Application of High Precision Magnetic Susceptibility Logging for Well Log Analysis in Oil Deposits

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High precision apparatus for magnetic susceptibility logging (MSL) and core measurements have been developed for investigation of sedimentary rocks in oil wells. We suggested and developed a new transducer for MSL - a solenoid probe. Features of the probe proposed differ greatly from those of dipole ones for MSL. At the MSGA the apparatus for MSL having solenoid probe of different spacing - 0.06 m, 0.08 m 0.12 m and 0.15 m were tested in boreholes. The study of spaial characteristics of solenoid probes depending on the ratio between the length of the main transmitter and receiver coils and the spacing made it possible to select an optimum correlation: the lenght of the main coils should 3.5 - 4 times exeed that of the spacing. The main parameters of solenoid probe are the following:

- diameter of exploration zone makes up 5 - 7 spacing of the probe;
- diameter of the exclusion zone with available compensation coils makes up 0.8 - 1.4 spacing;
- thickness of stratum (at such thickness it is considered to be unbounded) is 5 times as the probeís spacing (by 95% signal level);
- minimum thicness of definitely distinguishable stratum makes up 1.4 of the probe spacing (by 50% signal level);
- amplitude of marginal effects on the curve in the vicinity of homogeneous magnetic stratum makes up not over 3% of the amplitude opposite of the stratum centre.

The manufactured apparatus consists of two probes with different spacing, and, therefore, the difference in radial and vertical characteristics allows to investigate the radial distribution of magnetic susceptibility in distinquished beds with thickness of 0.4 m and over. Main distinction of solenoid probes from dipole ones are the follows: a high level of signals, low sensitivity to local nonuniformities, a comparatively large depth of investigation, a favourable shape of curve, which is not complicated by marginal and sceen effects. Registration of MSL curves with the horisontal scale 5-10E-06 SI units/cm allows a good reproduction.

Representative testing in many oil wells in different regions of Russia permit us to solve problems of log analysis. High precision MSL offers greater opportunities for litological and stratigraphical differentiation of sedimentary sequences in boreholes. The lowest values are typical of hydrochemical sediments, the highest - of clays. In the majority of cases terrigene rocks are well distinquished in the carbonaceous sequences, beter than done by GR. Apart from the rock lithologic characteristic proper, high precision MSL gives evidence also of geochemical setting of sediments accumulation or its variability in the course of epigenesis.

The derivation of petrophisical equations for magnetic susceptibility is based on the principle of electromagnetic analogy - well known resistivity equations were implemented as initial. We have produced theoretical and experimental equations of magnetic susceptibility with porosity and volume of clay. In difference to resistivity, where the type of shaleness mainly effect the value of apparent resistivity, geochemical conditions (oxidental or restorative) of shale sediments accumulation mainly effect magnetic susceptibility of rocks. Under constance of geochemical conditions there are dependencies of relative magnetic susceptibility (the ratio of MS bed to MS matrix) with porosity in pure and shale sandstones. The equation type is similar to one of Archie's formula and looks like:

$$\chi_{bed}/\chi_{matrix} = a/\phi^m .$$

In carbonate rocks with less magnetic susceptibility, the persentage of limestones, dolomites, siderites create a more powerful effect on magnetic susceptibility. The solytion of linear petrophysical equation for Magnetic, Neutron, Density or Sonic logs allows to more accurately and easier determine the above mentioned persentage of the components.

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The calmatation zones in fractural intervals are eisily recognized by dual MSL through normalization of traces and studing of radial deviation of magnetic susceptibility. Additional use of MSL in cross-plotting and PCA increases the reliability of petrophysical analysis.

High precision MSL can be successfully applied for the well correlation. There are examples of both local correlation and regional stratigraphic correlation based on the differentiation of sedimentary rocks according to their magnetic susceptibility.

Magnetic susceptibility could also be applied for depth matching the core data, studies of interfluens of conductivity and susceptibility on IL and MSL, correlation, cross sections and mapping.