An example of a fractured interval as per electrical micro imager data is shown on Figure 4.

Well 1429 located at the flank of the structure, according to high-tech methods identified much less fracture intervals. Fast flooding is most likely to be caused by presence of sub-vertical fractures associated with underlying aquifers. The cause of Well flooding is in presence of natural fracturing of rocks.

Therefore, high-tech methods identified a reason of fast flooding which is associated with natural fracturing of sub-vertical trend.

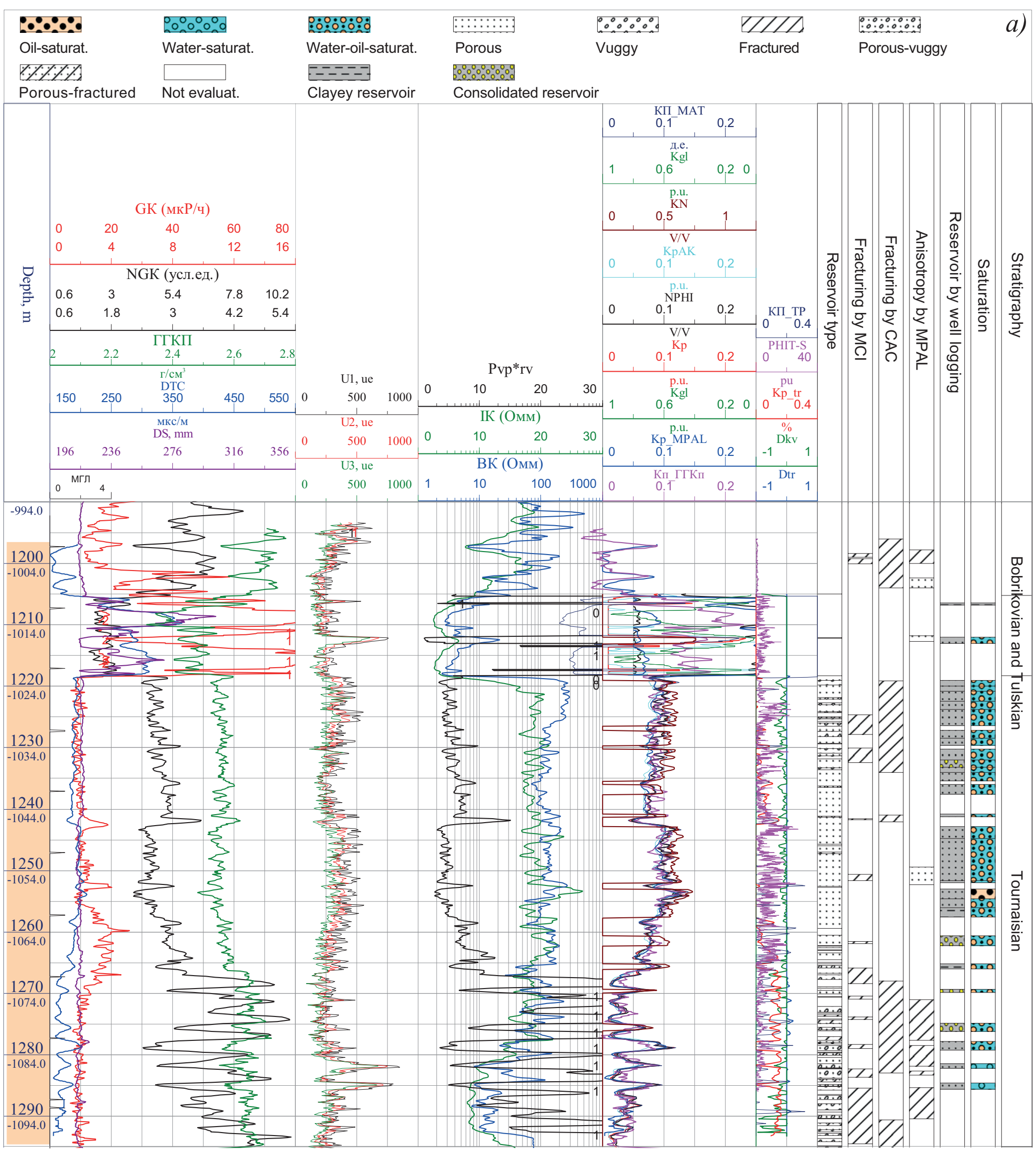
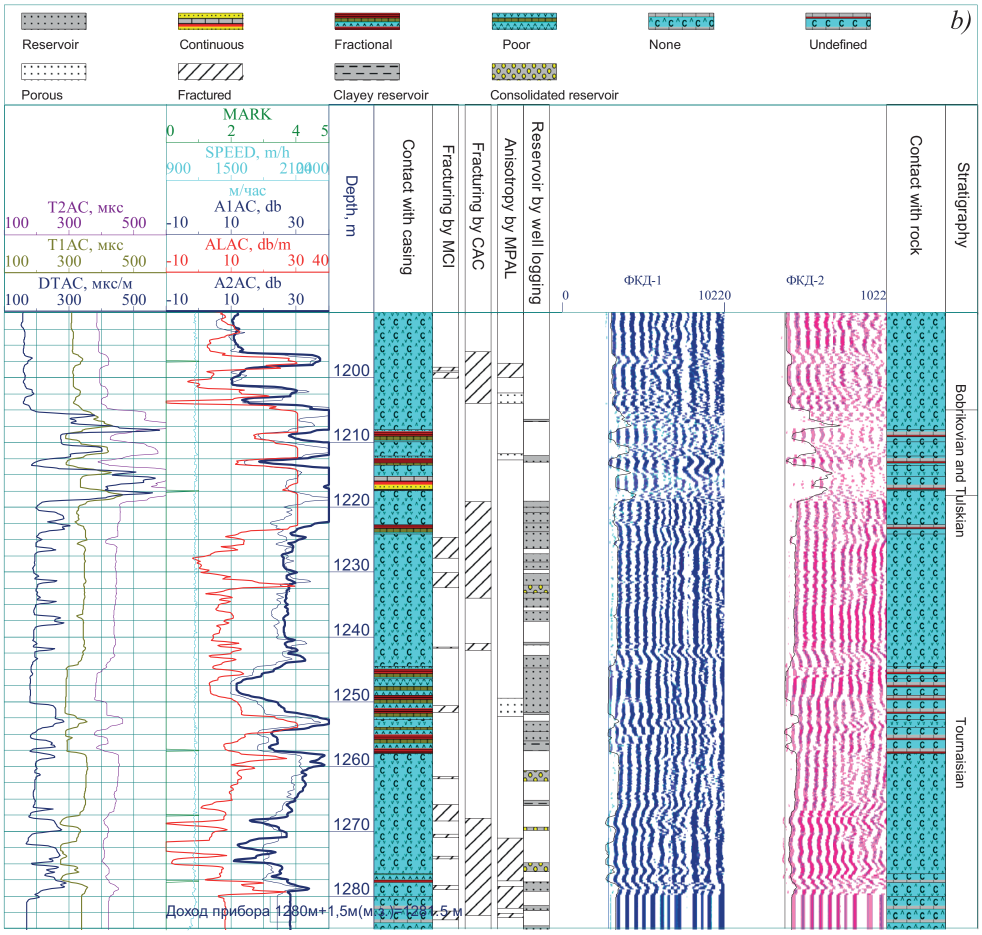


