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Earths-field surface spin echo of aquifer

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1. Introduction

Soundings using surface NMR in the Earth's magnetic field can be applied to measure subsurface movable water content (effective or producible porosity) [1-3]. The distribution of water saturation down to depth of 100 m and more is determined by inversion of an integral equation, including model and measured SNMR signal amplitude [4].

2. Experimental

The excitation and reception of the signal is accomplished with the help of an antenna, circle of 100 m diameter, placed at the surface. The frequency of magnetic resonance in amounts 2,5 kilohertz, the dead time of the instrumentation - 40 ms, Earth's field inclination - 74° (Fig. 1). Two pulses have been used to study spin echoes [5, 6].

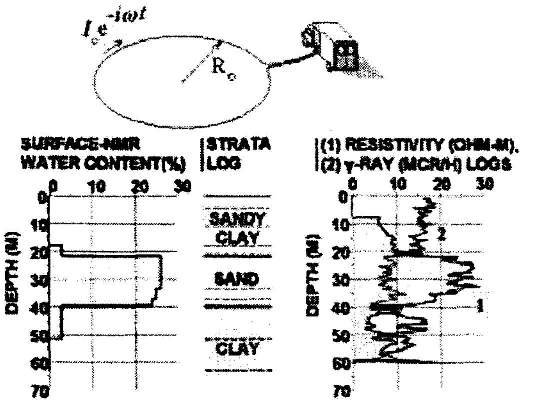

Figure 1: Scheme of MRS experiment at the No 37 borehole

3. Results and discussion

Free-induction decay T_2^* equal to 60 milliseconds, spin-echo T_2 equal to 220 milliseconds, and inversion-recovery T_1 equal to 700 milliseconds relaxation times have been measured using earth's-field magnetic-resonance sounding of medium to coarse-grained sand aquifer (depths at 21 to 40m) near borehole No 37, Novosibirsk (Fig. 1,2).

The porosity $\phi = 25$ % (as well as saturation of groundwater with depth distribution) has been estimated sing inversion procedure. Microscopic characteristics of the aquifer, such as: longitudinal relaxivity $\rho_1 = 7\cdot 10^{-3}$ cm/s, transverse relaxivity $\rho_2 = 3.5\cdot 10^{-2}$ cm/s, and local magnetic field gradient $G = 2\cdot 10^{-2}$ Gauss/cm have been estimated using both the experimental data and the following equations set:

$$1/T_1 = 1/T_{1bulk} + \rho_1 S/V$$

$$1/T_2 = 1/T_{2bulk} + \rho_2 S/V + (\gamma G t)^2 D/12$$

$$1/T_2^* = 1/T_{2bulk}^* + \rho_2 S/V + (\gamma G t)^2 D/3 + \gamma G a,$$

where S/V is the pore surface area to volume, D is the self-diffusion coefficient, $T_{1bulk} = 1.4$ s and $T_{2bulk} = 1$s are the longitudinal and transverse relaxation times of bulk water measured independently, a is a grain radius, γ is the gyromagnetic ratio of protons, t is time.

Using diffusion coefficient $D = 1.3\cdot 10^{-5}$ cm^2/s for water at 277 K one can estimate the diffusion term $\sim 4\cdot 10^{-2}$ s^{-1}. Also experimental data of spin-spin relaxation times T_2, T_2^* measurement did not vary with time, confirming that the diffusion term in the equations must be approximately zero for this aquifer [6].

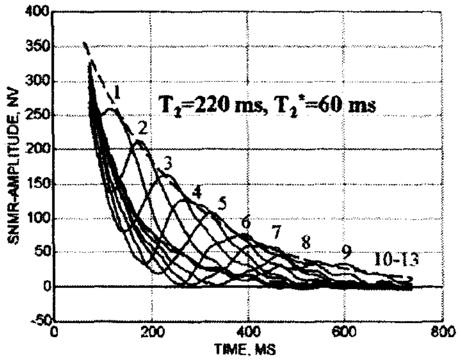

Figure 2: FID and spin-echo (16-34 ms pulse sequence). Hole No 37, Novosibirsk. 1-13 - delay 100 - 700 ms.

4. Conclusion

The results obtained could be applied to investigate the microstructure of pores and fractures, as well as filtration properties of aquifers and diamagnetic, hydrocarbon, and paramagnetic contamination.

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