ABSTRACTS

of the 6th International Conference "Inverse Problems: Modeling and Simulation"

held on May 21 - 26, 2012, Antalya, Turkey

Edited by

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IZMIR UNIVERSITY - 2012

Electromagnetic sounding data interpretation at thermal exposure to oil reservoir

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In [1] novel method of probing wells using high frequency electromagnetic signals equipment is proposed. The method consists of four main parts. The first part is describing focusing properties of isoparameter three reel probe using probabilistic convolutions. The second part is studying distribution of non-mixing fluids near the well using mathematical model of mud filtrate penetration. The third, conductive properties of the changed deposit area (multiphase heterogeneous medium) are estimated using the model of interaction between mineralized ground waters and mud filtrate. The fourth part is solving inverse problems. The main purpose is to establish prior filtration characteristics of the deposits using minimal deviation of the measurement results from theoretical estimations.

The link between physical measurements and changes in the field of true resistivity of specific electric resistance (SER) caused by filtrate penetration is the Archie Law [2]:

$$R_{s_1} = s_1^{-n} a \frac{0.0123 + 3647.5C^{-1}}{1.8T + 39}, \tag{1}$$

where R_{s1} – SER of deposits with water saturation s_1 and concentration C; T – temperature in Celsius; n – index, approximately equal to 2; a – some constant, which characterizes given saturated rock. In accordance with (1), penetration area resistance, cooled or heated by filtrate R_{nT}, is as follows:

$$R_{nT} = \frac{1.8T_p + 39}{1.8T_0 + 39} R_n, \tag{2}$$

where T_p and T_0 - temperature of the formation and fluids, injected into the well. Equipment measures data "apparent" SER, which is subject to the following check [1]:

$$R_i = \int_0^{\infty} R(r)\rho_i(r)dr, \tag{3}$$

where ρ_i — density of lognormal distribution of the sensor i sensitivity.

When mud filtrate penetrates into sub-well area the salt exchange happens between fluids in interdiffusion area, and may be regarded as instant. In this case, as shown in [3], fluid mixing area borders can be obtained from simple balance ratio. When considering heat and mass exchange in porous media electric resistance by convention is divided into four zones

$$R = \begin{cases} R_{nT} = R_n(1.8T_p + 39)/(1.8T_0 + 39), 0 < r < r_T \\ R_n = R_n^0/(1 - \langle s \rangle)^2, r_T < r \le r_{oz} \\ R_{oz} = R_0^0/(1 - \langle s \rangle)^2, r_{oz} < r < r_f \\ R_0 = R_0^0/(1 - s_0)^2, r_f < r. \end{cases} \tag{4}$$

Distribution of apparent SER $\overline{R}(r_i)$ is derived from integral view of the resistance with regards to (3).

In our case we use the proposed model and temperature influence (denoted by α - viscosity ratio of water and oil) on the distribution of SER and conclude that: when heating (or cooling) sub-well area, it's SER has greater (lower) importance in an area up to the border of temperature comparing to the models, where temperature influence is not included.

Results obtained in [1] match real measurement results well, but do not include temperature field influence on electric resistivity distribution. In order to obtain closer matching of the estimated results it is important to solve given inverse problem in complex. In other words, estimate both α and s_0, which influence apparent resistance $\overline{R} = \overline{R}(\alpha, s_0, r_i)$. Following is the problem of oil reservoir electromagnetic measurement data interpretation via estimating prior distribution of oil saturation s_0 and parameter α through minimizing mean deviation of measured data from the theoretic curve:

$$J(\alpha, s_0) = \left[\sum_{i=0}^{n} \left(\overline{R}(\alpha, s_0, r_i) - R(r_i) \right)^2 \right]^{1/2} \quad (5)$$

Because functional (5) depends on α in nonlinear and implicitly, solving interpretation problem it is hard to formulate corresponding an adjoin problem or use other known methods of solving inverse problems, which explicitly allow identifying relations between an unknown parameter and functionality. As a result, a new computational algorithm was proposed. It is based on a modified gradient method [4].

In this study, we investigated the influence of temperature on the distribution of the electrical resistivity. The establishment of conductive properties of the oil reservoir was based on mathematical model of different temperature mud filtrate penetration into the oil deposits with according to constructed computing algorithm, which calculates the effect of temperature on the process of oil displacement.

Achieved results and programmed module (which implements the designed algorithm) allow correcting interpretation of physical measurements, done using electromagnetic equipment.

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Short-Bio

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