Fig. 2. Analysis of fracturing for well 1426 in Lower Carboniferous deposits: a) open hole, b) cased hole



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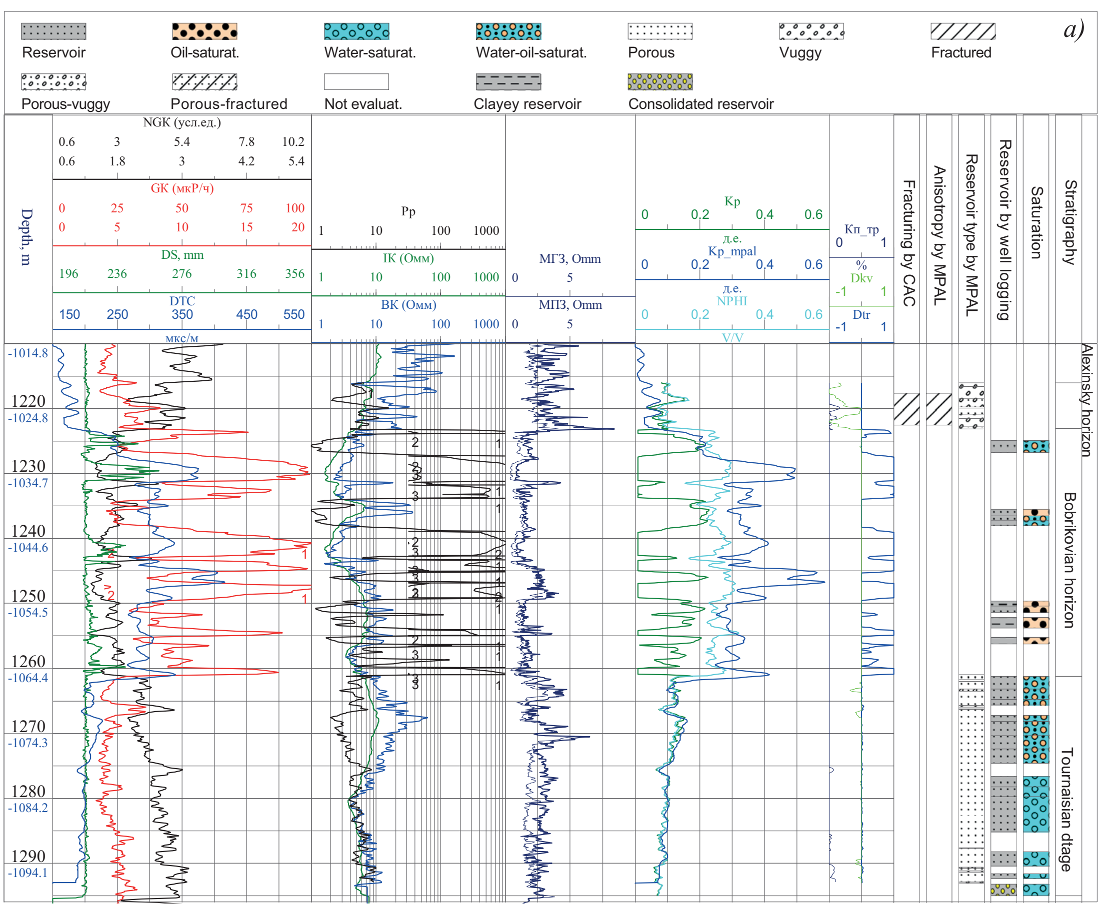

Fig. 3. Analysis of fracturing for well 1429 in Lower Carboniferous deposits: a) open hole, b) cased hole

