Evaluation of Formation Permeability from Borehole Stoneley Waves

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The propagation of borehole Stoneley waves has been shown to be sensitive to fluid mobility (ratio of permeability to viscosity). When crossing a permeable formation Stoneley wave energy attenuates and slowness increases, a phenomenon that is well described by Biot theory and one that has been verified in laboratory experiments.

However, as mobility effects on Stoneley waves are secondary and rather small, an accurate Stoneley wave propagation model as well as an optimal inversion technique is required to perform quantitative inversions of borehole log data. Effects of the mudcake on the borehole wall, which reduces pressure communication between the borehole fluid and the formation and thereby decreases Stoneley wave mobility effects, need to be included in the Stoneley wave propagation model. As such, an elastic membrane model was devised to include these effects in the Biot model. An inversion technique, which uses both slowness and attenuation of the Stoneley wave over a range of frequencies to evaluate mobility, was developed to optimize the sensitivity of the inversion to formation mobility.

This presentation describes the implementation of an interpretation methodology based on the above technique. The Stoneley wave propagation model employed is described with 13 parameters, not all of which are of equal importance. With a few explicit exceptions, they are determined by other logging measurements. The error analysis shows that the accurate determination of the fluid mobility requires that critical parameters, such as the mud slowness, mud attenuation and pore-fluid modulus be precisely determined. When using the proposed methodology within the applicable measurement range limited by Biot physics, the Stoneley wave can provide a continuous estimation of the formation permeability along a borehole depth. Field data examples will be presented to demonstrate the methodology.