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Early Bed Boundary Detection While Drilling - Testing and Application of a Bit Resistivity Device

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Abstract

Early detection of a change in formation is often key to making safe and efficient decisions while drilling. Where sudden changes in pore pressure or wellbore stability relating to lithology are expected, reducing bottomhole assembly (BHA) penetration into these zones allows either changes to mud parameters or casing seat selection to be made with reduced risk. Where reservoirs are intercepted, early reservoir detection offers the chance to maximize the productive interval by placing the casing the top of the reservoir, which is often most important for production. It also allows to perform conventional coring instead of bypass coring or to change the mud system to avoid damge of the reservoir.

This paper outlines results of testing a bit resistivity device. The tool induces and measures an electric current along the BHA through bit and formation. It can be used both in water-based and oil-based mud applications. Data are available in real time to provide answers while drilling, in particular to raise an early alert when approaching a specific target. The correction into borehole and mud corrected readings is outlined.

Using examples from test wells, the relationship between modeled and observed response is discussed with reference to real-time applications such as coring point and casing point detection. Comparison to conventional resistivity measurements and high resolution electrical images shows good agreement between these measurements. Finite element modeling (FEM) is used to quantify depth of detection (DOD) and depth of investigation (DOI). Both define distances ahead of the receiver at which an interface can be detected; at 10% and 50% signal change for DOD and DOI, respectively. Understanding these improves application planning. As part of the testing process, different BHA configurations and different formation resistivity contrasts were evaluated. Balancing BHA design versus service response in a specific environment provides a wide range of deployment opportunities.

Introduction

Data from formation evaluation (FE) sensors are often required to support the decision-making process during drilling operations. However, measurements are usually placed far behind the bit, causing delays in decision-making that can be responsible for safety problems or lost revenue.. Examples include setting of the casing just at the top of the reservoir to maximize the pay, early detection of a coring point, or the early detection of lithologies hazardous to safe drilling operations.

Avoiding these problems requires FE measurements as close as possible to or even ahead of the drill bit. The invention of a measurement system using toroidal transmitters by J.J. Arps[1] is one technology to achieve resistivity measurements in the Logging While Drilling (LWD) environment. The transmitter toroid induces a current along the drillstring that can be measured by a second toroid. Current designs of this technology usually combine the bit resistivity measurement with a lateral measurement[2,3,4].

The tool presented here is a dedicated sub entirely for the bit resistivity measurement. Therefore it has a small footprint in the BHA and can be located very close to the bit without compromising steering ability. Due to its modular build, it can be run together in rotary closed-loop drilling system (RCLS), rotary drilling, and motor systems. The following sections will first discuss the theory of the measurement, followed by results from field testing the device.