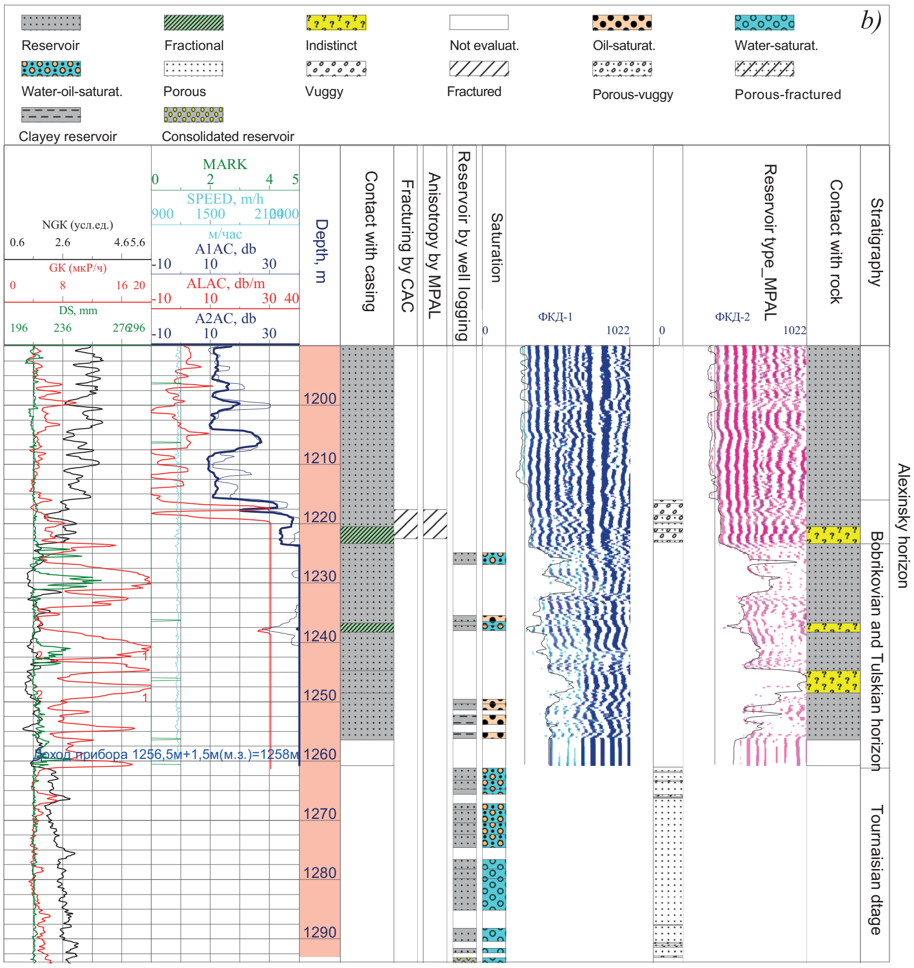

Fig. 3. Analysis of fracturing for well 1429 in Lower Carboniferous deposits: a) open hole, b) cased hole

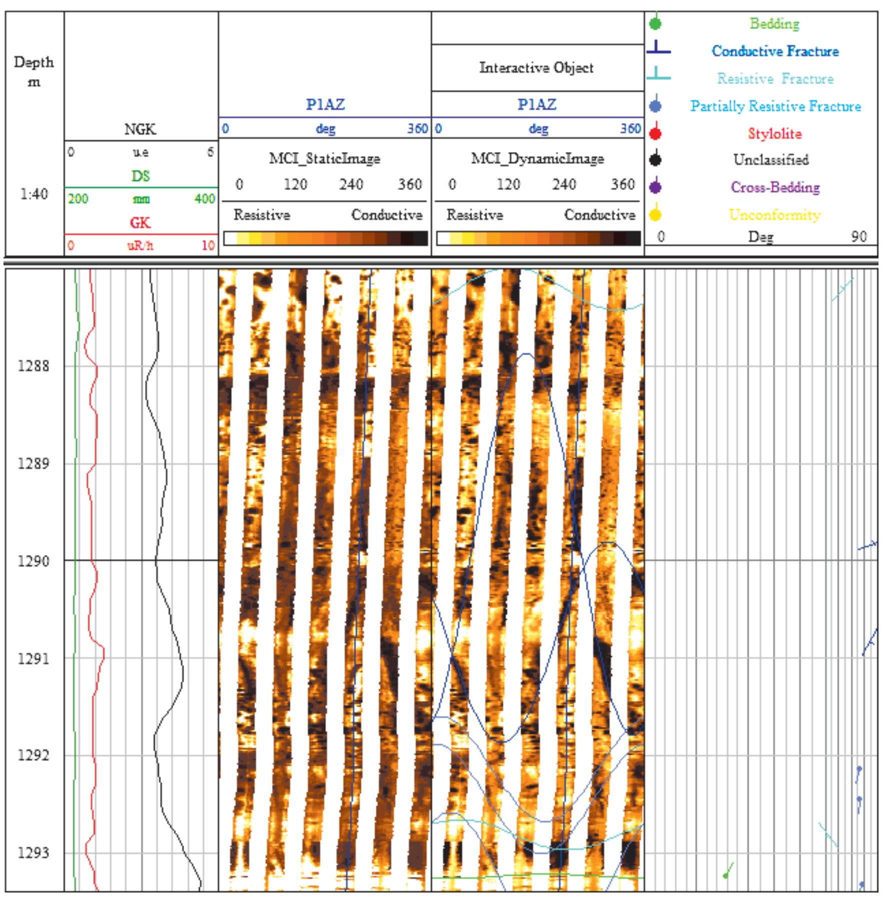

Fig. 4. Example of a fractured area according to electrical micro imager data

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